Charette, C, Blanchet, S, Maganaris, CN, Baltzopoulos, V and McFadyen, BJ

Community-dwelling older adults with mild cognitive impairments show subtle visual attention costs when descending stairs.

http://researchonline.ljmu.ac.uk/id/eprint/12187/

Article

Citation (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

Charette, C, Blanchet, S, Maganaris, CN, Baltzopoulos, V and McFadyen, BJ (2019) Community-dwelling older adults with mild cognitive impairments show subtle visual attention costs when descending stairs. Human Movement Science. 69. ISSN 0167-9457

Community-dwelling older adults with mild cognitive impairments show subtle visual attention costs when descending stairs.

Caroline Charette[1], Sophie Blanchet[2], Constantinos N. Maganaris[3], Vasilios Baltzopoulos[3], Bradford J. McFadyen[1,4,*]

1. Center for Interdisciplinary Research in Rehabilitation and Social Integration (CIRRIS), CIUSSS-CN, Quebec City, Canada
2. Laboratoire Mémoire, Cerveau et Cognition (LMC[2], EA 7536), Université Paris Descartes, Paris, France
3. Research Institute for Sport and Exercise Sciences (RISES), Liverpool John Moores University, UK
4. Department of Rehabilitation, Faculty of Medecine, Université Laval, Quebec City, Canada

* Corresponding author at :
CIRRIS-IRDPQ, 525 boul. Wilfrid-Hamel, Québec, QC, Canada, G1M 2S8
Tel.: 1-418-529-9141 x6584; fax: 1-418-529-3548
E-mail address: brad.mcfadyen@fmed.ulaval.ca (B.J. McFadyen)

Abstract

Background: Older adults are at greater risk of falls while descending stairs. Cognitive deficits can further influence one's ability and mild cognitive impairments (MCI) specifically affect visual attention and dual tasking behavior. The present study aimed at comparing the attentional costs at different points during the approach to and descent of a staircase between older adults with and without MCI.

Methods: Eleven older adults with MCI and twenty-three healthy older individuals without cognitive impairments were recruited. Neuropsychological tests were carried out. In addition, participants approached and descended a 5-step staircase while a simultaneous visual Stroop dual-task was randomly introduced during the approach, transition or steady state descent phases across trials. Three-dimensional kinematics and accuracy on the Stroop task were analysed and dual task costs were calculated.

Results: The MCI group showed deficits for visuo-spatial attention, memory and multi-tasking abilities, as well as balance and decreased confidence for falls efficacy, but not for daily activity scores. Despite such changes, this group of community-dwelling individuals with MCI presented a functional capacity to descend stairs even during divided visual attention. However, there were subtle, but significant, group differences for movement fluidity and performance on the simultaneous cognitive task, particularly during the approach and transition to descent phases. The MCI group also tended to descend slower while using the handrails more than healthy older adults.

Conclusion: The present cohort of community-dwelling older adults with MCI were functional, but appeared to prioritize locomotor demands over the simultaneous cognitive task in a possible "posture first" strategy to descend stairs. The present findings should be considered for developing more ecologically based clinical assessments of mobility deficits following cognitive impairments, with the approach and transition phases during stair descent as key points of focus.

Keywords: Stair gait; locomotion; dual-task; elderly; executive function; aging

1. Introduction

Maintaining independent mobility is essential to social participation and healthy ageing. However, the risk of falling increases considerably with ageing and falls can lead to serious injury, hospitalisation and even death (Blazewick et al., 2018, Seniors' fall in Canada, second edition, 2014). In Canada, falls are the leading cause of injuries among seniors and it is estimated that between 20-30% of older adults fall each year (Seniors' fall in Canada, second edition, 2014). Fall-related injuries also represent an important public health issue with a direct healthcare cost estimated at two billion dollars annually in Canada (Smartrisk, 2009).

Stair negotiation, particularly stair descent, is one of the most demanding and precarious locomotor tasks for the elderly, and represents a great risk for falling and injuries (Verghese et al., 2008, Bosse et al., 2012, Svanström 1974). Thirteen percent of all fall-related injuries for Canadian seniors occur while negotiating stairs (Seniors' fall in Canada, second edition, 2014). The transition on the first or last two steps of a staircase have been specifically targeted as crucial points in stair descent, with nearly 60% of falls at these points (Jackson and Cohen, 1995).

Bosse et al. (2012) have showed that older adults are at greater risk of falls while descending stairs potentially because of a reduced ability to generate adequate muscle strength to control efficiently and safely the body center of mass motion while stepping down. However, vision is crucial as well. While ascending stairs and engaging in a concurrent visual task, healthy young adults have fewer gaze fixations towards stair features (e.g. stairs, handrails), suggesting that peripheral vision is sufficient to collect information to successfully guide stair walking (Miyasike-daSilvia et al., 2012). While both younger and older adults spend the majority of time fixating aspects of the stairs while descending (Zietz et al., 2011), healthy, older adults spend more time looking at the next steps prior to stepping down (Zietz & Hollands, 2009), and thus require greater attentional resources at the transition to descent (Telonio et al., 2014).

Cognitive deficits can influence one’s ability to anticipate and adapt to environmental constraints in order to maintain balance (Hauer et al., 2003). Muir and Colleagues (2012) have demonstrated that executive function (EF) impairments were consistently associated with higher fall risks. Given the increased risk of falling associated with ageing, it is thus not surprising that older individuals with cognitive impairment or dementia have two to three times higher risks of falling and sustaining injuries compared to other seniors without cognitive impairments (Härlein et al., 2009, Muir et al., 2012). Mild cognitive impairments (MCI) specifically afflict approximately 16-20% of older adults (Roberts et al., 2013) and are known to affect both visual attention (Okonkwo et al., 2008) and dual-tasking during level walking (Gillain, 2009). Okonkwo and colleagues (2008) reported that divided attention was the most compromised form of visual attention in MCI individuals, but they also present decrements for selective attention and simple attention. In addition, under a cognitive dual-task, individuals with MCI decreased their gait speed, stride length and stride frequency (Gillain et al., 2009). Therefore, MCI would also be expected to affect stair negotiation and specifically increase risk of falls through deficit attention at the most crucial point of transition to stair descent.

One way to study the effects of attention and executive functioning during locomotor tasks it the use of dual-task (DT) paradigms (Yogev-Seligmann et al., 2008; Snijders et al., 2007; Woollacoot et al., 2002; McFadyen et al., 2017). Some studies have suggested that falls in the elderly population may not simply be due to balance deficits per se, but rather to the inability of these individuals to effectively allocate attention to balance while multitasking (Shumway-Cook, 2000a ; Shumway-Cook, 2000b). Yet, only a few studies have used the DT paradigm during stair negotiation with older adults. Some studies have shown that while dual-tasking during stair negotiation, healthy older adults reduce their gait speed, change lower limb kinematics and kinetics and increase foot clearances (Qu and Hu 2014; Madehkhaksar and Egges, 2016). Telonio et al. (2014) also showed DT effects on slowing gait speed and increasing foot clearance in healthy older adults descending stairs as compared to healthy young adults. Their results also suggested greater attention required by older adults at the transition point of the first step for descending, highlighting this critical point of stair descent. It was previously shown that young healthy adults had increased reaction time during the transition steps while ascending stairs, again suggesting that transition imposes additional cognitive demands (Miyasike-daSilva et al., 2012). During steady-state ascent and descent, Ojha et al. (2009) showed that healthy older adults had longer response times for an auditory DT compared to young adults suggesting greater attentional challenges across stair negotiation with ageing. However, little is understood about attention deficits exposed by dual-task costs during stair descent in older adults with MCI.

