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Effects of simultaneous aerobic and cognitive training on executive functions, cardiovascular fitness and functional abilities in older adults with mild cognitive impairment

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Persons with Mild Cognitive Impairment (MCI) experience greater cognitive decline than that experienced as part of the normal ageing process. There is increasing evidence that, in addition to their cognitive impairment, persons with MCI also show a reduction in their motor capacities and particularly, in executive MCI. For instance, some studies have reported reduced gait speed in simple task or dual task conditions (Muir et al., 2012). Thus, improving motor functions in addition to cognitive functions may contribute to an improved quality of life for people with MCI. No curative pharmacological treatments are available; nonetheless, physical and cognitive stimulation does have the potential to increase cognitive function and motor capacities in people with MCI. Such stimulation has been shown to have beneficial effects on levels of cognitive performance. Furthermore, practicing physical activities and/or stimulating mental activities can be seen to reduce the risk of dementia (Barnes & Yaffe, 2009; Grande et al., 2014; Lyketsos, Steinberg, Tschanz, Norton et al., 2000). Intervention studies with healthy older adults (Kramer et al., 2002) or those with MCI (Baker et al., 2010) have identified aerobic training as the physical program that performs best in terms of improving cognition, particularly in terms of executive functions. Interestingly, studies of cognitive training programs (CT) for MCI patients which target executive functions (Gagnon & Belleville, 2012; Li et al., 2011) show that they can improve cognition, as well as motor performance (Smith-Ray et al., 2013). Thus, the two types of programs may be beneficial in terms of improving executive functions in those with MCI. Improvements in executive

functions can have a significant impact on the everyday activities they undertake; indeed, their impairment has been shown to accelerate dependency (Jekel et al., 2015).

Physical training (PT) and some cognitive training have demonstrated improvement in cognition (Baker et al., 2010; Gagnon & Belleville, 2012). Nonetheless, recent reviews have raised concerns with regard to the small numbers of studies involved and the large variety of procedures involved (for a review, see Martin, Clare, Altgassen, Cameron, & Zehnder, 2011). Indeed, the evidence for efficacy of any intervention in those with MCI is not certain. For example, in the systematic review of Gates et al. (2013) of cognitive outcomes in 14 RCTs of exercise specifically in MCI, 42% of effect sizes were potentially clinically relevant (effect size > 0.20), but only 8% statistically significant. Similarly, the review of 5 cognitive/executive training trials in MCI, only 3 had significant effects (Barnes et al., 2009; Gagnon & Belleville, 2012; Law, Barnett, Yau, & Gray, 2014). In particular, most studies have relied on single interventions; for example, they have measured either the effect of physical activity training or of cognitive training. Moreover, individuals with MCI demonstrate difficulties in cognitive, motor and quality of life domains. Hence, the use of interventions in isolation may be insufficient given the complex and multifactorial nature of the disease (Fissler, Küster, Schlee, & Kolassa, 2013). Further, Schneider and Yvon (2013) and Teixeira et al. (2012) regretted that the interventions offered to people with MCI have the unique objective of impacting on cognitive performance. Thus, they recommended the building of programs that deliver multiple types of intervention. Finally, there is strong evidence from cross-sectional, prospective cohort, and experimental studies that participation in physically and mentally stimulating activities is associated with decreased dementia prevalence and/or incidence as well as improved cognitive function in healthy individuals and some clinical cohorts. Given that, physical and cognitive trainings can modulate neuro-cognitive benefits

via specific mechanisms that are directly linked to the classical pathological features of some neurological disorders (Shah & Martins, 2017), combine intervention could be increase the benefits of the two types of training (Yeh et al., 2017).

These can be provided sequentially (combined intervention) or simultaneously. In combined interventions, participants start with PT or CT and are then provided with other training (Desjardins-Crépeau et al., 2016). In simultaneous interventions, PT and CT are provided at the same time; for instance, with cycling and attentional cognitive exercises (Theill et al., 2013; Yoon et al., 2013). Combined interventions have the disadvantage of increasing the time that participants need to invest in training. Furthermore, it is more methodologically challenging to design studies that compare successive interventions with single interventions because an appropriate design should match practice time between groups. Additionally, a combined presentation of training sessions may reduce the potential synergies between the two modalities (Schneider & Yvon, 2013; Teixeira et al., 2012). Providing physical activity and cognitive training simultaneously may be an innovative and promising way of boosting their effects on cognitive and motor functions (Bherer, 2015). The mechanisms involved in physical and cognitive training could, if practiced at the same time, initiate synergies that generate increased effects (Falbo, Condello, Capranica, Forte, & Pesce, 2016; Fissler et al., 2013; Schneider & Yvon, 2013). Moreover, simultaneous cognitive and physical training reproduces a dual task situation that could bring improvements to daily activities (Doi et al., 2014). Finally, simultaneous training limits the methodological hurdles related to matching training time in studies that compare single training with combined training. Thus, one critical question is whether cognitive and physical training have a synergistic effect, increasing the benefits of the two types of training when performed simultaneously.

