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ARTICLE

Educational status influences cognitive-motor learning in older adults: going to university provides greater protection against aging than going to high school

Impacto da escolaridade na aprendizagem de uma tarefa cognitivo-motora em idosos: cursar a faculdade fornece maior efeito protetor contra o envelhecimento do que cursar o ensino médio

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ABSTRACT

Objective: To investigate if middle-aged and older adults with a higher education would differ from those with an average education in cognitive-motor tasks involving lower limb function. **Methods:** A walking version of the Trail Making Test (Walking Executive Function Task, [WEFT]) was used. Eighty volunteers (40: 50–65 years; 40: 66–80 years) were subdivided into average (6–11years of education) and higher education (12–17 years). They received two training sessions (session 1: eight repetitions, session 2: four repetitions), with a one week-interval between them. The Timed Up and Go (TUG) test was performed before and after the training. **Results:** Volunteers with an average education showed longer times on the WEFT than those with a higher education. Older adults showed lower retention than middle-aged adults ($p < 0.001$). The TUG was faster after the WEFT training ($p < 0.001$). **Conclusion:** The impact of education was observed when locomotion was associated with cognitive tasks. Average education resulted in poorer performance and learning than higher education, mainly in older adults. Gait speed increased after training.

Keywords: cognition; aging; evaluation; executive function; locomotion; visual perception.

RESUMO

Objetivo: Investigar se adultos e idosos com escolaridade alta teriam aprendizagem diferente de adultos e idosos com escolaridade média em uma tarefa cognitivo-motora envolvendo função de membros inferiores. **Método:** A tarefa foi baseada no *Trail Making Test* (Tarefa de Deambulação Funcional, TDF). Oitenta voluntários (40:50–65 anos; 40:66–80 anos) foram subdivididos em escolaridade média (6–11 anos) e alta (12–17 anos) e realizaram duas sessões de treinamento (1: oito repetições, 2: quatro repetições), com intervalo de uma semana. O *Timed Up and Go* (TUG) foi realizado antes e após o treinamento. **Resultados:** Voluntários com escolaridade média levaram mais tempo para concluir a TDF do que voluntários com escolaridade alta ($p < 0.001$). Idosos apresentaram menor retenção do que adultos ($p < 0.001$). TUG foi mais rápido após o treinamento. **Conclusão:** O impacto da escolaridade foi observado quando a locomoção foi associada com tarefas cognitivas. Voluntários com escolaridade média apresentaram menor aprendizagem do que com escolaridade alta, principalmente idosos. A velocidade da marcha aumentou com o treinamento.

Palavras-chave: cognição; envelhecimento; avaliação; função executiva; locomoção; percepção visual.

Education influences visuospatial perception[1], memory[2] and verbal fluency[3]. A higher educational status allows more leisure and occupational activities across a lifespan[4], higher income[5] and better health[6]. Cognitive and brain reserves explain the protective effect of education on normal and pathological aging[7]. Higher functional cognitive reserve is associated with more years of education, which makes the brain networks more efficient[7] and increases the ability of dealing with environmental difficulties, compensating for cognitive and motor deficits[8].

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Highly-educated individuals can use compensatory strategies to offset the repercussions of the first stages of neurodegenerative processes[9,10,11]. Brain reserve is responsible for the compensatory strategies that recruit intact networks during disease progression (e.g. dementia)[7].

The complex abilities of processing internal and environmental information, establishing and achieving goals, solving problems and making decisions are known as executive functions[12,13,14,15]. Highly-educated individuals have better performances on executive function tasks. For instance, the educational level has a considerable influence on both parts A and B of the Trail Making Test (TMT)[16,17].

The performance on tasks involving executive function and lower limb control (e.g. balance and gait) are related[18,19,20]. Individuals with poorer performance on executive function tasks tend to have higher postural instability, with a higher risk of falling while standing quietly and walking[18,19,20]. They usually walk more slowly through an obstacle pathway than individuals with high executive function[18,19]. Poorer performance on the TMT has been correlated with a lower speed on the Timed Up and Go (TUG) test[21]. The TUG test consists of measuring the time taken to rise from a chair, walk for three meters and return to the chair.

Individuals with more years of education have shown better performance in complex sensory-motor tasks involving coordination and motor sequencing to reproduce gestures or figures[22]. However, few studies have investigated the relationship between education and lower limb performance. Young and, mainly, older adults with a high educational status (HES) had better dual-task performances on lower limb alternation from the ground to a step and simultaneous visual discrimination of two targets on a screen[23,24]. The educational status has also been associated with ability on some tasks involving balance and gait in older adults[25,26].