The purpose of the present study was to compare the attentional costs of older adults with MCI to healthy older adults without cognitive impairments at three points related to the approach to and descent of a staircase. The specific hypothesis was that persons with MCI would show greater attention effects in relation to greater response costs, gait fluidity changes and foot clearances compared to healthy older adults without cognitive impairments, particularly at the point of transition to descent.

2. Materials and methods

2.1 Participants

Eleven older adults with a diagnosed mild cognitive impairment (MCI group; 72.6±5.6 years; seven women) were compared to twenty-three healthy older adults (OA group; 70.7±5.3 years; twelve women), all community-dwelling. For both groups, exclusion criteria included alcoholism or substance abuse, color blindness, physical, neurological (other than MCI) or cardio-respiratory problems, walking speed less than 1 m/s and a visual acuity score below 20/30 on the Snellen chart (eyeglasses or contact lenses used as needed). For the OA group, participants were also excluded if they self-reported a history of falls, fear of falling or if they presented mild cognitive impairment detected by the neuropsychological tests screening. The MCI group were referred from local memory clinics and had a confirmed clinically diagnosed MCI in reference to the criteria of Petersen (2004) with impaired cognitive performance to a battery of standardized neuropsychological tests. Ethics approval was obtained from the Institut de réadaptation en déficience physique de Québec and all participants provided written informed consent prior to the experiment.

2.2 Materials

A staircase of five steps (average riser heights of 19 cm, tread depths of 30 cm, and 102 cm wide; see Telonio et al. (2014) with bilateral handrails (2.9 cm diameter, 83 cm high from step nose) made of hard wood was used. The top of the staircase was a platform (102 cm wide x 244 cm long) used for the approach phase. Participants wore a harness attached by a rope to a rail on the ceiling, for which the length was controlled by a trained experimenter through a belay mechanism that locked immediately should a fall occur. Four computer monitors were placed at the bottom of the staircase to present the visual stimulus during dual tasking conditions. The monitor placements also allowed participants to maintain the staircase within their field of view during descent. Room lighting was controlled to be between 726 to 787 lux at the level of the first edge at the top platform.

An Optotrak system (model 3020, NDI, 50 Hz) with three infrared sensor bars was used to collect kinematic data. Eleven triads of non-collinear infrared markers were placed on the head, trunk, wrists, pelvis, thighs, shanks and feet. Principal axes of each segment were defined in reference to specific, previously digitized anatomical points. An average of 90 points were also digitized on the soles of each shoe in order to create a 3D surface to calculate minimal foot clearance (Telonio et al., 2013). Participants also wore a microphone to record (1000 Hz) verbal responses to the cognitive tasks (described below). Handrail posts were instrumented with strain gauges calibrated to measure applied forces in three axes.

2.3 Clinical Assessment

2.3.1 Initial Screening

All participants were first contacted by telephone to evaluate their general eligibility for the project. Participants selected for the OA group were then invited for neuropsychological screening for excluding those with mild cognitive impairments (Blanchet et al., 2002; Petersen, 2004). Screening included general cognitive functioning (Mini-Mental State examination, Folstein et al., 1975), verbal (California Verbal Learning test, Nolin, 1999) and visuo-spatial (Visual Reproduction of Wechsler Memory Scale, Wechsler, 1997) episodic memory, attention and executive processes (Digit symbol of Wechsler Adult Intelligence Scale, Wechsler, and Category Fluency from the Delis-Kaplan Executive Function System, Delis et al., 2001), visuo-spatial processes (Copy of the Osterreith-Rey Figure, Rey, 1959; Benton Judgments of Line Orientation, Benton et al., 1978) and language functions (short version of the Boston Naming test, Kaplan et al., 1983). OA participants were excluded if this screening showed any abnormal cognitive function related to being at least 1.5 standard deviations below standardized average norms for age and educational level for episodic memory tests or other cognitive tests. Functional walking speed over 10 m was also evaluated at this session. Since the MCI group was already diagnosed with cognitive impairments, they did not take part in this screening session.

2.3.2 Neuropsychological and physical testing

All eligible participants after screening performed further neuropsychological tests first to assess cognitive functions related to planning (Wisconsin Sorting Card Test Resources, 2003), working memory (Brown Peterson Paradigm, Belleville et al., 2002), attentional switching (Trail Making Test from the Delis-Kaplan Executive Function System, Delis et al., 2001), inhibition

(Stroop from the Delis-Kaplan Executive Function System, Delis et al., 2001), as well as sustained and selective attention (Conners' Continuous Performance II, Conners, 1995; and Test of everyday attention, Robertson et al., 1994). Regarding MCI participants recruited from local memory clinics, the tests that were administered within 6 months or less in the routine clinical assessment were conserved for avoiding repetition effects. The Activities Confidence Balance Scale (ABC, French version; Filiatrault et al., 2007), the Baecke Physical Activity Questionnaire for activity levels (Baecke et al., 1982), the Berg Balance Scale (BBS, Berg et al., 1989), the walking section of the Tinetti test (Tinetti, 1986), and finally, the comfortable and maximal speed over 5 m were assessed by a physical therapist.

2.4 Experimental protocol

The laboratory tests were performed on a separate day in order to avoid fatigue. All participants were asked to descend the staircase first without any simultaneous task for five trials in order to accommodate to the environment. Then, participants descended the staircase for 20 more trials during which four conditions (5 trials each) involving different visual demands were randomly presented: 1) a single task (ST) of descending the staircase with no additional visual task at any point of the approach and descent; and the addition of a visual dual-task (DT) using a Stroop stimulus (see below) presented 2) during the first step of the approach to staircase; 3) at foot contact at the edge of the platform to begin transition; or 4) during steady-state descent beginning at foot contact on the second step down (see Telonio et al., 2014). During these 20 trials for data collection, the participant was aware that there could be a dual visual task, but was unaware if it would be presented. The simultaneous visual Stroop task required participants to name the incongruent color of the ink of the words red, green, or blue (only one word presented per trial) while ignoring the lexical meaning of the word. Words were projected for 1 second simultaneously on the four computer monitors. For the approach and transition DT conditions, the Stroop stimuli were triggered by light beams placed on the top platform adjusted to the participant's step length. For the steady-state condition, the Stroop stimulus was triggered by a loading force of 20 N on a force platform placed on the second step from the top of the staircase. During the experimental protocol, rest periods were provided as necessary. All participants were instructed to name the color of the word, if available, projected on the screens as quickly as possible while maintaining their walking speed. Therefore, participants were asked to prioritize both locomotor and cognitive tasks. No instructions were given on which foot to start with. Baseline Stroop task performances were collected while sitting both before and after the stair descent trials where twenty Stroop words were presented at a rate of 1 Hz.

2.5 Dependent variables

Gait speed was calculated as the mean forward velocity of trunk center of mass (CM) for the two footsteps following the step where Stroop stimuli would be presented for each phase with the exception of approach where only the second footstep after gait initiation was analyzed due to the limited field of view of the Optotrak cameras. Fluidity was calculated as the number of zero crossings in trunk anterio-posterior acceleration corresponding to changes between forward acceleration and deceleration. A greater number of zero crossings indicates a less fluid motion. Minimum foot clearance (MFC) was calculated as the minimal distance between the shoe sole and the edge of each staircase step (Telonio et al., 2013), where the first edge corresponds to the top platform, for the transition and the steady-state conditions only. Cognitive task performance was characterized by the response errors to the Stroop task committed during stair descent and verbal response time to the Stroop task was calculated as the time between stimulus presentation and the beginning of the recorded voice response. Dual-task cost (DTC) was calculated for kinematic variables and for response time to the Stroop task as the difference between DT and ST performances divided by ST performance. Finally, uni- and bi-lateral handrail use (duration of hand contact) was calculated as the total time of force contact on the handrails.