Only a few studies have examined the effect of simultaneous physical and cognitive training (PCT); these have involved healthy older adults and those with dementia, but not those with

MCI. Theill, Schumacher, Adelsberger, Martin and Jäncke (2013) randomly allocated healthy older people to PCT, CT or no-intervention groups. Their results showed an increase in executive control for both training groups; however, only the simultaneous PCT group revealed an improved cognitive score for the learning task and a significant decrease in walking variability for the dual task conditions. Yoon et al. (2013) also compared the effects of PCT and CT training alone in patients with Alzheimer's disease. The CT program focused on working memory training whereas the PCT one consisted of low intensity cycling sessions whilst simultaneously solving cognitive exercises. After training, the PCT group showed significant improvements in terms of balance, walking, and cognition, including working memory, spatial orientation, and verbal fluency, whereas the CT group showed improvements only for verbal fluency and spatial orientation.

The results of these two studies show that PCT training can be a more effective way of improving motor performance and cognitive functioning than programs which focus only on cognition. However, the methodology used does not allow them to test for synergistic effects. Indeed, no studies have sought to compare a PCT group with single PT training groups. Moreover, existing studies have not tried to examine simultaneous intervention in people with MCI. Finally, existing studies have not assessed the long-term effect of this kind of training, as was recommended in a number of literature reviews (for a review, see Kelly et al., 2014).

Objectives

The purpose of the present study was to determine whether or not simultaneous aerobic and executive cognitive training have an impact on executive functions and motor abilities in older adults with MCI. Any impact was measured immediately after the end of the training and six months later. It was hypothesized that the effects of PCT training are higher than the effects of physical or cognitive training on their own.

Methods

Participants

Participants were recruited from an urban university's memory clinic. They were included if the diagnostic for single or multiple domain MCI were clinically determined by a neuropsychologist with evidence on executive deficits (Petersen, 2004), were retired and older than 65 years, and had a medical certificate allowing them to engage in physical activity. Exclusion criteria included having undergone orthopedic surgery on the lower limbs, being depressed (i.e., Geriatric Depression Scale (GDS) > 11) and being on a medication that could influence gait, scoring < 23 on the Mini Mental State Examination (MMSE), being unable to speak French, and being unable to walk alone, hear and read correctly at a distance of 1.50 m. Participants gave their oral informed consent in accordance with the guidelines of the local hospital's ethics committee. They did not receive any monetary compensation.

Outcome measures for pre- and post-test

The same data was collected pre- and post-test for executive and motor measures.

Executive measures

To measure the impact of any interventions on executive functions, we used the Matrix Reasoning test (WAIS, 1999), the flexibility part of the Stroop Color Word test (Bohnen, Jolles, & Twijnstra, 1992), the Digit Span Forward test (DSF) and the Digit Span Backward test (DSB, WAIS, 1999).

Motor measures

The Rockport test was used to estimate relative maximal oxygen uptake (VO_{2max}). Participants were instructed to walk as fast as possible for one mile without stopping. VO_{2max} was evaluated using an equation based on their age, height, weight, sex, walking time and heart rate at the end of the one-mile walk (Poher, Freedson, Kline, McInnis, & Rippe, 2002).

The Timed Up and Go test (TUG) was used to estimate the locomotion and dynamic balance ability of the participants in our study (McGough et al., 2011).

Single-task walking was measured using a functional evaluation of single-task spontaneous walking for 5.2 m in a normal environment on a 4.3 m-long electronic walkway (GAITRite®, CIR Systems Inc, Sparta, NJ, USA). An additional distance of 1 m was arranged at the beginning and end of the track, because the recording of spatiotemporal gait parameters did not include the acceleration and deceleration phases. The subjects were asked to perform this walking task five times at their own pace. The mean gait speed was recorded.

Complex walking was measured using the Walking Stroop Carpet test (WSC), which combined walking with the Stroop interference effect (for a complete description of the task, see Perrochon, Kemoun, Watelain, & Berthoz, 2013). In the WSC, three carpets were associated with the three conditions used in the Stroop Color Word test. The stimuli were presented in lines of four different words and/or colors (red, yellow, blue, and green). Thus, one congruent situation was followed by two incongruent situations. The first condition, WSC bw (black & white), consisted of walking on the word that corresponds to the name of a color. The second condition, WSC w (word), consisted of walking on a word that was written in several different colors. The third condition, WSC c (color), consisted of walking on words written in a color while having to avoid reading the words. The gait speed and errors were noted.

Finally, we used a dual task walking condition. Participants were asked to walk while performing a working memory task by counting backwards three by three and forwards six by six, alternately (Evans, Greenfield, Wilson, & Bateman, 2009). The gait speed, the number of calculations and errors were noted.

Secondary measures

We examined a number of variables to assess feasibility and adherence: rate of attendance, appreciation, and intensity. The rate of attendance was calculated over the 24 sessions.

Appreciation was measured using a subjective scale from 0 to 10 (0 = program is not liked; 10 = program is well liked). Intensity was measured during training using a trough heartbeat captor.

