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Multiple Object Tracking While Walking: Similarities and Differences Between Young, Young-Old, and Old-Old Adults

Kristell Pothier,[1,2,3,4] Nicolas Benguigui,[2,5] Richard Kulpa,[6] and Chantal Chavoix[1,2,3]

[1]Institut national de la santé et de la recherche médicale, U1075 COMETE, Caen, France.
[2]Normandie University, School of Medicine, Caen France.
[3]University of Caen Basse-Normandie, COMETE Laboratory (Mobilités: Orientation, Attention et Chronobiologie), Caen, France.
[4]Department of Rheumatology, CHU (Centre Hospitalier Universitaire) de Caen, France.
[5]University of Caen Basse-Normandie, CESAMS (EA 4260, Centre d'étude sport et actions motrices), Caen, France.
[6]M2S Laboratory Mouvement, Sport, Santé, Rennes 2 University, France.

Objective. Walking while simultaneously engaged in another activity becomes more difficult as one grows older. Here, we address the issue of changes in dual-task behavior at different stages of life, particularly in the latter stages.

Methods. We developed a dual task that combined walking along an 8-m walkway with a multiple object tracking (MOT) task of increasing difficulty. This secondary cognitive task imitates visuospatial daily activities and provides reliable quantitative measurements. Our dual-task paradigm was tested on 27 young adults (23.85 ± 2.09 years old) and two groups of older adults (18 young-old and 18 old-old adults, aged 63.89 ± 3.32 and 80.83 ± 3.84 years, respectively).

Results. Significant decrease in tracking performance with increasing complexity of the MOT task was found in all three groups. An age-related decrease in MOT and gait performance was also found. However, young-old adults performed as well as young adults under low attentional load conditions (in the MOT task and simple walking), whereas their performance was as impaired as those of old-old adults under high attentional load conditions (in the MOT task and walking under dual-task condition).

Discussion. These different profiles between the two groups of older participants could be explained in terms of compensation strategies and risk of falling.

Key Words: Aging—Dual task—Gait—Multiple object tracking—Visuospatial ability.

A dual-task paradigm requires an individual to perform a primary task while carrying out a concurrent secondary task. This method has been widely employed to reveal interrelationships between gait and cognition, particularly the involvement of attention in walking (see Montero-Odasso, Verghese, Beauchet, & Hausdorff, 2012 for a review). The effects of dual tasking on gait have been studied in various populations, including healthy participants (young and older adults; see Yogev-Seligmann, Hausdorff, & Giladi, 2008 for a review) and patients suffering from neurological (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998; Hausdorff, Balash, & Giladi, 2003 for Parkinson's disease) and vestibular disorders (Bessot, Denise, Toupet, Van Nechel, & Chavoix, 2012). In most populations, including young adults, slower walking has been found under dual-task conditions (Beauchet, Dubost, Herrmann, & Kressig, 2005; Yogev-Seligmann et al., 2008 for a review). This decrease in gait speed has been interpreted as a tendency to focus on safe walking and to refrain from correctly performing the secondary task, which can be considered as an accurate "posture first" strategy to avoid falls (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

Substantial evidence indicates that dual-task cost (i.e., the difference in performance between single- and dual-task conditions) is larger in the elderly adults than in young adults (see Woollacott and Shumway-Cook, 2002 for a review). Indeed, greater reduction in gait speed in older adults than in young people is frequently observed when participants are asked to walk and simultaneously perform another task. This attentional cost of dual tasking may increase falls risk (see Segev-Jacubovski et al., 2011 for a review). As such, dual-task paradigms are recognized as appropriate predictive tests for falls, as first demonstrated with the well-known "stops walking when talking" paradigm (Lundin-Olsson, Nyberg, & Gustafson, 1997). These authors showed, in a population of frail elderly persons, that those who stop walking when talking are at higher risk for falls in the 6 following months. Reduced gait speed under dual-task conditions also supports the idea that walking is not entirely automatic, especially in older adults in whom this reduced gait speed is more marked (see Woollacott & Shumway-Cook, 2002 for a review). Although greater slowing of gait in the elderly adults is consistent with the decline in physical ability that occurs with increasing age, numerous studies