2.6 Data analysis

Group characteristics and clinical tests were compared using independent T-tests. Kinematic variables and their corresponding DTCs were analyzed using separate repeated measures ANOVAs (SPSS 23.0; GLM with EMMEANS post-hoc tests) for the approach step [2 visual tasks (ST or DT) x 2 groups] as well as transition [2 visual tasks x 2 steps x 2 groups] and steady-state [2 visual tasks x 2 steps x 2 groups] steps. Response times for Stroop tasks and their associated DTC were analyzed using separate repeated measures ANOVAs [3 positions x 2 groups]. When considering education as a co-variable, the only variable that showed significance was speed for all positions (approach: $p = 0.031$, transition: $p=0.043$ and steady: $p=0.035$). Therefore, the number of years of education was added as a co-variable only in the repeated measures ANOVAs for speed. For errors on the Stroop task and for handrail use analysis, a two-sample test for equality of proportions with continuity correction was used and time contact on handrails was analyzed using repeated measures ANOVAs [4 positions x 2 groups]. Significance level was set to $p \leq 0.05$ and all p values are presented.

3. Results

3.1 Group characteristics and clinical assessment

There was no difference between the two groups for age (OA = 70.7±5.3 years; MCI = 72.6±5.6 years; p=0.358), but there was a difference for level of education (OA = 17.00±3.80 years; MCI = 11.55±3.93 years; p=0.01). Table 1 presents the results of physical and neuropsychological tests for both groups. For the physical tests, there was no difference between the two groups for the Beacke questionnaire (p=0.937) and normal walking speeds (p=0.162). However, the results of ABC questionnaire (p<0.001), Berg balance test (p=0.03), Tinetti test (p=0.018), and maximum walking speed (p=0.031) were significantly different between groups, with the MCI group showing less confidence to maintain balance in their everyday activities, have lower capacity in balance and have slower maximum walking speeds. MCI individuals walked slower at the comfortable walking speed, but it was not significant (p=0.162). For neuropsychological data, one MCI participant was missing from the Letter sequencing and Number-Letter switching of the Trail Making tests due to diminished knowledge of the alphabet. However, it was felt justified to retain this participant for all other analyses of the study after noting that their Stroop D-KEFS test scores were in fact among the best performances compared to the other individuals with MCI and the only indication of "outlying" behavior was for DTC for minimum clearance at the 1st step of steady-state descent, but this condition showed high variability across all participants of both groups. Individuals with MCI were slower than older adults without cognitive impairments at tasks evaluating visual selective attention (Number and Letter sequences, TMT, p = 0.001 for both subtests; Telephone search, TEA, p = 0.007) and visual scanning (Visual scanning, TMT, p = 0.005). The MCI group performances were also lower at tasks assessing attentional switching ability (Inhibition-switching, Stroop, p < 0.001; Number-Letter switching, TMT, p < 0.001;

Telephone search while counting, TEA, $p = 0.008$), working memory (Brown-Peterson Paradigm, $p = 0.001$) and planning (WCST correct response, $p < 0.001$ and perseverative errors, $p = 0.002$).

3.2 Kinematic variables and DTC

Although MCI participants appeared on average to descend the staircase slower (Fig. 1), there were no main group effects for speed (approach: F (1,32)= 0.014, p= 0.907, $\eta^2_{partial} <0.001$; transition: F (1,32)= 0.001, p= 0.978, $\eta^2_{partial} <0.001$; steady: F (1,32)= 0.033, p=0.857, $\eta^2_{partial}$= 0.001) and no main effects of visual tasks (approach: F (1,32)= 0.910, p= 0.347, $\eta^2_{partial}$= 0.029; transition: F (1,32)= 0.874, p= 0.357, $\eta^2_{partial}$= 0.027; steady: F (1,32)= 0.661, p=0.422, $\eta^2_{partial}$= 0.021). Thus, both groups adopted similar behaviours for descending gait speed.

For minimal foot clearance (Fig. 2) during transition, there was no main group effect (F (1,32)= 0.120, p= 0.732, $\eta^2_{partial}$= 0.004), but there was a main effect of step (F (1,32)= 56.155, p<0,001, $\eta^2_{partial}$= 0.637) and a step by visual tasks interaction (F (1,32)= 6.759, p= 0.014, $\eta^2_{partial}$= 0.174). The data showed that clearance on the second step was higher than for the first step for both groups. MFC also increased from single to dual task for the second step, but was not statistically significant for both MCI (p=0.078) and OA (p=0.208) groups. During the steady-state condition, no main effect of group (F (1,32)= 0.038, p=0.846, $\eta^2_{partial}$< 0.001) and no effect of visual tasks (F (1,32)= 1.649, p=0.208, $\eta^2_{partial}$= 0.049) were observed, but there was a main step effect for MFC (F (1,32)= 9.622; p=0.004, $\eta^2_{partial}$= 0.231) and a step by group interaction (F (1,32)= 7.523,p=0.010, $\eta^2_{partial}$= 0.190). Although not significant, post-hoc analysis showed a tendency for the MCI individuals to increase their clearance during DT at step 4 (p=0.066).

On average, older adults with MCI appeared to show less fluidity (Fig. 3) throughout all conditions, especially during the first step of the transition. However, no main group effects were found for the approach (F (1,32)= 1.734, p=0.197, $\eta^2_{partial}$= 0.051), transition (F (1,32)= 3.496, p=0.071, $\eta^2_{partial}$= 0.098) and steady-state (F (1,32)= 0.592, p=0.447, $\eta^2_{partial}$= 0.018) conditions.

For the approach condition, no significant effects of visual tasks (F (1,32)= 0.849, *p*=0.364, $\eta^2_{partial}$= 0.026) or of visual tasks by group interaction (F (1,32)= 0.459, *p*=0.503, $\eta^2_{partial}$= 0.014) were found. Fluidity during transition resulted in main visual tasks effects (F (1,32)= 4.538, *p*=0.041, $\eta^2_{partial}$= 0.124), step effects (F (1,32)= 36.266, $p<0.001$, $\eta^2_{partial}$= 0.531) as well as a step by group interaction (F (1,32)= 7.312, *p*=0.011, $\eta^2_{partial}$= 0.186) and a visual tasks by step interaction (F (1,32)= 7.155, *p*=0.012, $\eta^2_{partial}$= 0.183). Post-hoc tests demonstrated a significant difference between DT and ST for the first step of transition for the MCI group only (*p*=0.006). In addition, the MCI group was less fluid during DT of the first step of transition compared to the OA group (*p*=0.017). For steady-state descent, there was only a significant main step effect (F (1,32)= 27.329, $p<0.001$), and a visual tasks by step interaction (F (1,32)= 10.034, *p*= 0.003, $\eta^2_{partial}$= 0.461). However, during the first step of steady-state descent (i.e step 3), there was a significant difference during DT and ST for both OA (*p*=0.020) and MCI (*p*=0.001) groups, with both groups following the same tendency with greater fluidity during DT.