Interventions

After being randomly allocated to training groups, participants completed two one-hour sessions per week over 12 weeks, amounting to a total training time of 24 hours. All groups received the same amount of training; only the types of stimulation varied between groups. Training was carried out in a small room equipped with training bikes for PT training and a large-size screen was used to provide the CT.

Physical training (PT). Each session began with a warm up and finished with a cool down. The main body of each session was focused on aerobic training on bikes (Domyos VA 300). Sessions were supervised by a physiotherapist, who adapted the level activity to each individual with the aim of reaching moderate intensity (i.e., 60% HR). For participants that used medication that attenuate heart rate, we used modified formula (i.e., $FCe = FCr + 0,8 (FCmax-FCr)$), to target moderate aerobic intensity. Thus, for all participants, the difficulty and duration of the exercises were regularly increased throughout the 12 weeks. The objective was to improve cardiorespiratory function in order to improve cognitive function. The heart rate was monitored objectively using Polar FT2 monitors to match the capacities of each individual.

Cognitive training (CT). We elaborate the cognitive training with the recommendations from reviews: variable priority (e.g., Bherer et al., 2005), level of difficulty cloth to the level of the capacity (e.g., Smith-Ray et al., 2013), feedback (for review, Kelly et al., 2014), and group training (for review see Kelly et al., 2014). Hence, we built our cognitive program and more

generally our procedure of trainings, in respect with those recommendations. The CT aimed to stimulate attention and executive functions, namely working memory, mental flexibility, inhibition, reasoning and updating. Commercialized gaming software was used:

"HAPPYneuron" and Presco (Scientific Brain Training group, Tarpin-Bernard & Croisile, 2012). Each session comprised exercises that covered all functions in equal quantity. Thirty-three preselected games stimulated those functions by using words, numbers, colors, shapes, and logical exercises. The cognitive exercises were projected on a white wall via an overhead projector. In turn, each participant answered orally to the questions posed in the game.

Feedback was provided for some of the exercises by the examiner.

Combined simultaneous physical and cognitive training (PCT). The PCT program delivered a combination of CT and PT within the same intervention. Both types of training started and ended simultaneously (for an example, see Figure 1). Thus, participants had to pedal whilst at the same time completing the tasks contained in the cognitive games. Participants were trained with the same modalities as described above for each program.

Control group. The participants in the control group were committed to maintaining their usual lifestyle. They were also committed to not starting a new physical activity or cognitive stimulation within the 14-week duration of the study.

Design

A cluster randomized and controlled four-group design was used, which involved CT, PT, PCT and a passive control group. The design is shown in Figure 2. Training was delivered in two urban seniors' clubs to small groups of four to eight participants. This allowed the program to feel more enjoyable to encourage adherence (for a review, see Kelly et al., 2014). Participants were able to select their training location place and schedule. Groups were randomized to the training conditions. The PCT group included 21 participants, whilst the PT group had 18. There were 16 in the CT group and 14 in the control group. Before

randomization, participants first received their clinical characterization and pre-test assessment. After the 12-week period, all groups completed a post-test session that involved the same procedure as the pre-test session. A further post-test session was performed six months after the end of the intervention program. As we were mostly interested in the impact of different training formats and because of the difficulty in precluding control participants from engaging in physical activity during the intervening period, we chose to evaluate the long-term effect only for the three training groups (n = 55).

Statistical analysis

One-way analyses of variance (ANOVA) with Group as the between-group factor were used to compare the participants' demographic, cognitive, motor and fitness characteristic across intervention conditions prior to training. ANOVAs were also used to compare adherence and feasibility (i.e., rate of attendance, appreciation, and intensity).

The effects of training in the short term and then the long term were analyzed for statistical significance by using a two-way mixed ANOVA (group x time), combined with planned comparisons for pre-test vs post-test sessions for each group. Planned comparisons were made for two reasons. Firstly, we made a precise hypothesis, that we wanted only to observe comparisons between: Pre PCT vs Post PCT; Pre PT vs Post PT; Pre CT vs Post CT; and Pre C vs Post C. Secondly, given that we had many groups, we did not want to increase type 1 errors. Hence for each test, we compared the Pre vs Post mean for all groups. We carried out those tests on each of the component measures, using the Bonferroni procedure to protect against an inflated chance of a Type I error.

Results

Baseline characteristics and performance

The ANOVA showed no significant group differences in terms of age, level of education, weight, size or scores on the MMSE, and GDS (all $p > 0.05$, see Table 1). Furthermore, there were no group differences prior to training on the executive and cardiorespiratory fitness tests (see Table 2). However, the PCT group was significantly slower than the PT group ($p < 0.001$) and the CT group ($p < 0.01$) on the TUG. In the single walking task, the PT group was significantly faster than the control group ($p < 0.05$). Note that although statistically significant, these differences were not clinically significant for either the walking task or TUG tests (Kristensen, Foss, & Kehlet, 2009; Shumway-Cook, Brauer, & Woollacott, 2000). Nevertheless, we examined whether these modified our results using covariance analysis and found this not to be the case.