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have demonstrated that it may also be partly explained by age-related deficits in attention and executive function (Shumway-Cook et al., 1997; O'Halloran, Finucane, Savva, Robertson, & Kenny, 2014). Involvement of cognitive function in walking is consistent with the fact that older adults with cognitive impairments slow down their walking to a greater extent than cognitively intact older adults under dual-task conditions (see Yogev-Seligmann et al., 2008 for a review). The secondary task is also frequently impaired in older adults with or without cognitive impairments, thus highlighting the difficulty of older adults in sharing attention between walking and a secondary task.

Another important issue is the change in dual-task behavior across one's life span. Up to the present, this topic has seldom been addressed, including changes in the latter stages of life. However, comparing different age groups of older adults could lead to a better understanding of the compensations that can be accurately developed up to a certain age. With these compensations come likely consequences on the level of priority given to walking, and consequently on falls risk. Camicioli, Howieson, Lehman, and Kaye (1997) compared young-old (66 to 80 years old) and old-old (81 to 94 years old) healthy adults in the "talking while walking" task, but they did not find any difference in dual-task performance, which was explained by a likely insufficient statistical power. It is also possible that the methodological procedure used did not allow them to detect intergroup differences.

Several methodological biases have indeed been incriminated in the divergent results frequently reported in dual-task studies. Many studies have a tendency to focus on the analysis of one task only (see Yogev-Seligmann et al., 2008 for a review) although evaluation of both tasks is crucial to accurately assess mutual interaction between walking and a secondary task. Indeed, interpretation of normal gait performance under dual-task conditions would not be the same when secondary task performance is impaired or unimpaired. The reverse holds for interpreting normal performance in the secondary task. Furthermore, in numerous studies, performance of the secondary task is difficult to quantify, as in the "stops walking when talking" paradigm. Although very useful from a clinical perspective, such dual-task paradigms may be less relevant for certain issues. Another important criticism that has been made is the domain of interference of the secondary task and the level of the induced interference. For instance, two concurrent tasks that rely on the same modality interfere more with each other than two tasks that rely on different modalities (Baddeley, 1986). In addition, cognitive secondary tasks that involve external interfering factors (also called "stimulus-driven" tasks, e.g., reaction time tasks) seem to disturb gait performance to a lesser extent than those involving internal interfering factors (or "goal-directed" tasks, e.g., mental tracking). This would explain the lack of impaired gait performance under dual-task conditions in aging with stimulus-driven tasks (see Al-Yahya et al., 2011 for a review). Another major criticism is that most gait dual tasks lack of ecological validity even though multitasking while walking is part of everyday life and numerous falls occur during multitasking. The pertinence of an ecological approach is well illustrated in the dual-task study recently performed by Nagamatsu and her colleagues (2011) in a virtual environment where participants crossed a simulated street while conversing on a phone.

Walking in real life requires navigating through visual space. In daily life, this navigation is commonly associated with additional, attentional demanding visual tasks (e.g., walking through a crowd while keeping an eye on one's child). Very few studies have, however, combined a visual secondary task with walking, including in the elderly people. Yet, in their recent review on age-related deficits of dual tasking while walking, Beurskens and Bock (2012) point out how disruptive a visual secondary task is in aging. When a visual secondary task is added to walking, two streams of visual information must be managed concurrently: one related to navigation and the other to an additional visual task. This could exceed the capability of an aging prefrontal cortex. Furthermore, because the dependency of locomotion on visual information increases with age (Anderson, Nienhuis, Mulder, & Hulstijn, 1998), the age-related difficulty of simultaneously walking and being engaged in another visual activity would consequently be amplified. It is therefore not surprising that the use of a visually demanding secondary task results in high dual-task cost with advancing age, as found by Bock and Beurskens (2011). In this rare study that employed a visuospatial task during walking, the task required mental-rotation judgment in regards to letters displayed on monitors located to the right and left of the pathway. The task is, however, somewhat removed from daily activity. Furthermore, the impact of walking on cognitive performance was not examined.