DTCs for each kinematic variable are presented in Table 2. For DTC for speed, there was a main effect of step (F (1,32)= 4.024, *p*=0.005, $\eta^2_{partial}$= 0.112), but no main group effect (F (1,32)= 1.348, *p*=0.254, $\eta^2_{partial}$= 0.040) and no step by group interaction effect (F (1,32)= 0.231, *p*= 0.910, $\eta^2_{partial}$= 0.007). The data showed that there was a greater effect of DT during the approach for both groups, and especially for the MCI group, there were greater effects of DT during step 2 and step 4. For DTC for clearance, no main effects were found for step (F (1,32)= 0.520, *p*=0.637, $\eta^2_{partial}$= 0.016), for group (F (1,32)= 1.764, *p*=0.194, $\eta^2_{partial}$= 0.052) and for step by group interaction (F (1,32)= 0.552, *p*=0.617, $\eta^2_{partial}$= 0.017). Finally, for fluidity, a main effect of step was found (F (1,32)= 5.708, *p*=0.001, $\eta^2_{partial}$= 0.151), but there was no main effect of group (F (1,32)= 0.044, *p*=0.835, $\eta^2_{partial}$= 0.001) or step by group interaction (F (1,32)= 0.535, *p*=0.692, $\eta^2_{partial}$= 0.016). Variability across participants was great for DTC fluidity.

3.3 Handrail use

Ten of eleven participants with MCI (90.9%) used the handrail at least one time during stair descent compared to only 43.5% (10/23) for the OA group (p=0.024). From these handrail users, 90% (9/10) of the MCI participants used the handrail on the majority of trials compared to only 60% (6/10) of the OA sub-group (p=0.302). Of these same sub-groups of handrail users, 70% (7/10) and 50% (5/10) of the MCI and OA groups respectively used both handrails (p=0.648). Finally, the duration of the time of contact on the handrails was not different between the two groups, for the approach (OA: 1.51±0.80 sec, MCI: 1.65±1.38 sec; p=0.659) transition (OA: 1.55±0.82 sec, MCI: 1.28±1.26 sec; p=0.348) and steady-state (OA: 1.37±0.80 sec, MCI: 1.32±1.24 sec; p=0.905) conditions.

3.4 Cognitive task performance

Response times to the Stroop task during the approach, transition and steady-state of stair descent and the associated DTC for both groups are illustrated in Fig. 4. For the response times, there was a main group effect (F (1,32)= 6.319, p=0.017, $\eta^2_{partial}$= 0.165) and a main effect of position (F (1,32)= 3.747, p=0.034, $\eta^2_{partial}$= 0.105), but no position by group effect (F (1,32)= 0.797, p=0.443, $\eta^2_{partial}$= 0.024). Specifically, there was a statistically significant difference between the two groups for the approach phase (p=0.015) and for steady-state descent (p=0.013), but only a tendency for transition (p=0.052), with greater response times for the MCI group. The data in Fig. 4b illustrate that DTC were higher for the OA group compared to the MCI group for all positions. However, both groups performed similarly with greater DTC for approach compared to steady-state descent and statistical analysis showed no main effects of position (F (1,32)= 3.057, p=0.061, $\eta^2_{partial}$= 0.087), or group (F (1,32)= 2.271, p=0.142, $\eta^2_{partial}$= 0.066), and no position by group interaction (F (1,32)= 0.408, p=0.644, $\eta^2_{partial}$= 0.013). Regarding response errors (see Table 3), 90.9% (10/11) of participants in the MCI group committed errors compared to only 39.1% (9/23) of OA participants (*p*=0.001). The maximal number of errors committed per participant was 4 for the OA group and as high as 11 for the MCI group. More precisely, during the approach phase, 6 OA and 8 MCI individuals committed errors, with a range of respectively 1-2 and 1-6 errors. At transition, 6 OA made 1-2 errors compared to 7 MCI participants who committed 1-3 errors. Finally, during steady-state descent, 5 OA committed only 1 error, while 6 MCI individuals made between 1-3 errors.

4. Discussion

The present study compared visual attention costs between older adults with and without MCI during the approach to and descent of a staircase. Despite decreased confidence, general balance and cognitive deficits, community-dwelling individuals with MCI maintained their locomotor capacity to descend stairs even with divided visual attention. Interestingly, however, the individuals with MCI had poorer movement fluidity in dual task cognitive performance. In addition, the MCI group showed slightly slower gait speed and used the handrails more during stair descent. Overall, these findings show a continued functional level in community-dwelling older adults with MCI, but with an apparent sacrifice of performance on the simultaneous cognitive tasks. This suggests a possible “posture first” (Yogev-Seligmann et al., 2008) approach for these individuals with MCI while descending stairs.

It is important to note that both groups were comparable in terms of age, comfortable level walking speeds and physical activity levels. This underlines the fact that the MCI group was quite functional and any subtle differences were due to the mild deficits in cognitive ability. While there were differences between groups for balance ability, BBS scores remained within normative ranges according to age with no clinical indication of fall risk (BBS cut-off score of <45/56, Steffen et al., 2002). Yet, there were differences between the two groups on their confidence to maintain balance in everyday activities, with MCI being less confident overall.

Thus, despite a functional physical capacity, individuals with MCI had decreased self-confidence in their ability. This may be why the MCI group was less fluid at the transition to stair descent and showed on average slower speed during stair descent with more of the MCI group using the handrails, and more often bilaterally, which would increase stability.

To ensure that handrail use was not speed related, we conducted a post-hoc analysis by looking at Spearman correlations between handrail use and speed. There were no significant correlations for either group during approach (OA: $p = 0.110$, MCI: $p = 0.223$), transition (OA: $p = 0.708$, MCI: $p = 0.370$) and steady-state descent (OA: $p = 0.901$, MCI: $p = 0.770$). In the literature, handrail use is not well documented for the aging population, and not reported, to the best of our knowledge, for an MCI population. Zietz et al. (2011) stated that only an OA group with higher risk of falls used the handrail while descending stairs. Put in perspective with the current observations, individuals with MCI appear to have adapted a more cautious locomotor behaviour during stair descent whether related to mild cognitive deficits or related decreased self-confidence levels.

Interestingly, MFC did not change between groups and both groups increased foot clearance during the second transition step. This increase may be explained by the visual competition made by the simultaneous Stroop task that was also observed in a previous study comparing younger and older adults using the same protocol (Telonio et al., 2014). The authors suggested that the first step at transition could have benefited from peripheral and possibly direct vision of the foot, while the second step was taken without visual feedback from the foot. Individuals thus likely relied on somatosensory information as well as on optic flow from the staircase during descent. Given the cautious behaviour discussed above, we would have expected a group difference in MFC as well. There may be different reasons for the present results. First, such foot clearance is a relatively well-programmed, crucial movement that may not have been affected by decreased confidence or conscious attempts to be cautious. Second, MFC at the second step was already raised in comparison to the other steps and may have been sufficient to appease even one's lower level of confidence. Alternatively, any further elevation could result in unwanted balance disturbances and higher effort and energy demands. Finally, more of the MCI group used the handrails and this could have provided more confidence during descent. The reasons may also include a combination of these or other factors. Smith et al (2016) concluded that tasks involving internal interference (e.g., mental tracking, memory) appear to disturb gait more than those that involve external interference (e.g., reaction time tasks). Thus, it is possible that another form of DT could have resulted in more obvious group differences. However, the present protocol mimicked visual interference that occurs frequently in daily mobility tasks. Overall, the subtle changes noted above for fluidity and speed tendencies with no MFC group changes further supports the argument that individuals with MCI may have been prioritizing their locomotor performance.