Adherence, physical intensity and feasibility

The rates of attendance for the PT, CT and PCT groups were, respectively, 74.8%, 78.4% and 84.0%, which did not differ significantly, $F(2, 52) = 2.45, p = n.s.$ The assessment rates given by the participants were, respectively: 8.1, 8.2 and 8.5 for the PT, CT and PCT groups. Again, they did not differ significantly: $F(2, 52) = 0.017, p = n.s.$ We also calculated the intensity of the efforts made by the PT and PCT groups, which were, respectively, 47.25% (± 23.7) and 32.2% (± 16.02). A student t -test indicated that the effort was larger in the PT than PCT group, $t = 2.37, p < 0.05$.

Training effects

Executive measures. The ANOVAs on executive tests showed a significant effect of time for the four tests and no significant effect of group. Moreover, there was a group x time interaction for performance on the Matrix reasoning ($F(3,65) = 4.46; p < 0.001$).

Planned comparisons indicated that performance (see Table 3) was improved on the Matrix reasoning, and DSF and DSB tests after PT, CT and PCT interventions. An improvement was

seen for the Stroop test after PCT training, although the difference just missed significance ($p = 0.06$).

Motor Measures. The ANOVA on motor measures shows a significant effect of time for the Rockport test ($F(3, 65) = 4.73$; $p < 0.05$), the TUG ($F(3, 65) = 19.02$; $p < 0.001$), the gait speed WSC bw ($F(3, 65) = 7.67$; $p < 0.01$) and WSC c ($F(3, 65) = 6.02$; $p < 0.05$). There was also a significant group effect on in the TUG ($F(3, 65) = 4.99$; $p < 0.01$) and on the single task condition of the gait speed ($F(3, 65) = 4.86$; $p < 0.01$). Finally, there was a group x time interaction on the Rockport test ($F(3, 65) = 6.64$; $p < 0.01$), on the TUG ($F(3, 65) = 7.67$; $p < 0.001$), on the single task condition of the gait speed ($F(3, 65) = 10.28$; $p < 0.001$), and on the WSC bw ($F(3, 65) = 3.18$; $p < 0.05$).

Planned comparisons (see Table 4) show that the Rockport test and TUG improved after PT and PCT intervention. The single task condition of gait speed, WSC wb, WSC c, and the dual task counting were improved only after PCT training. CT participants showed no improvement on motor tasks.

Long-term effect

Of the 55 trained participants, seven did not come back for the follow-up test. This was due to mobility issues, change in their phone number, absence for long holidays or unavailability.

Thus the six-month post-test analysis was carried out on 48 participants in total: 14 participants in the PT group (2 lost to follow-up), 14 in the CT group (4 lost to follow-up) and 20 in the PCT group (1 lost to follow-up). The analysis compared pre-test and post-test data at six months only on the intervention groups PCT, CT & PT as in Table 5.

Executive measures. The ANOVAs on the executive tests indicated a significant effect of time for all variables except for the Stroop flexibility tests where the difference just missed significance ($p = 0.06$). Planned comparisons indicated that performance on WAIS was still significantly better at six-month post test relative to pre test for PT and CT participants, and

that the DSF was still improved at the six-month post test relative to the pre test for the PT and PCT participants. The DSB was better at the six-month post-test analysis than at the pre-test analysis for all groups, although the difference missed significance.

Motor measures. The ANOVAs for the motor tests showed a significant effect of time on the TUG ($F(2, 45) = 15.08$; $p < 0.001$), and WSC w b gait speed ($F(2, 45) = 14.06$; $p < 0.001$).

There was a significant group effect for the TUG ($F(2, 45) = 6.29$; $p < 0.01$), and WSC w gait speed ($F(2, 45) = 3.12$; $p < 0.05$). Lastly, there was a group x time interaction for the TUG ($F(2, 45) = 9.08$; $p < 0.001$), and gait speed in WSC w b ($F(2, 45) = 3.58$; $p < 0.05$).

Planned comparisons did not indicate VO_2 max improvement six months after training, whatever the group. The gait speed of WSC w b remained improved at the six-month follow-up relative to the pre test for PT and PCT participants. The TUG was still better at the six-month post-test analysis than at the pre-test analysis for the PCT participants. There was no gain for the CT participants on any of those variables.

Discussion

The purpose of this study was to determine whether simultaneous physical and cognitive stimulation offers older MCI patients a wider range of cognitive and walking benefits compared with simple training and no intervention.

Overall training effect. The results indicate that all training modalities improved their performance of executive tasks, but with certain groups demonstrating both executive and motor effects. Specifically, the two groups that received physical training also improved their performance of the motor tests.. These results confirm that people who suffer from MCI may benefit from training programs based on physical activities and/or on cognitive training (Calero, 2004; Gagnon & Belleville, 2012). However, there were some differences in the breadth of the effects, as discussed below.

Differences between training programs

Our results showed that the CT group improved on two of the 11 measures: all of these were cognitive measures. The PT group improved on two measures: one cognitive measure and one motor measure. In contrast, the PCT group improved on 8 measures and these measures included both cognitive and motor dimensions. Thus, the PCT group showed a larger range of improvement than the groups who engaged in single training. Simultaneous training appears, therefore, to play a significant role in increasing the cognitive and motor capacities of MCI participants.