We hypothesized that cognitive-motor tasks involving lower limb function could minimize the influence of education. Besides, assessing executive functioning during a locomotion task has logical validity, because, as in real life, walking is performed in association with cognitive tasks. Older adults must be able to develop strategies to keep their functional performance, e.g. locomotion and balance reactions to prevent falls, to deal with the physiological and pathological aging processes[14,18,19]. The participation of older adults in new stimulating activities, e.g. a computer course or an exercise program, might delay cognitive decline[25,26,27]. The knowledge of how age and education interact in cognitive-motor learning might complement the theories of brain and cognitive reserves. This study aimed to investigate whether age and educational status would influence the cognitive-motor learning in a cognitive-motor locomotion task in middle-aged and older adults. Cognitive-motor learning was evaluated by describing the learning curve (including all trials) and the possible training effects on the TMT and the TUG.

METHODS

Participants

Ninety-two individuals (students, teachers and employees of the University of São Paulo) volunteered to participate and 84 met the inclusion criteria (a minimum of six years of formal education, no visual impairment tested by the Snellen and Jaeger charts, and age between 50-80 years). Exclusion criteria were a score < 26 on the Mini Mental State Examination (MMSE); scores < 50 on the Berg Balance scale (BBS); cardiovascular, respiratory, neurological, or orthopedic diseases that could influence the performance; absence at the second evaluation. Two volunteers were excluded because they did not attend the second evaluation and two because of comorbidities. This study was approved by the Ethics Committee of the Clinics Hospital of the Faculty of Medicine of University of São Paulo (protocol 254/08).

Trail making test

Part A of the TMT contained a rectangle (18 X 14 cm), with 25 circles inside. Each circle had 1.1 cm diameter. Inside each circle was a number (1-25), 0.5 cm tall. Volunteers were instructed draw a line from one number to the next, in chronological order. Part B of the TMT contained a rectangle (18 X 14 cm) with 25 circles inside. Each circle had 1.1 cm diameter. Inside each circle was a number (1–13) or a letter (A-M), 0.5 cm tall. As in another study performed in Brazil with the TMT[28], the letter K was eliminated, because it is not familiar to Brazilians. Volunteers were instructed draw a line alternating from the first number to the first letter, then the next consecutive number and next letter, and so on. The TMT was conducted according to Bowie & Harvey's recommendations[29]. Volunteers were to complete the trail as fast as possible, avoiding errors. Every time an error occurred, the volunteer was instructed to go back to the last correct circle and continue the task. Time was measured with a chronometer and registered in seconds.

Walking executive function task

The Walking Executive Function Task, (WEFT) had the same elements as the TMT, but was 14 times bigger, to allow the ambulation from one circle to another (in the same sequences as the TMT above). It consisted of two instruction parts and two task parts (A and B). Instead of writing with a pencil on a sheet of paper, the volunteer had to walk on mats. Two rubber mats (1.96 X 2.52 m) were used for parts A and B. Each one had white circles (20 cm diameter). Part A had 25 black numbers (1–25). Each number (10 cm tall) was positioned inside a circle. Part B, had 13 black numbers (1–13) and 12 black letters (A–M, without K), in the same size as in part A. Each number or letter was positioned inside a circle.

Time was measured with a chronometer and registered, in seconds. The volunteer had to step on each circle with both feet before going to the next circle. The errors (stepping on the wrong circle) were recorded as complementary information about the performance of the volunteer. Each error resulted in an increase in time, because when the volunteer stepped in the wrong circle, the examiner asked them to go back to the last correct circle. Volunteers wore running or walking shoes during the task.

Experimental procedure

Volunteers were divided into four groups: 50–65 years and a high educational status (middle-aged, HES); 66–80 years and a high educational status (older adult, HES); 50-65 years and an average educational status (AES) (middle-aged, AES); and 66–80 years and an average educational status (older adult, AES). Each volunteer was assessed in two sessions. Between session 1 and session 2 there was an interval of one week.

In session 1, visual acuity and clinical tests were performed before the WEFT. Then, all volunteers performed seven repetitions of the WEFT A and seven repetitions of the WEFT B. In session 2, all volunteers performed four repetitions of the WEFT A and four repetitions of the WEFT B for retention evaluation.