At the cognitive level, the neuropsychological tests indicated that the MCI group had impairments in visual scanning, selective attention, as well as in executive functions such as planning, working memory and in attention switching. It has already been shown that OA take longer to respond to a simultaneous task during steady-state descent (Ojha et al., 2009). However, in our study response times during stair descent were greater for the MCI group. More specifically, both groups made more errors during the approach and transition periods with significantly greater errors for the MCI group. This may be explained by the visual interference task used in the present work. Ziet & Hollands (2009) showed that OA spend more time looking at the next steps than younger participants before stepping onto it. Uiga et al (2015) demonstrated that when walking up and down stairs, OA fixated longer on the stairs and travel path than younger adults. While difficult to prove with the present data, it is possible that individuals with

MCI had greater difficulty in dividing such visual focus due to their deficits. However, DTCs for response times were not statistically different between groups. This could be explained by the fact that at baseline, MCI individuals already had greater response times compared to OA likely due to visual information processing deficits. Yet, a greater number of errors during the planning and transition stages for descent may suggest that individuals with MCI were not able to properly divide attention despite taking more time. Since the conditions were randomized and unannounced, participants from both groups were required to maintain attention during approach and descent across conditions. However, differences between groups were observed, again suggesting that MCI individuals' attentional capacities are affected. Given these more obvious changes in cognitive performance along with the findings for locomotor behaviour, and considering that the protocol used required all participants to prioritize both locomotor and cognitive tasks, this further supports that the MCI group ended up putting more priority on a cautious decent behaviour than on simultaneous cognitive task.

Gait performance in general, and dual task walking paradigms specifically, have been suggested as important markers to detect declines in mobility and cognitive abilities (e.g., Cullen et al., 2018, Bahureksa et al., 2017). In their systematic review, Bahureksa and colleagues (2017) concluded that high cognitive load is required in DT walking paradigms in order to observe gait changes in MCI and, therefore, discriminate between MCI and healthy individuals. Contrary to dementia, increasing cognitive demands in DT protocols appear to increase sensitivity (i.e., verbal fluency have less sensitivity than an arithmetic task). While the present results showed that community-dwelling older adults with MCI maintain their general capacity to descend stairs with divided attention, clear differences in cognitive performance along with subtle change in gait were evident, particularly when demands on visual attention were greater at transition during stair descent. Transition to stair descent represents a critical point while negotiating stairs

(Telonio et al., 2014) and is where most falls occur (Jackson & Cohen, 1995). In real public and home environments, there are many stimuli (e.g., visual, auditory) that compete for our attention along with a variety of physical demands of the built environment (e.g., obstacles, weather, irregular sizes). More realistic, complex, community environments could render stair decent more difficult and challenging, especially for individuals with MCI. Given the subtle, but evident changes in an active MCI group here, the present findings might be used to further explore variables and DT conditions to be exploited to expose MCI deficits. In a less controlled and predictable environment than the one in the present study, it is possible that gait or cognitive adjustments will be more evident.

5. Limitations

The sample size of the MCI group was smaller than that of the OA group due to recruitment constraints. Although a larger MCI cohort might better highlight more group differences, having a larger control group allows for a better comparison to “normal” behaviour in older adults. There was a significant difference in the level of education between groups, but we took this into account in our statistical analyses by adding education as a co-variable when relevant. In addition, visual acuity was only verified with the Snellen chart test, and not with an extensive testing, so that we cannot be completely certain whether both groups had the same corrected vision. Participants were not evaluated for color perception, so we do not know if this affected the results. In addition, foot dominance may have had an effect, but was not considered in the present study.

6. Conclusions

MCI community-dwelling older adults maintained their general capacity to descend stairs even with divided attention, but adopted a more cautious behaviour, particularly at transition. The longer response time to the visual stimuli along with greater errors during approach and transition indicate that MCI individuals have difficulty dividing visual attention and are, therefore, more susceptible to visual interference than healthy OA. The added observation that locomotor changes were more subtle and suggested greater caution supports the fact that individuals with MCI prioritized the locomotor behaviour. The present findings highlight the importance of looking at approach and transition phases during stair descent and may inform the development of more ecological clinical assessments of mobility.

Conflict of interest

Declarations of interest: none

Acknowledgments

The authors would like to thank Mr. Guy St-Vincent, Ms. Sophie Villeneuve, Mr. Frédéric Bolduc and Ms. Isabelle Lorusso for their technical assistance and Mr. Jean Leblond for statistical consulting. We also acknowledge Dr. Alessandro Telonio for the protocol design and programming.

Funding: This work was funded in part by the Canadian Institutes for Health Research of Canada as part of a partnership grant with the New Dynamics of Ageing Research Initiative in the United Kingdom.

References

Baecke, J.A., Burema, J., & Frijters, J.E. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am. J. Clin. Nutr, 36*, 936–942.

Bahureksa, L., Najafi, B., Saleh, A., Sabbagh, M., Coon, D., Mohler, J., & Schwenk, M. (2017). The Impact of Mild Cognitive Impairment on Gait and Balance: A Systematic Review and Meta-Analysis of Studies Using Instrumented Assessment. *Gerontology,63*(1), 67-83.

Belleville, S., Chatelois, J., Fontaine, F., & Peretz, I. (2002). Mémoria: Batterie informatisée d'évaluation de la mémoire pour Mac et PC. Institut Universitaire de Gériatrie de Montréal.

Benton, A.L., Varney, N.R., & Hamsher, K.D. (1978). Visuospatial judgment. A clinical test. *Arch. Neurol*. *35*, 364–367.

Berg, K., Wood-Dauphinee, S., Williams, J., & Gayton, D. (1989). Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can*. *41,* 304–311.

Blanchet, S., McCormick, L., Belleville, S., Gely-Nargeot, M.C., & Joanette, Y. (2002). Mild cognitive impairments in the elderly: a critical review. *Rev Neurol*, *158,* 29–39.

Blazewick, D.H., Chounthirath, T., Hodges, N.L., Collins, C.L., and Smith, G.A., (2018). Stair-related injuries treated in United States emergency departments. *American Journal of Emergency Medicine, 36,* 608-614.

Bosse, I., Oberlander, K.D., Savelberg, H.H., Meijer, K., Bruggemann, G.P., & Karamanidis, K., 2012. Dynamic stability control in younger and older adults during stair descent. *Hum Mov Sci*, *31* (6), 1560–1570.

Conners, C.K. (1995). Conners' Continuous Performance Test. MHS, Toronto.

Cullen S., Montero-Odasso, M., Bherer, L., Almeida, Q., Fraser, S., Muir-Hunter, S., et al. (2018). Guidelines for Gait Assessments in the Canadian Consortium on Neurodegeneration in Aging (CCNA). Canadian Geriatrics Journal, 21 (2), 157-165.

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). The Delis – Kaplan Executive Function System. The Psychological Corporation, San Antonio.

Filiatrault, J., Gauvin, L., Fournier, M., Parisien, M., Robitaille, Y., Laforest, S., Corriveau, H., & Richard, L. (2007). Evidence of the psychometric qualities of a simplified version of the Activities-specific Balance Confidence scale for community-dwelling seniors. *Arch Phys Med Rehabil, 88*, 664–672.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res. 12*, 189–198.

Gillain, S., Warzee, E., Lekeu, F., Wojtasik, V., Maquet, D., Croisier, J-L., Salmon, E., & Petermans, J. (2009). The value of instrumental gait analysis in elderly healthy MCI or Alzheimer's disease subjects and a comparison with other clinical tests used in single and dual-task conditions. *Ann Phys Rehabil Med*. *52*(6), 453-474.

Härlein, J., Dassen, T., Halfens, R.J.G., & Heinze, C. (2009). Fall risk factors in older people with dementia or cognitive impairment : a systematic review. *J Adv Nurs.* 65(5), 922-933.