Interestingly, the PCT group showed more improved walking tests than those engaged in PT alone (i.e., on 6 tests PCT = 4; PT = 0; CT = 0) and PCT group showed more improved executive tests than those engaged in CT alone (i.e., on 4 tests, PCT = 3; CT = 2; PT = 1).

Separately, the two training components bring their own benefits; by combining them, they also deliver added value. These results are consistent with two existing studies of simultaneous physical and cognitive training, which have both shown the benefits derived in terms of cognitive and motor performance (Theill et al., 2013; Yoon et al., 2013). Thus, our results reinforce the hypothesis that simultaneous training is more efficient in improving the abilities of older people, either with or without cognitive decline, than cognitive or physical training alone (Eggenberger, Theill, Holenstein, Schumacher, & de Bruin, 2015).

Hypotheses can be proposed to explain the larger effect found with the combined simultaneous training condition. Firstly, the PCT training sessions provided a more varied and richer physical and social environment. This brought into play a wide variety of cognitive and physical stimuli. These multiple stimuli provided a range of new sensory and motor experiences which could have led to an increase in the plasticity of the participants of the PCT group and, therefore, stimulated them. Thus, the PCT training may lead to better results simply because they increase exposure to diverse stimuli, an opinion put forward by

Frantzidis, Ladas, Vivas, Tsolaki, and Bamidis (2014) in their work on neurophysiological synchronization. Here, they showed that multiple stimuli engender new neuronal networks (i.e., synaptogenesis) or a strengthening of synaptic activity.

Moreover, PCT involves concurrent cognitive and physical tasks, which allow participants to vary the kind of stimulation they receive. It has been proposed that cognitive training studies that include variability are associated with larger gains through transfer tasks (Lussier, Gagnon, & Bherer, 2012). In our experiment, participants had to pay attention to the successful performance of the cognitive games and the preservation of physical intensity. Thus, simultaneous training may increase stimulation, leading to the development of new capacities that enable participants to divide their skills between multiple tasks. Finally, the pleasant and challenging character of the combined training sessions certainly played an important role overall. Indeed, we consider that the pleasure people found in participating in combined activity was key to the wider benefits of the PCT program. Indeed, Eggenberger et al. (2015) suggested that older adults enjoy the novel training concepts of simultaneous cognitive and physical activity more than traditional training. We thought that the pleasure generated by cognitive games during physical training could help to increase the benefits derived from physical activity.

Furthermore, our results are consistent with recent papers that have proposed the combination of physical and cognitive training to generate greater synergistic beneficial changes compared with those that are provided individually (for a review, see Bamidis et al., 2014; Kraft, 2012; Schneider & Yvon, 2013). We found some physiological information that is relevant to this question. Participants in the PCT group performed at a somewhat lower intensity of physical activity than those in the PT group, although this was not associated with poorer results. Consequently, the combined action of cognitive training and physical activity appears to generate benefits on a larger scale. These benefits derive from aerobic training, which acts as

the promoter of new intellectual structures, and cognitive training, which acts as the creator of cognitive skills (Kleemeyer et al., 2017). Thus, the new neuronal cells that are initiated by aerobic training may be guided by cognitive training towards neuronal networks loops. Combining the two types of training may, then, compensate for cognitive impairment.

Moreover, it seems that CT and PT together helped to keep the interest of participants. Indeed, the groups of physical activity alone and cognitive training alone lost three people each during the intervention, whereas the simultaneous group lost none. It may be the case, therefore, that simultaneous training could reduce people's reluctance to become engaged in physical activity or cognitive training. Furthermore, this kind of therapy could be a good way to introduce regular physical activity or cognitive stimulation into the daily lives of older adults.

Long-term impact. The results indicate that some long-term benefits may be derived for all training groups, with no particular additional benefits for the PTC group. It is possible that the physical intensity maintained by the participants in PCT training is not enough to result in durable cognitive improvement. Of particular note in the motor domain is the finding that the PCT group retained significant gains some six months after the training sessions had ended. Thus, it is possible to argue that long-lasting benefits can be derived for PCT combined, compared with CT and PT along, but in terms of motor skills rather than cognition. However, Eggenberger et al. (2015) found maintained gait performance under "preferred" and dual task walkings one year after the end of the of training. Training sessions was provided during six months. Hence, the duration of the training may have long-term benefits on motor performance.

Limitations. The current study does, however, have some limitations that should be considered. One limitation was that we did not have a comparison group that was involved in a social participation program. Hence, we could not isolate the social component of training. Many studies have shown that social interaction may protect against cognitive decline (Glei, 2005). The extent to which social interaction contributes to cognitive and physical training effect should be addressed in future studies. A further limitation was that we did not measure direct gain in the cognitive tasks completed during the cognitive training programs. Group working made it impossible to evaluate the level reached by individual participants in the cognitive training program; nor did it allow the level of training difficulty to be set for individuals. Whilst we chose to use software with adjustable parameters in order to match the levels of difficulty with the skill levels of the participants (Herrera, Chambon, Michel, Paban, & Alescio-Lautier, 2012) and create more attractive and stimulating cognitive exercises for the players (Clare et al., 2010), it was technically impossible to measure the level of difficulty for individual participants at the start and at the end of each exercise. Hence, to remedy this, we think that future studies should look to adapt the evaluation strategy.