An attentional visuospatial activity that is common while walking in real life is keeping track of objects moving around us, such as watching for traffic when crossing the road. These visual tracking activities are very similar to that carried out in the multiple object tracking (MOT) task from Pylyshyn and Storm (1988) that requires keeping track of multiple target items as they move among identical items. Numerous studies have already found it of value to use MOT paradigms to investigate visual cognition, either as a phenomenon (e.g., Liu et al., 2005) or as a tool particularly suitable for assessing attentional load in working memory and task switching (e.g., Fougnie & Marois, 2006). This task seems of particular interest for use as a visuospatial task in walking dual-task paradigms. In addition to the fact that it mimics daily life activities and the goal-directed action it requires, the magnitude of the attentional demand can be easily manipulated, thus advantageously providing a task of increasing difficulty. To our knowledge, only one study has combined walking with a MOT task (Thomas & Seiffert, 2011). The authors quantified the cost of self-motion on tracking performance and found that self-moving hampers tracking performance compared with a quiet standing position. However, gait performance was not analyzed, so interference effects of the tracking objects task on walking could not be assessed, and the experiment was conducted only with young adults.

The objective of this study is thus twofold: (a) to propose an original dual task with an ecological value and reliable, quantitative parameters for both tasks: multiple object tracking while walking and (b) to assess the interference between a visuospatial attentional task and walking in aging, by comparing performance of young and older adults in both tasks. Moreover, in an attempt to better understand the reported impaired dual-task performance with increasing age, we further compared different age groups of older adults (60–74 years old vs older than 75 years).

METHODS

Participants

Sixty-three participants took part in this study. They were divided into three groups: (a) 27 young adults ranging from 20 to 29 years old ($M = 23.85$; $SD = 2.09$), all students at the University of Caen, Lower Normandy; (b) 18 young-old adults from 60 to 74 years old ($M = 63.9$; $SD = 3.32$); and (c) 18 old-old adults older than 75 years old ($M = 80.8$; $SD = 3.84$). Older adults were all volunteers and recruited from an ongoing study at the University Hospital of Caen.

As shown in Table 1, which displays the main characteristics of the participants, older adults were all cognitively intact as assessed by the Montreal Cognitive Assessment ("MoCA"), a test of global cognitive efficiency (Nasreddine et al., 2005); furthermore, they all obtained the allocated point from this MoCA test for the Trail Making Test, part B (evaluating task-switching abilities) for their error-free performance, except one old-old adult. All participants had completed at least 9 years of education and had normal or corrected-to-normal visual acuity (6/6 or better) as tested by the Monoyer visual acuity chart. Contrast sensitivity as evaluated by the Pelli–Robson contrast sensitivity test (Pelli et al., 1988) and color vision as assessed using the Ishihara color vision deficiency test (Ishihara, 1917) were in the normal range in each group. No history of a previous fall in the year prior to the study had been reported. Participants were informed about the experimental procedure, approved by the local ethics committee.

Materials and Procedure

The participants were given the three following tasks in a pseudo-random order: (a) a walking task; (b) a multiple object tracking (MOT) task; and (c) a dual task that combined both tasks, named "Walk–MOT."

Walking task.—The participants were asked to walk twice along an 8-m walkway, at a self-selected speed (Figure 1A). The gait velocity was obtained with the OptoGait® system and was averaged over the two trials.

MOT task.—The MOT task, set up and run on a PC computer using software developed in the M2S Laboratory of Rennes 2 University, was projected onto a wall. The tracking field consisted of a black square (1.95 m × 1.95 m) surrounded by a white line in which 10 discs (Ø 4.5 cm), randomly displayed over the screen, moved randomly at a constant speed for 10 s (Figure 1B). The moving speed was either slow (8 m/s) or fast (12 m/s) for a given trial. Along their trajectory, the discs could hit the border of the tracking field, but they never hit or overlapped each other.