Hauer, K., Pfisterer, M., Weber, C., Wezler, N., Kliegel, & M. Oster, P. (2003). Cognitive impairment decreases postural control during dual tasks in geriatric patients with a history of severe falls. *J Am Geriatr Soc*. *51*, 1638-1644.

Jackson, P.L., & Cohen, H.H. (1995). An in-depth investigation of 40 stairway accidents and the stair safety literature. *J. Saf. Res*. *26*, 151–159.

Kaplan, E.F., Goodglass, H., & Weintraub, S. (1983). The Boston Naming Test, 2nd ed. Lea & Febiger, Philadelphia PA.

Madehkhaksar, F, & Egges, A. (2016). Effect of dual task type on gait and dynamic stability during stair negotiation at different inclinations. *Gait Posture*. *43*, 114-119.

McFadyen, B.J., Gagné, M.E., Cossette, I., & Ouellet, M-C. (2017). Using dual task walking as an aid to assess executive dysfunction ecologically in neurological populations: A narrative review. *Neuropsychol Rehabil*. *27* (5), 722-743.

Miyasike-daSilva, V., & McIlroy, W.E. (2012). Does it really matter where you look when walking on stairs? Insights from a dual-task study. *PloS One*. *7* (9), e44722.

Muir, SW., Gopaul, K., & Montero Odasso, MM. (2012). The role of cognitive impairment in fall risk among older adults : a systematic review and meta-analysis. *Age and Ageing*. *41,* 299-308.

Nolin, P. (1999). Analyses psychométriques de l'adaptation française du California Verbal Learning Test (CVLT). *Rev Québécoise Psychol. 1* : 39–55.

Ojha, H.A., Kern, R.W., Janice Lin, C-H., & Winstein, C.J. (2009). Age affects the attentional demands of stair ambulation : Evidence from a dual-task approach. *Phys Ther. 89* (10) : 1080-1088.

Okonkwo, O.C., Wadley, V.G., Ball, K., Vance, DE., & Crowe, M. (2008). Dissociations in visual attention deficits among persones with mild cognitive impairment, *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*. *15* (4) : 492-505.

Petersen, R.C. (2004). Mild cognitive impairment as a diagnostic entity. *J Intern Med. 256* (3) : 183–194.

Public health Agency of Canada. *Seniors' falls in Canada : second report*. Available from https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/seniors-aines/publications/public/injury-blessure/seniors_falls-chutes_aines/assets/pdf/seniors_falls-chutes_aines-eng.pdf. Published 2014. Assessed september 7, 2018.

Qu, X., & Hu X. (2014). Lower-extremity kinematics and postural stability during stair negotiation : effects of two cognitive tasks. *Clin Biomech. 29* (1), 40-46.

Resources, P.A. (2003). Computerised Wisconsin Card Sort Task Version 4 (WCST).

Rey, A. (1959). Test de copie d'une figure complexe: Manuel. Les Éditions du Centre de psychologie appliquée, Paris.

Roberts, R., Knopman D.S. (2013). Classification and epidemiology of MCI. *Clin Geriatr Med. 29* (4), 753-772.

Robertson I.H., Ward T., Ridgeway V., & Nimmo-Smith I. (1994). The Test of Everyday Attention Thames Valley Test Company, Bury St. Edmunds.

Shumway-Cook, A., & Woollacott, M. (2000). Motor Control: Theory and Practical Applications, 2nd ed. Baltimore, MD: Lippincott, Williams and Wilkens. (a)

Shumway-Cook, A., & Woollacott, M. (2000). Attentional demands and postural control: the effect of sensory context. *J Gerontol A Biol Sci Med Sci, 55* (1), M10-6. (b)

Smartris K. *The economic Burden of injury in Canada*. Available from: http://www.parachutecanada.org/downloads/research/reports/EBI2009-Eng-Final.pdf. Published 2009. Assessed september 7, 2018.

Smith, E., Cusack, T., & Blake, C. (2016). The effect of a dual task on gait speed in community dwelling older adults : A systematic review and meta-analysis. *Gait Posture. 44,* 250-258.

Snijders, A.H., Verstappen, C.C., Munneke, M., & Bloem, B.R. (2007). Assessing the interplay between cognition and gait in the clinical setting. *J Neural Transm. 114* (10), 1315–21.

Steffen, T.M., Hacker, T.A., & Mollinger, L. (2002). Age- and gender-related test performance in community-dwelling elderly people : Six-minute walk test, berg balance scale, timed up & go and gait speeds. *Phys Ther, 82* (2), 128-137.

Svanström L. (1974). Falls on stairs : an epidemiological accident study. *Scand J Soc Med, 2* (3), 113-120.

Telonio, A., Blanchet, S., Maganaris, C.N., Baltzopoulos, V., Villeneuve, S., & McFadyen, B.J. (2014). The division of visual attention affects the transition point from level walking to stair descent in healthy, active older adults. *Exp Gerontol, 50,* 26-33.

Telonio, A., Blanchet, S., Maganaris, C.N., Baltzopoulos, V., McFadyen, B.J. (2013). The detailed measurement of foot clearance by young adults during stair descent. *J. Biomech*. 46, 1400–1402.

Tinetti, M.E. (1986). Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc. 34*, 119–126.

Uiga, L., Cheng, K.C., Wilson, M.R., Masters, R.S.W., & Capio, C.M. (2015). Acquiring visual information for locomotion by older adults : A systematic review. *Ageing Res Rev. 20* : 24-34.

Verghese, J., Wang, C., Xue, X., & Holtzer, R. (2008). Self-reported difficulty in climbing up or down stairs in nondisabled elderly. *Arch. Phys. Med. Rehabil*, *89*, 100–104.

Wechsler, D. (1997). MEM-III: Échelle clinique de mémoire de Wechsler. Les Éditions du Centre de Psychologie Appliquée, Paris.

Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review an emerging area of research. *Gait Posture, 16* (1), 1–14.

Yogev-Seligmann, G, Hausdorff, JM, & Giladi N. (2008). The role of executive function and attention in gait. *Mov Disord, 23*(3), 329-342.

Zietz, D., & Hollands, M. (2009). Gaze behavior of young and older adults during stair walking. *J. Motor Behav, 41*(4), 357-365.

Zietz, D., Johannsen, L., & Hollands, M. (2011). Stepping characteristics and Centre of Mass control during stair descent: effects of age, fall risk and visual factors. *Gait Posture*, *34*, 279–284.

Figure Captions:

Fig 1. Gait speed across approach (step 0), transition (steps 1,2) and steady-state (steps 3,4) steps during single (ST) and dual (DT) tasks. Data represent means±SD.

Fig 2. Minimum foot sole clearance across transition (steps 1,2) and steady state (steps 3,4) steps during single (ST) and dual (DT) tasks. Data represent means±SD.

Fig 3. Fluidity over the second step (step 0) of approach, the two steps of transition (steps 1 and 2) and the two steps of steady-state descent (steps 3 and 4) for both the single (ST) and dual (DT) tasks. Data represent means±SD.

Fig 4. Response time (A) and dual task cost with baseline (B) for Stroop presentation during stair descent. Data represent means±SD.