Finally, the magnitude of the effects was not always large enough to allow statistical distinctions to be made between the single programs or between CPT and single interventions. It is possible that longer training periods would produce larger benefits for those engaged in CPT training and, hence, result in larger statistical effects. However, small effects in initial stages can lead to much public health gain for example, in the conversion rate in dementia or in the sustaining of cognitive and motor capacities in older adults (Ngandu et al., 2015).

Moreover, in this perspective, we are still following the cohort on general cognitive capacities and conversion to dementia.

In conclusion, the results of our study demonstrate the potential of using simultaneous cognitive and physical training programs to increase cognition and motor performance in people with MCI. Gains in both domains could allow these individuals to better adapt to situations that require the recruitment of multiple resources. Our results indicate that this kind of training has important and singular effects on walking tests, which most closely match functioning in daily life. This highlights the potential impact that those programs could have for people with MCI both in terms of their sustainability of their independence and quality of life. Future studies should propose training that offers broader interventions to promote cognition in old age and generate easily usable effects in everyday life.

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Table 1

Demographic and health variables for the control and training groups (mean and standard-deviations)

Variables	PT (n=18)		CT (n=16)		PCT (n=21)		C (n=14)		<i>F</i> (3,65)	<i>p</i> <
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Age (years)	77.1	1.44	76.3	1.5	75.2	1.3	79.2	4	1.23	0.31
Self rated health	3.5	0.15	3.6	0.16	3.3	0.14	3.4	0.2	0.86	0.47
Level of education	6.1	0.34	5.5	0.36	5.9	0.31	5.8	0.4	0.48	0.70
Size (cm)	160.5	1.68	165.2	1.78	165.4	1.55	161.9	1.9	2.06	0.12
Weight (kg)	64.8	3.06	63.3	3.25	70.3	2.83	63.7	3.5	1.17	0.33
MMSE	28.2	0.43	27.3	0.42	28.1	0.36	27.3	0.5	0.88	0.46
GDS	8.7	1.46	9.75	1.55	10.61	1.36	10.85	1.7	0.44	0.73

Note. *M* = Mean; *SD* = Standard Deviation; MMSE = Mini Mental State Examination; GDS = Geriatric Depression Scale.

Table 2. Comparisons between groups of walking performance before training.

<i>Walking tests</i>	PT	CT	PCT	C	<i>F(3;65)</i>	<i>p <</i>
	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>		
TUG (sec)	9.96 ± 1.75 *	10.24 ± 2.68 **	12.79 ± 2.17 * **	11.65 ± 2.04	6.9	0.001
Gaits speed in single task(cm/s)	115.93 ± 18.6 ***	111.34 ± 19.91	102.43 ± 12.60	99.64 ± 14.29 ***	3.6	0.05
Gait speed WSC bw (cm/s)	31.71 ± 6.34	28.38 ± 7.07	28.18 ± 8.13	35.55 ± 11.33	2.8	0.05
Gait speed WSC w (cm/s)	32.36 ± 7.21	29.22 ± 6.23	33.06 ± 10.03	30.54 ± 7.82	0.2	ns
Gait speed WSC c (cm/s)	41.93 ± 13.27	34.12 ± 11.80	33.72 ± 13.79	36.8 ± 11.70	1.6	ns
Gait speed DT counting (cm/s)	28.12 ± 21.22	25.96 ± 18.96	28.94 ± 15.57	26.90 ± 12.77	0.1	ns

Note. M = Mean. SD = Standard deviation. ns = no significant. TUG = Timed Up and Go test. *significance between PT and PCT. ** significance between CT and PCT. ***significance between PT and C.

Table 3. Within-group comparison of executive performances before and after training

<i>Executive tests</i>	PT		CT		PCT		C		Planned comparisons			
	Pre test	Post test	<i>t</i>	<i>p</i> <	<i>d</i>							
	<i>M</i> ± <i>SD</i>											
Matrix Reasoning test	11.45 ± 5.73	16.83 ± 5.86	11.35 ± 6.84	15.18 ± 6.84	12.38 ± 6.48	16.42 ± 7.33	9.85 ± 6.21	9.5 ± 4.95	PT pre x post	4.99	0.001	1.17
									CT pre x post	3.38	0.001	0.84
									PCT pre x post	4.04	0.001	0.88
									C pre x post	/	ns	/
Stroop : task switching (number)	28.89 ± 6.45	30.94 ± 6.24	27.19 ± 8.82	25.5 ± 8.37	26.52 ± 6.8	29.05 ± 7.19	24.71 ± 10.16	26.42 ± 6.53	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	1.38	0.06	0.30
									C pre x post	/	ns	/
Digit Span Forward	5.38 ± 1.14	5.94 ± 0.87	5.18 ± 0.91	6.18 ± 1.11	5.48 ± 0.88	6.15 ± 1.06	5.21 ± 1.12	5.36 ± 0.84	PT pre x post	2.09	0.05	0.49
									CT pre x post	3.54	0.001	0.89
									PCT pre x post	2.7	0.01	0.59
									C pre x post	/	ns	/
Digit Span Backward	4.22 ± 1.06	4.72 ± 1.18	4.06 ± 0.68	4.63 ± 1.09	4.10 ± 1.18	4.95 ± 1.12	3.86 ± 0.86	3.79 ± 0.97	PT pre x post	1.67	0.09	0.39
									CT pre x post	1.77	0.08	0.44
									PCT pre x post	3.1	0.001	0.65
									C pre x post	/	ns	/