The TMT and TUG were performed, to evaluate learning transfer. The TUG is a relatively simple motor task, which consists of rising from a chair, walking for three meters and returning to the chair. The one-week interval between sessions 1 and 2 was previously determined in a pilot study[28]. The pilot study showed that adults and older adults reached a plateau in the first session, after the sixth WEFT repetition. Therefore, eight repetitions were performed[28].

Statistical analysis

One-way ANOVA and chi-squared tests were used to compare demographic data. The ANOVA (4 X 2 X 12) compared four groups (50–65 years/AES, 50–65 years/HES, 66–80 years/AES, 66–80 years/HES); the two parts of the WEFT (A and B) and 12 trials (assessments 1-12) in each part. The ANOVA for repeated measures compared the TMT and TUG before and after the WEFT training. Alfa was set at 0.05.

RESULTS

Table shows the demographic data and scores. The AES and HES did not differ in age, sex, MMSE and BBS scores. They differed in education and scores in parts A, B and the TMT delta. The performance on the WEFT is represented in Figure 1. The ANOVA showed interactions between age, part and trial ($F_{11,847} = 2.14$; $p = 0.016$) and between education, part and trial ($F_{11,847} = 3.54$; $p < 0.001$). The ANOVA showed age ($F_{1,77} = 47.01$; $p < 0.001$), education ($F_{1,77} = 32.98$; $p < 0.001$), part ($F_{1,76} = 172.83$; $p < 0.001$) and trial effects ($F_{11,847} = 163.88$; $p < 0.001$) on the WEFT times. Tukey's *post hoc* test investigated these differences.

Age and education differences

In part A, the Tukey tests showed no age and education differences between groups, except between the subgroups 50–65/AES and 66–80/AES, which differed on trial 1. In part B, the subgroup 66-80/AES showed longer times than the 66-80/HES in all trials (1–12). The subgroup 66-80/AES showed longer times than the 50–65/AES in all trials (1–12) ($p < 0.01$ for all comparisons).

Part differences

Tukey tests showed that all the trials in part B had longer times than in part A in the subgroups 50-65/AES and 66-80/AES. In the subgroup 50–65/HES, part B times were higher than part A times on trials 1–5 and 9. In the subgroup 66–80/HES, part B times were higher than part A times on trials 1–5, 7 and 9–11 ($p < 0.05$ for all comparisons).

Trial differences (retention)

In the subgroup 50-65/AES, in parts A and B, Tukey tests showed that the times on trials 5–12 were shorter than the time on trial 1. The time on trial 12 was shorter than the time on trial 2. In part B, the times on trials 6–8 and 10–12 were shorter than the time on trial 3. The times on trials 7, 8, 11 and 12 were shorter than the time on trial 4. The times on trials 11 and 12 were shorter than the time on trial 9 ($p < 0.05$ for all comparisons, Figure 1).

Table. Sample characteristics (mean ± standard deviation). The ANOVA did not show differences between high and low education subgroups.

Group	Education	Age	Sex	MMSE score	TMTA score	TMTB score	TMT delta	TUG	BBS score
50–65	High (16.9 ± 1.9)	56.5 ± 4.7	12 ♀ 8 ♂	28.4 ± 0.9	31.5 ± 7.3	60.8 ± 16.5	25.7 ± 18.4	7.15 ± 1.35	55.8 ± 0.6
	Average (9.0 ± 1.5)	57.7 ± 4.7	11 ♀ 9 ♂	27.9 ± 1.2	37.6 ± 9.9	80.1 ± 23.6	46.2 ± 28.8	8.55 ± 2.48	55.4 ± 1.5
p*	0.001	0.406	0.646	0.144	0.031	0.005	0.006	0.016	0.278
66–80	High (16.8 ± 1.8)	71.3 ± 3.6	11 ♀ 9 ♂	28.4 ± 1.3	38.8 ± 15.4	75.7 ± 32.2	35.1 ± 26.0	8.15 ± 1.46	55.0 ± 1.5
	Average (8.6 ± 1.5)	73.2 ± 6.9	14 ♀ 6 ♂	27.2 ± 1.5	68.8 ± 30.3	177.6 ± 93.7	80.6 ± 41.4	12.15 ± 2.73	54.0 ± 2.1
p*	0.001	0.280	0.404	0.015	0.001	0.001	0.001	0.001	0.091

MMSE: Mini Mental State Examination; TMTA: Part A of Trail Making Test; TMTB: Part B of Trail Making Test; TMT delta: delta of Trail Making Test (score on Part B – score on Part A); TUG: Timed Up and Go Test; BBS: Berg Balance Scale. P: ANOVAs were run to compare education, age, MMSE scores, TMTA, TMTB, TMT delta, TUG, BBS and the chi-squared test compared the number of men and women on each subgroup.