At the beginning of each trial, the participant faced 1 to 3 yellow (targets) and 9 to 7 red (distractors) stationary discs, respectively. The color of the discs were chosen so as to provide high contrast between the yellow targets (RGB (Red, Green, Blue) [255, 0, 0]; HSL (Hue, Saturation, Lightness) [0, 100, 50]; Lum of 54%, as obtained on http://www.workwithcolor.com/hsl-color-picker-01.htm) and the red distractors (RGB [255, 255, 0]; HSL [60, 100, 50]; Lum of 94%). Once the participant had identified the target(s) to be tracked and was ready, the experimenter pressed a button to initiate the movement of the discs. In the 1-s acquisition

Table 1. Main Characteristics of the Participants

	Young adults; mean (*SD*)	Young-old adults; mean (*SD*)	Old-old adults; mean (*SD*)
Age (years)	23.85 (2.09)	63.89 (3.32)	80.83 (3.84)
Education[a]	4 (0)	3.88 (0.32)	3.5 (0.51)
Montreal Cognitive Assessment	—	29.72 (0.46)	28 (1.46)
Trail Making Test B[b]	—	18/18	17/18
Binocular visual acuity[c]	9.25 (0.73)	7.16 (2.14)	7.47 (1.69)
Color perception[d]	1.25 (0.96)	2.33 (1.66)	2.6 (1.52)
Contrast sensitivity[e]	2.25 (0.09)	1.66 (0.08)	1.63 (0.11)

[a] Poitrenaud scale (out of 4).
[b] Number of participants obtaining the Trail Making Test B point from the Montreal Cognitive Assessment.
[c] Monoyer visual acuity chart (out of 10).
[d] Number of errors in the Ishihara 38 plates test.
[e] Pelli–Robson contrast sensitivity test (in log units).

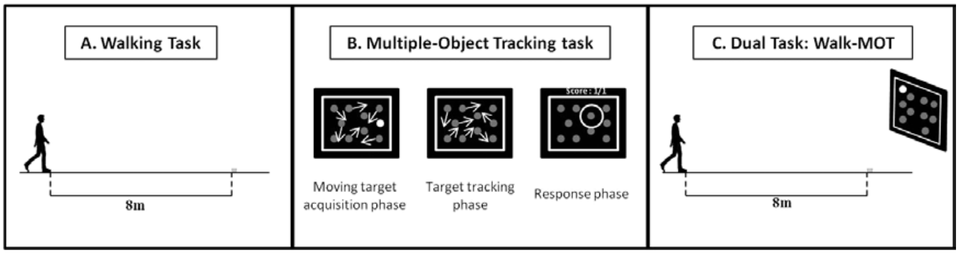

Figure 1. Tasks used in the dual-task paradigm. (A) Walking task along an 8-m walkway; (B) Multiple object tracking (MOT) task. As described in more detail in the text, the target(s) to be tracked was(were) of a different color from the distractors in the stationary and moving target(s) acquisition phases (here shown in white and gray, respectively), then they were changed to the same color as the distractors in the target tracking phase; all discs moved in various directions in both the moving target acquisition and target tracking phases, as indicated by the arrows. In the response phase, the items stopped moving, and the participants had to indicate the disc(s) they considered as target(s); the selected target(s) was(were) thus surrounded by a white circle that was immediately followed by feedback: display of the current trial score above the tracking field. (C) Walk–MOT dual-task that combines the MOT and the walking tasks.

phase with moving discs that followed, the participant was required to track the yellow target(s) among the red distractors. Then, in the 9-s tracking phase, the yellow target(s) became red, and the participant was required to continue tracking the newly red disc(s). Finally, in the response phase, the 10 discs stopped moving, and the participant was asked to point to the target(s) with a light pen. Visual feedback was given to the participant at the end of each trial via a current trial score displayed above the tracking field (Figure 1B).