Note. M = Mean. SD = Standard deviation. d = effect size (Cohen, 1988). ns = no significant. / = no effect. Only p values in a bold front type remain significant after Bonferroni correction.

Table 4. Within-group comparison of motor performances before and after training

	PT		CT		PCT		C		Planned comparisons			
	Pre test	Post test	Pre test	Post test	Pre test	Post test	Pre test	Post test		<i>t</i>	<i>p</i> <	<i>d</i>
<i>Cardiorespiratory fitness test</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>				
VO2max	21.04 ± 5.39	22.25 ± 5.29	22.57 ± 7.85	22.52 ± 8.11	23.32 ± 6.28	24.99 ± 6.51	21.67 ± 7.30	20.90 ± 7.98	PT pre x post	2.64	0.01	0.62
									CT pre x post	/	ns	/
									PCT pre x post	3.94	0.001	0.86
									C pre x post	/	ns	/
<i>Walking tests</i>												
TUG (sec)	9.96 ± 1.75	8.90 ± 1.21	10.24 ± 2.68	9.97 ± 3.44	12.79 ± 2.17	9.84 ± 1.18	11.65 ± 2.04	11.58 ± 2.18	PT pre x post	-2.18	0.05	-0.51
									CT pre x post	/	ns	/
									PCT pre x post	6.60	0.001	-1.44
									C pre x post	/	ns	/
Gaits speed in single task(cm/s)	115.93 ± 18.6	119.42 ± 17.89	111.34 ± 19.91	112.58 ± 26.13	102.43 ± 12.60	114.44 ± 16.03	99.64 ± 14.29	90.56 ± 15.23	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	4.95	0.001	1.08
									C pre x post	/	ns	/
Gait speed WSC bw (cm/s)	31.71 ± 6.34	33.50 ± 6.35	28.38 ± 7.07	30.12 ± 6.55	28.18 ± 8.13	32.69 ± 6.87	35.55 ± 11.33	34.55 ± 9.79	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	3.95	0.001	0.86
									C pre x post	/	ns	/
Gait speed WSC w (cm/s)	32.36 ± 7.21	33.34 ± 6.87	29.22 ± 6.23	30.75 ± 8.24	33.06 ± 10.03	35.66 ± 7.54	30.54 ± 7.82	30.74 ± 7.4	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	/	ns	/
									C pre x post	/	ns	/
Gait speed WSC c (cm/s)	41.93 ± 13.27	43.04 ± 14.57	34.12 ± 11.80	37.95 ± 15.01	33.72 ± 13.79	41.55 ± 15.24	36.8 ± 11.70	36.23 ± 13.86	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	3.51	0.001	0.77
									C pre x post	/	ns	/
Gait speed DT counting (cm/s)	28.12 ± 21.22	35.46 ± 24.01	25.96 ± 18.96	28.19 ± 19.01	28.94 ± 15.57	37.80 ± 20.92	26.90 ± 12.77	24.63 ± 17.43	PT pre x post	/	ns	/
									CT pre x post	/	ns	/
									PCT pre x post	2.05	0.05	0.45
									C pre x post	/	ns	/

M = Mean. SD = Standard deviation. d = effect size (Cohen, 1988). ns = no significant. / = no effect. TUG = Timed Up and Go test. Only p values in a bold front type remain significant after Bonferroni correction.

Table 5. Comparisons between the three trained groups of executive, cardiorespiratory and motor performances before training and six months after training