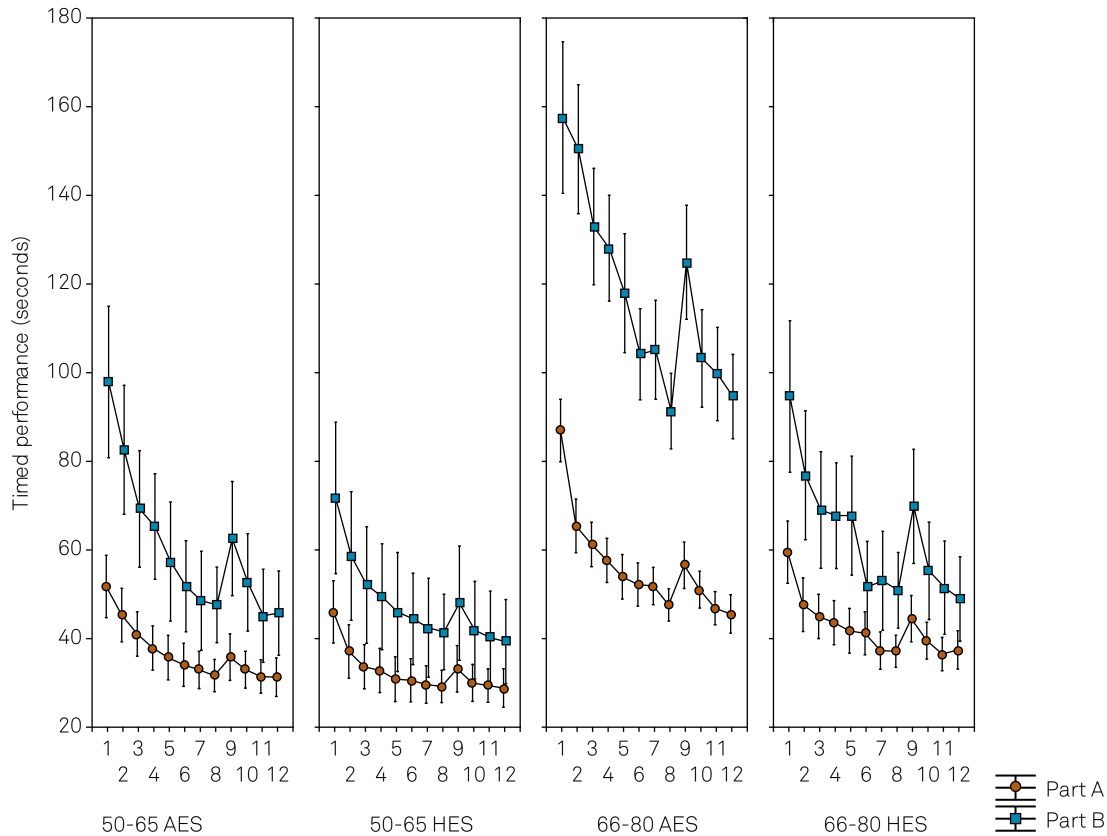


Figure 1. Timed performance on trials 1 to 12 in parts A and B of the Walking Executive Function Task: comparison between groups (50–65/AES; 50–65/HES; 66–80/AES; 66–80/HES). Trials 1 to 8 were performed in session 1 and trials 9 to 12 were performed in session 2. AES: average educational status; HES: high educational status.

In the subgroup 50-65/HES, in parts A and B, the times on trials 5–8 and 10–12 were shorter than the time on trial 1. In part B, the times on trials 6–8 and 10–12 were shorter than the time on trial 2 ($p < 0.05$ for all comparisons, Figure 1).

In subgroup 66-80/AES, in parts A and B, the times on trials 2-12 were shorter than the time on trial 1. The times on trials 8 and 10–12 were shorter than the time on trial 2. The times on trials 11 and 12 were shorter than the time on trial 3. In part B, the times on trials 6–8 and 10–12 were shorter than the time on trial 4. The times on trials 8 and 10–12 were shorter than the time on trial 5. The times on trials 6-8 and 10-12 were shorter than the time on trial 9 ($p < 0.05$ for all comparisons, Figure 1).