Regardless of which task came first (single MOT or dual walk–MOT task), practice trials of the MOT task were provided prior to test trials until the participant succeeded in four trials with one target, one trial with two targets, and one trial with three targets. The practice trials were carried out in a quiet standing position as in the single MOT task and at the slow moving speed. Furthermore, an additional practice trial with two targets was carried out while walking to familiarize the participant with the dual-task condition, with no obligation to succeed. At the beginning of each trial of this practice phase, we made sure that each participant was able to distinguish the target from distractors by asking him/her to point to the target(s) with the light pen. During the single MOT task, the participants were standing still at 8 m from the wall. Each participant was given 18 trials, with 3 trials per combined condition (2 moving speeds × 3 number of targets), in random order. For each participant, the number of correctly detected target(s) was expressed in percentage and averaged over the three trials for each condition.

Dual task walk–MOT.—Walk–MOT is the combination of the MOT and the walking tasks (Figure 1C). No instructions were given as to which task to prioritize. The experimenter initiated the MOT trial as soon as the participant took his or her first step, and the participant was asked to stop walking immediately after the MOT discs stopped moving. As in the MOT task, the dual task consisted of 18 trials, with 3 trials per combined condition (2 moving speeds × 3 number of targets), presented in a random order.

Statistical Analysis

Gait.—An intergroup comparison of gait speed during simple walking was performed with a one-way analysis of variance (ANOVA). In the dual-task condition, gait performance was analyzed using a three-way repeated measures ANOVA with group (young adults, young-old adults, and old-old adults) as a between-participant factor, and moving speed of the MOT discs (slow or fast) and number of targets in the MOT task (1, 2, or 3 targets) as within-participant repeated factors.

MOT task.—Because we observed a ceiling effect for tracking a single moving target in most participants regardless of the condition of the MOT task (single or dual task) and the group considered, only descriptive comparison will be given for the one-target data. Statistical analysis was thus carried out on the two- and the three-target data only. MOT performance was then analyzed using a three-way repeated measures ANOVA with group (young adults, young-old adults, and old-old adults) as a between-participant factor, and moving speed (slow or fast) and number of targets (2 or 3 targets) as within-participant repeated factors, in both the single- and dual-task conditions.

Comparison between single- and dual-task conditions.—To compare performance in the single- and dual-task conditions, a two-way repeated measures ANOVA with group (young adults, young-old adults, and old-old adults) as a between-participant factor and task condition (simple or dual task) as the repeated measures was performed for each type of performance (cognitive performance and gait performance). For this purpose, individual MOT performance obtained with the two moving speeds and the three numbers of targets were pooled for each condition, which was further referred to as global performance. This was done to more specifically focus on the dual-task interference effects. Post hoc analyses were all computed with Fisher's least significant difference test.

RESULTS

Gait Performance

Single task.—Gait velocity significantly differed between groups (1.21 ± 0.19 m/s, 1.14 ± 0.15 m/s, and 1.03 ± 0.21 m/s in the young, young-old, and old-old adults, respectively; $F(2,60) = 5.252$; $p < .01$; $r^2 = .14$) (Figure 2). Post hoc analysis indicated that the young adults walked significantly faster than the old-old adults ($p < .01$).

Dual task.—The three-way repeated measures ANOVA showed significant effects on the gait performance for the group ($F(2,59) = 13.702$; $p < 10^{-4}$; $r^2 = .29$) (Figure 2), the moving speed of the MOT discs ($F(1,59) = 6.985$; $p < .05$; $r^2 = .001$), and the number of targets in the MOT task ($F(2,118) = 51.464$; $p < 10^{-6}$; $r^2 = .02$). Significant “moving speed × number of targets” interaction was also found ($F(2,118) = 4.829$; $p < .01$; $r^2 = .001$). Post hoc analysis indicated that (a) the young adults walked significantly faster than the young-old adults and old-old adults ($p < .01$ and $p < 10^{-4}$, respectively); (b) participants walked faster under the fast moving speed of the MOT discs ($p < .05$); and (c) participants walked faster when they had to track a single target compared with two ($p < 10^{-6}$) or three ($p < 10^{-6}$) targets.

Performance in the MOT Task

All participants achieved the required criterion for performance with one target within the first four practice trials (i.e., four correct responses in a row) except two old-old adults who required a fifth trial.