Table 1. Clinical assessment results

	Mean ± SD	
Variables	**OA (n=23)**	**MCI (n=11)**
Physical assessment		
Activities Balance Confidence Scale (/48)	43.57±3.24	37.18±5.84**
Baecke Questionnaire (/15)	7.97±1.31	4.78±4.25
Berg Balance Scale (/56)	55.30±1.08	52.45±4.01*
Tinetti -- Walking (/16)	15.87±0.35	15.18±1.25*
Normal Walking speed (m/s)	1.40±0.16	1.30±0.26
Maximum Walking speed (m/s)	2.01±0.28	1.75±0.39*
Neuropsychological assessment		
Wisconsin Card Sorting test		
Correct responses (/64)	45.56±7.95	32.82±9.36**
Categories completed (/6)	3.04±1.33	1.27±1.01**
Perseverative errors	8.35±4.14	15.09±7.49**
Brown-Peterson Paradigm (/36)	26.87±4.61	21.09±4.11**
Conners' Continous Performance test II		
Omissions	6.21±8.64	9.91±11.43
Comissions	13.26±7.63	14.36±5.73
Variability	8.35±3.85	10.56±4.83
Trail Making Test (sec)		
Visual scanning	21.63±3.35	27.56±8.11**
Number sequencing	38.80±12.40	63.00±26.59**
Letter sequencing†	42.98±17.14	78.00±36.88**
Number- Letter switching†	100.43±27.21	201.2±86.49**
Motor speed	22.97±4.60	36.71±10.71**
D-KEFS --Stroop (sec)		
Color	31.03±6.19	39.68±11.36**
Word	21.25±3.42	25.51±5.38**
Color-word	66.89±16.07	98.87±38.28**
Inhibition-switching	65.98±15.72	117.57±57.67**
Tests of Everyday Attention (sec)		
Visual elevator	3.66±0.83	4.53±1.92
Telephone search	4.10±0.72	4.94±0.92**
Telephone search while counting	6.53±3.87	14.07±11.79**

Notes: * $p < 0.05$, ** $p \leq 0.01$.

†Only 10 participants of the MCI group (vs 11) were analyzed because one participant has diminished knowledge of the alphabet.

Table 2. Dual-task cost (% change from ST) for gait speed, clearance and fluidity during stair descent.

Variables	Step	OA (mean±SD)	MCI (mean±SD)
Speed (%)	0	4.19 ± 5.26	5.20 ± 9.87
	1	-1.02 ± 6.10	1.42 ± 8.26
	2	1.64 ± 6.33	4.83 ± 11.13
	3	-1.35 ± 4.74	-0.90 ± 4.12
	4	0.13 ± 8.40	5.33 ± 7.82
Clearance (%)	1	-4.88 ± 34.40	17.24 ± 47.53
	2	10.78 ± 18.28	11.85 ± 22.90
	3	3.00 ± 25.29	8.79 ± 44.09
	4	9.44 ± 49.83	20.62 ± 33.07
Fluidity (%)	0	1.51 ± 14.40	-2.54 ± 11.76
	1	8.66 ± 31.38	14.31 ± 16.90
	2	3.13 ± 15.75	2.36 ± 22.72
	3	-9.27 ± 13.02	-8.51± -7.64
	4	4.89 ± 18.54	-0.94 ± 14.51

Notes: DTCs were calculated for the second step of approach (step 0), the two steps of transition (step 1 and 2), and the two steps of steady-state descent (step 3 and 4).

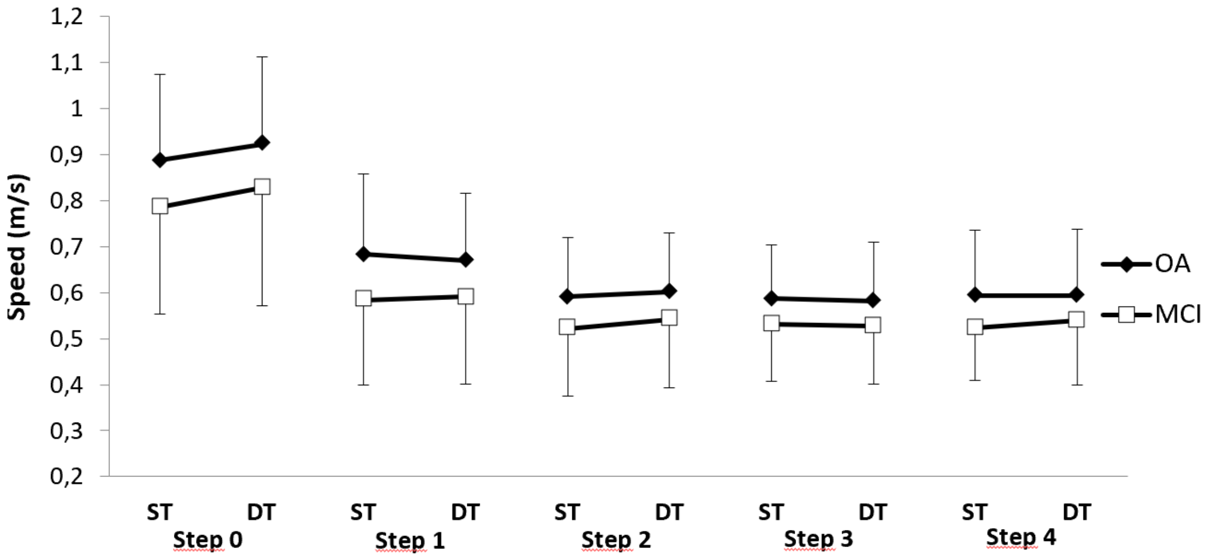

Fig 1. Gait speed across approach (step 0), transition (steps 1,2) and steady-state (steps 3,4) steps during single (ST) and dual (DT) tasks. Data represent means±SD.

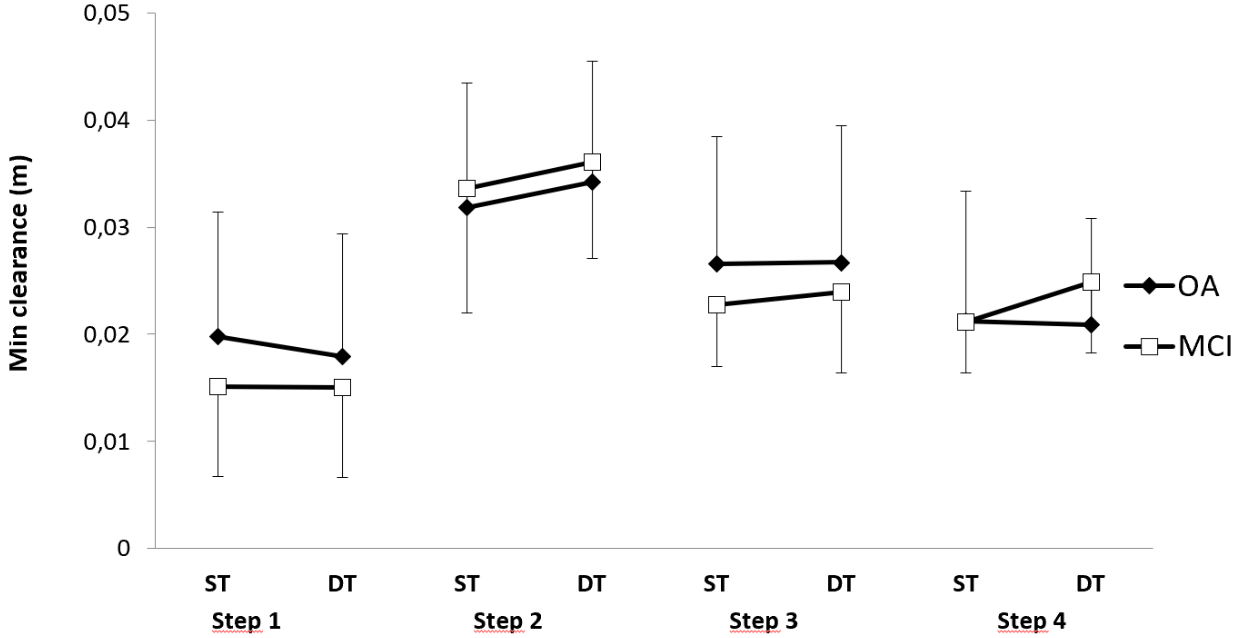

Fig 2. Minimum foot sole clearance across transition (steps 1,2) and steady state (steps 3,4) steps during single (ST) and dual (DT) tasks. Data represent means±SD.