In subgroup 66-80/HES, in parts A and B, the times on trials 3–12 were shorter than the time on trial 1. In part B, the times on trials 6–8 and 10–12 were shorter than the times on trials 2 and 3. The times on trials 6–8, 11 and 12 were shorter than the times on trials 4 and 5. The times on trials 6–8 and 10-12 were shorter than the time on trial 9 ($p < 0.05$ for all comparisons, Figure 1).

Differences in the TMT and TUG performances before vs. after the WEFT training (learning transfer)

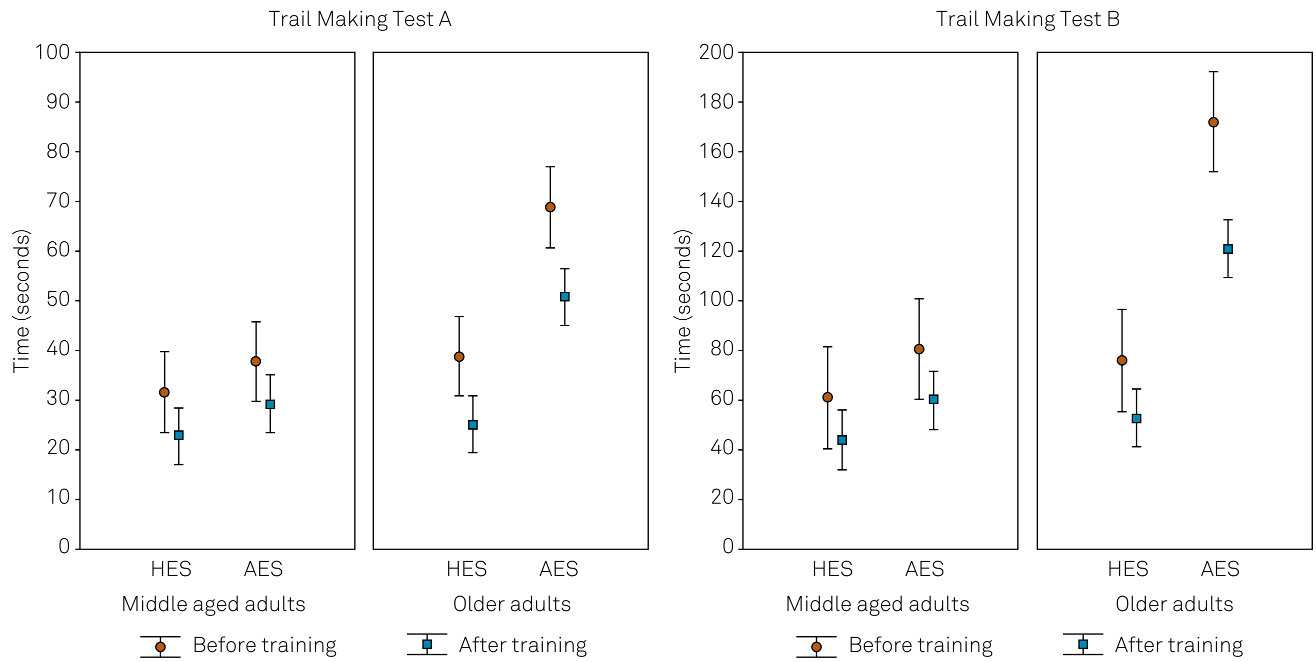
The ANOVA for repeated measures showed that the times on the TMT A and B were significantly longer before training, compared to the times after training. There were interactions between time and age, with $F_{1,77} = 7.39$; $p = 0.008$ and between time and education, with $F_{1,77} = 10.58$; $p = 0.002$. *Post hoc* Tukey tests showed that older adults with AES and HES performed significantly faster in parts A ($p < 0.001$ for both comparisons) and B ($p = 0.002$ and $p < 0.001$) after the WEFT training (Figure 2).

The ANOVA for repeated measures showed that the times on the TUG were significantly longer before training, compared to the times after training. There were interactions between time and age, with $F_{2,75} = 16.34$; $p < 0.001$ and between time and education, with $F_{2,75} = 13.23$; $p < 0.001$. *Post hoc* Tukey tests showed that middle aged adults with AES ($p = 0.003$) and older adults with AES ($p < 0.001$) and HES ($p < 0.001$) performed significantly faster after the WEFT training (Figure 3).