Single task.—All participants obtained 100% correct responses for tracking a single target at both the slow and fast moving speeds. The three-way repeated measures ANOVA showed significant effects for the group ($F(2,60) = 74.696$; $p < 10^{-6}$; $r^2 = .42$), the moving speed ($F(1,60) = 35.311$; $p < 10^{-6}$; $r^2 = .05$), and the number of targets ($F(1,60) = 106.174$; $p < 10^{-6}$; $r^2 = .11$). Significant “group × number of targets” ($F(2,60) = 6.180$; $p < .01$; $r^2 = .01$) and “group × number of targets × moving speed” ($F(2,60) = 7.808$; $p < .001$; $r^2 = .01$) interactions were also found. Thus, as expected, significantly better performance was found for the two compared with the three targets to be tracked (83.02% and 64.94%, respectively; see Figure 3A1 and A2) and for the slow compared with the fast moving speed of the discs (86.58% correct responses vs 78.73%; see also Figure 3B1 and B2). Furthermore, post hoc analysis indicated that (a) mean performance was significantly better in young adults than in young-old adults (90% correct responses vs 76.4%; $p < .001$), and in young-old adults than in old-old adults (47.4%; $p < 10^{-6}$) regardless of the number of targets and the moving speed of the discs; (b) the young adults also performed significantly better than the young-old adults when three targets had to be tracked ($p < .001$; Figure 3A2), and both groups performed better than the old-old adults as soon as two targets had to be tracked ($p < 10^{-6}$; Figure 3A1); and (c) the old-old adults performed similarly for fast tracking of two or three targets (Figure 3B2), whereas a significant difference in performance was found for the other two groups and for each moving speed, with better performance when tracking two targets (Figure 3B1 and B2 for the slow and fast moving speed, respectively).

Dual task.—Young and young-old adults obtained 100% correct responses for tracking a single target regardless of the moving speed of the discs, whereas the old-old adults obtained 95.83 ± 14.01% correct responses at both the slow and fast moving speeds. The three-way repeated measures ANOVA showed very similar results to those found in the single MOT condition: significant effects for the group ($F(2,60) = 83.959$; $p < 10^{-6}$; $r^2 = .4$), the moving speed ($F(1,60) = 20.171$; $p < 10^{-4}$; $r^2 = .02$), and the number of targets ($F(1,60) = 33.038$; $p < 10^{-6}$; $r^2 = .04$), and significant

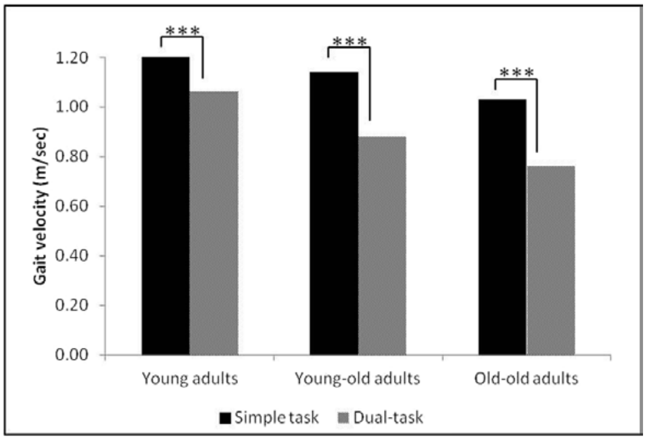

Figure 2. Mean gait performance under simple- and dual-task conditions in young, young-old, and old-old adults; ***$p < 0.001$.