		ANOVAs			Planned comparisons					
		<i>F</i> (2, 45)	<i>p</i> ≤	η^2	PT		CT		PCT	
<i>Executive tests</i>					<i>t</i>	<i>p</i> ≤	<i>t</i>	<i>p</i> ≤	<i>t</i>	<i>p</i> ≤
Matrix Reasoning test	Group effect	/	ns	/						
	Pre test-P6 test effect	13.38	0.001	0.23	2.5	0.01	2.1	0.05	/	ns
	Interaction effect	/	ns	/						
Stroop : task switching (number)	Group effect	/	ns	/						
	Pre test-P6 test effect	3.68	0.06	0.08	/	ns	/	ns	/	ns
	Interaction effect	/	ns	/						
Digit Span Forward (empan)	Group effect	/	ns	/						
	Pre test-P6 test effect	16.39	0.001	0.26	2.3	0.05	/	ns	3.4	0.001
	Interaction effect	/	ns	/						
Digit Span Backward (empan)	Group effect	/	ns	/						
	Pre test-P6 test effect	9.42	0.01	0.17	1.8	0.07	1.7	0.10	1.8	0.07
	Interaction effect	/	ns	/						
<i>Cardiorespiratory fitness test</i>										
VO ₂ max	Group effect	/	ns	/						
	Pre test-P6 test effect	/	ns	/	/	ns	/	ns	/	ns
	Interaction effect	/	ns	/						
<i>Walking tests</i>										
TUG (sec)	Group effect	6.29	0.01	0.22						
	Pre test-P6 test effect	15.8	0.001	0.26	1.62	0.10	/	ns	/	ns
	Interaction effect	9.8	0.001	0.30						
Gait speed in single task (cm/s)	Group effect	2.38	0.10	0.10						
	Pre test-P6 test effect	/	ns	/	2.5	0.01	2.1	0.05	/	ns
	Interaction effect	/	ns	/						
Gait speed WSC wb (cm/s)	Group effect	/	ns	/						
	Pre test-P6 test effect	14.06	0.001	0.24	2.2	0.05	/	ns	2.7	0.01
	Interaction effect	3.58	0.05	0.14						
Gait speed WSC w (cm/s)	Group effect	3.12	0.05	0.12						
	Pre test-P6 test effect	/	ns	/	1.89	0.07	/	ns	/	ns
	Interaction effect	/	ns	/						
Gait speed WSC c (cm/s)	Group effect	/	ns	/						
	Pre test-P6 test effect	/	ns	/	/	ns	/	ns	1.73	0.07
	Interaction effect	/	ns	/						
Gait speed DT counting (cm/s)	Group effect	2.99	0.06	0.12						
	Pre test-P6 test effect	/	ns	/	/	ns	/	ns	/	ns
	Interaction effect	/	ns	/						

Note. η^2 = effect size (Cohen, 1988). Anova = Analysis of variance. / = no effect. TUG = Timed up and Go test. WSC wb = Walking Stroop Carpet white and black. WSC w = Walking Stroop Carpet word. WSC c = Walking Stroop Carpet color. DT = Dual task

Figure 1. Illustration of the PCT arrangement: Domyos GO 300 bike and Presco software

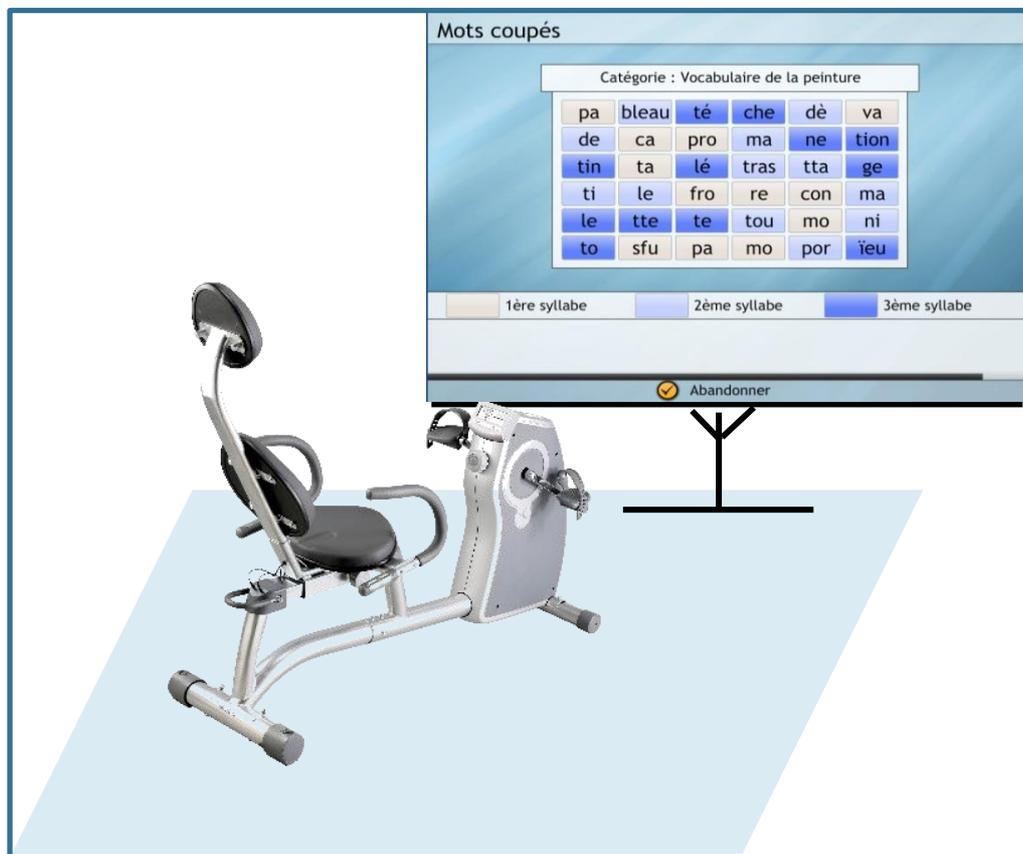


Figure 2. Consort flowchart of participants.