DISCUSSION

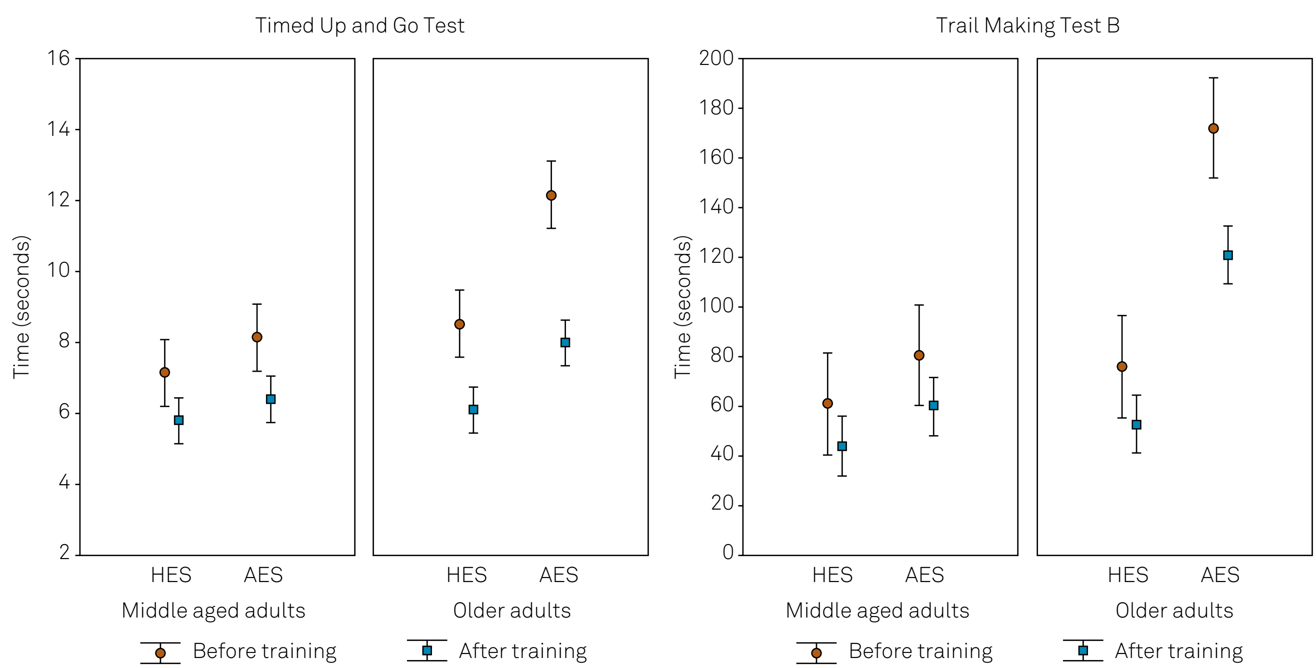
Age and education differences

In part A, the only difference found was between the AES subgroups, on the first time the sequence was performed. This means that, considering the 12 trials altogether, neither age, nor education differences influenced the WEFT A performance. However, considering only the AES subgroups



WEFT: Walking executive function task.

Figure 2. Performance on the Trail Making Test before and after the WEFT training. After training all times were significantly reduced, compared to before training.



WEFT: Walking executive function task.

Figure 3. Performance on Timed Up and Go Test before and after WEFT training. After training all times were significantly reduced, compared to before training.

on the first trial, older adults walked slower than middle-aged adults. This agrees with previous studies that showed a higher influence of age than education on simple balance and locomotion tasks in AES individuals[26,27,28].

Part B demanded a similar motor ability, but higher cognitive processing than part A. In this part, individuals aged 66-80 years with AES showed longer times than those with HES. The WEFT performance was similar to the results reported by studies that investigated age and education effects on the TMT[16,17]. Poor executive function, which is usually associated with lower educational status[11,12], correlated with a lower speed on motor tasks[20,21,23]. Although being a relatively simple task, the TUG test showed longer times in AES individuals[21]. A poorer dual-task performance and even a single-task performance, e.g. alternating steps from the ground to a step[24], was also associated with lower educational status.