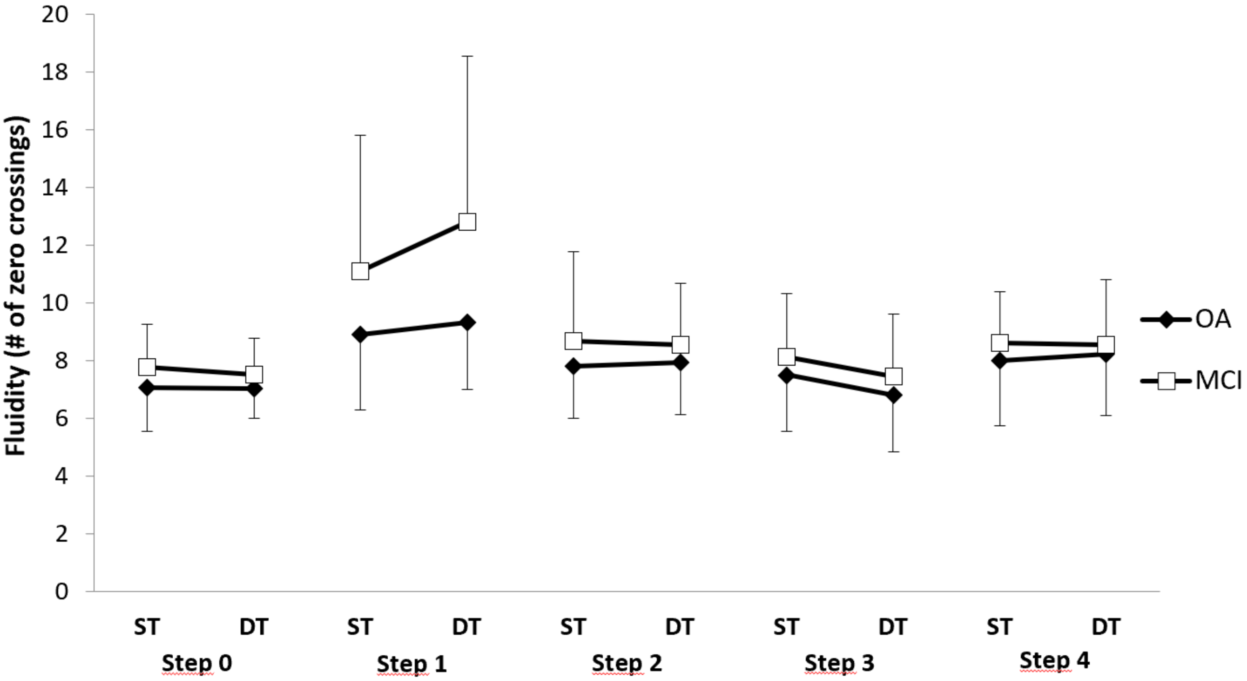

Fig 3. Fluidity over the second step (step 0) of approach, the two steps of transition (steps 1 and 2) and the two steps of steady-state descent (steps 3 and 4) for both the single (ST) and dual (DT) tasks. Data represent means±SD.

657

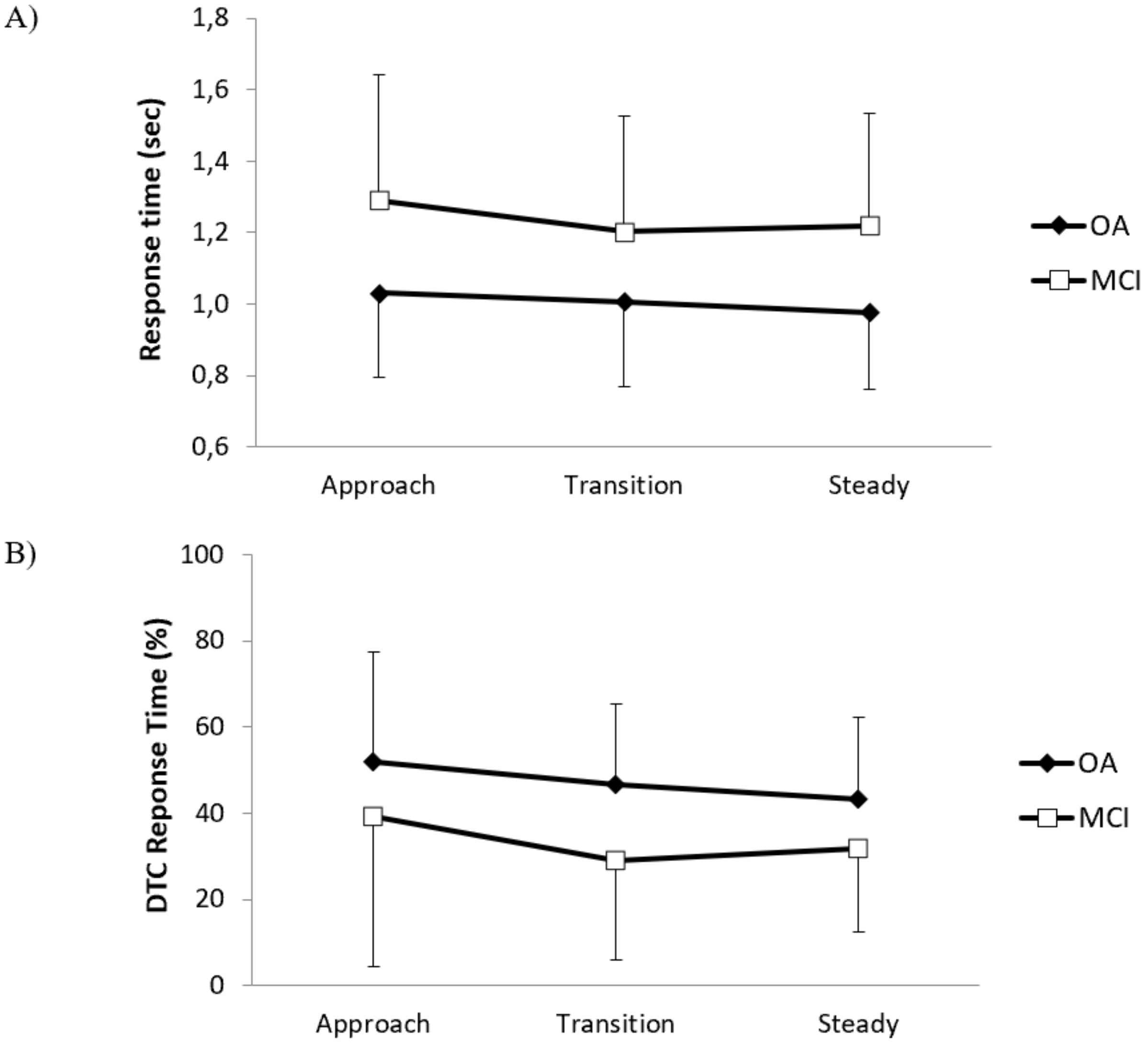

Fig 4. Response time (A) and dual task cost with baseline (B) for Stroop presentation during stair descent. Data represent means±SD.