In part B, the subgroup 66-80/AES showed longer times than the subgroup 50–65/AES. This age effect, causing performance deterioration among the subjects with AES, but not among HES individuals, is in consonance with the cognitive reserve theory. The cognitive reserve makes brain networks more efficient[7] and helps the brain deal with environmental challenges, compensating for both cognitive[7] and motor impairments[8] and maintaining functional performance for longer periods as the individuals get older[8,9].

This study adds important information about cognitive-motor learning and retention of a locomotion task. Considering the four subgroups, the learning curve of the 50-65/HES participants consistently showed the shortest times, whereas the 66-80/AES participants consistently showed the longest times. It is interesting to note that the subgroups 50–65/AES and 66–80/HES showed similar learning curves (Figure 1). This similarity between the performance of older adults with HES and middle-aged adults with AES has been discussed by Tun and Lachman[5], who investigated the reaction times on a task involving auditory stimuli and executive function processing. In that study, individuals with HES had a similar performance to individuals who were 10 years younger and who had a lower formal education, due to the effects of education on cognitive and brain reserves[5].

Part differences (task complexity)

In the AES subgroups, part B times were significantly longer than part A times on all trials. This did not happen on all trials of the HES groups. Among the HES individuals, in the group aged 50–65 years, part B times were significantly longer than part A times on trials 1-5 and on trial 9. In the group aged 66-80 years, part B times were significantly longer than part A times on trials 1–5, 7 and 9–11.

Longer times in part B have been extensively described in the literature for the TMT scores[9,16,17]. However, the present study showed that, in general, the learning curves of individuals with HES were closer and had some confidence interval bars superimposed, compared to the curves of individuals with AES. Based on this fact, we can conclude that the cognitive difficulty increment in part B had more impact on the AES groups than on the HES groups. Therefore, the groups with HES had better cognitive-motor strategies to deal with the cognitive difficulty of part B. In general, when a higher executive function processing is needed, individuals with low or average educational status have a poorer performance[7,16,17].

Previous studies from our group have shown the difficulty of individuals with only a few years of education in a dual task involving lower limb alternation from the ground to a step and the visual discrimination of two targets on a screen[23,24]. The task of the present study may be considered more logical, because it involves locomotion, instead of alternating steps from the ground to a stool, and finding the correct place to step, instead of discriminating objects on a screen.

Trial differences (practice effect)

We investigated whether practice would change the cognitive-motor locomotion performance in middle-aged and older adults. In 12 repetitions, distributed over two sessions of training, all participants showed significant improvement on the WEFT parts A and B. Participants also showed good retention, comparing sessions 1 and 2. Although their times increased on trial 9, which was the first trial of session 2, they showed improvement on trials 10 to 12, compared to trial 9. As well, participants showed significant differences between trials 10, 11 and 12, which suggests that the four subgroups stabilized their performances on the last trials of day 2.

Differences in the TMT and TUG performances before vs. after the WEFT training (learning transfer)

The times on the TMT A and B were significantly longer before the WEFT training, compared to the times after the WEFT training. The times on the TUG were also significantly longer before training, compared to the times after training. Very few studies have investigated the effects of cognitive-motor tasks training in middle-aged and older adults. Training can be useful to promote health and prevent impairments. A previous study showed that balance and gait training in dual-task conditions, which are also needed in the WEFT B, are associated with a lower risk of falls in older adults[30]. Therefore, cognitive-motor training in the WEFT B may be beneficial for middle-aged and, more importantly, for older adults, who showed executive function (TMT) and gait (TUG) improvement after training.

In a longitudinal clinical study, community-living older adults received their usual care or an intervention involving occupational and physical therapy. Less-educated persons showed greater improvement in their balance, compared to their control group counterparts[28]. Another study showed that not only exercise programs, but also the participation of older adults in new stimulating activities in general, e.g. computer courses, contributes to cognitive fitness and might delay cognitive decline[27]. As in the present study, these other two studies showed that individuals at greatest disability risk seem to be the most responsive to cognitive-motor practice interventions, because they have lower reserves. Cognitive-motor training increases brain activation and even cognitive and brain reserves, as the brain may change functional and structural networks after training[29,30].

As a limitation of the present study, we must mention that although we observed learning transfer from the WEFT to the TMT and TUG, there were no control (untrained) groups. Therefore, the repetition of the TMT and TUG may have contributed to performance improvement. Future studies should investigate this limitation by including control groups.

Educational status influenced the cognitive-motor learning and retention of a locomotion task. Older adults seem to be more impaired by a lower educational status than middle-aged adults on the learning of the task.

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