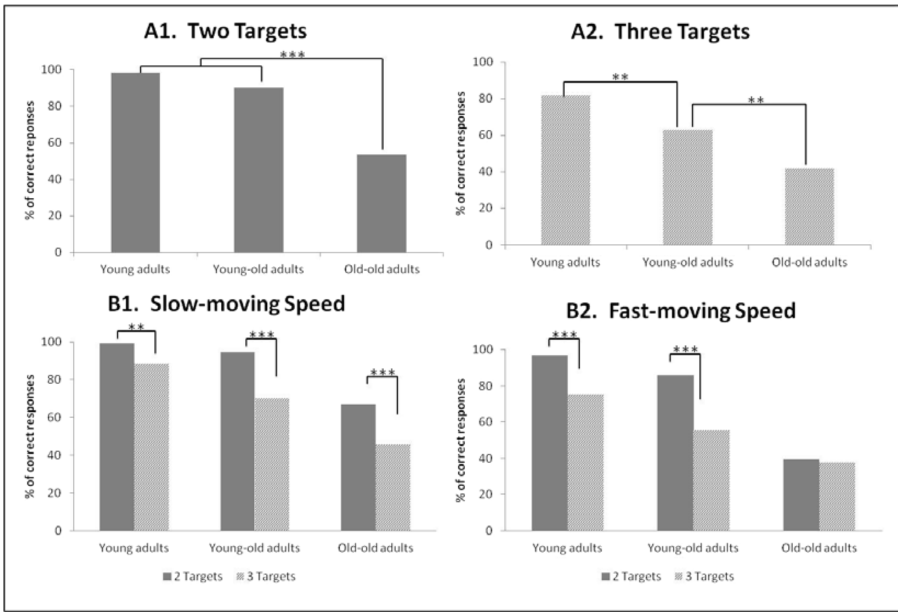

Figure 3. Mean performance on the Single multiple object tracking task in young, young-old, and old-old adults. (A) Mean correct responses for tracking two (A1) and three (A2) targets regardless of the moving speed of the discs. (B) Mean correct responses for tracking 2 or 3 targets at slow (B1) and fast (B2) moving speed of the discs; $^{**}p < 0.01$, $^{***}p < 0.001$.

"group × number of targets × moving speed" interaction ($F(2,60) = 4.373$; $p < .05$; $r^2 = .01$).

Comparison Between Simple and Dual-Task Conditions

Gait performance.—The two-way repeated measures ANOVA showed significant effects for the group ($F(2,60) = 10.484$; $p < 10^{-3}$; $r^2 = .18$) and the task condition ($F(1,60) = 224.519$; $p < 10^{-6}$; $r^2 = .21$), and a significant "group × task condition" interaction ($F(2,60) = 7.255$; $p < .01$; $r^2 = .01$). As shown in Figure 2, post hoc analysis indicated that each group walked significantly slower in the dual-task condition than in the single-task condition ($p < 10^{-6}$ for each group). Furthermore, intergroup comparison with a one-factor ANOVA showed that the decrease in gait velocity in the dual-task condition relative to simple walking significantly differed between groups ($F(2,60) = 12.608$; $p < 10^{-4}$; $r^2 = .29$) with a sharper decrease in both groups of older adults (22% and 26% decrease in the young-old adults and old-old adults, respectively) than in young adults (12% decrease; post hoc: $p < .01$ for both comparisons with young adults), but no significant difference between the two groups of older adults (Figure 2).

Performance in the MOT task.—The two-way repeated measures ANOVA showed a significant group effect ($F(2,60) = 104.151$; $p < 10^{-6}$; $r^2 = .72$), and post hoc tests again indicated that the young adults performed better than young-old adults (93.3% vs 84.3% correct responses; $p < .001$), with the latter being better than the old-old adults (62.6% correct responses; $p < 10^{-6}$). The other findings, including the condition effect, were not significant.

DISCUSSION

The present findings show that our original walk–MOT dual task is of great interest for the assessment of the interference between a visuospatial attentional task and gait in both young and older adults, as shown by (a) the decrease in attentional performance with increasing complexity of the visual tracking task and (b) the decline in gait and attentional performance in aging, here found in both the single- and dual-task conditions. Furthermore, different profiles appeared between the two groups of older participants investigated here, that is, between older adults younger than and older than 75 years. The interest of the walk–MOT dual task and the different profiles in performance between young-old and old-old adults will be successively discussed.

Several arguments highlight the interest and reliability of the walk–MOT dual task in assessing the interference between gait and visuospatial attention. First, to our knowledge, our original walk–MOT dual task is the first walking dual task in which both gait and visuospatial attention have been quantified in both the single and dual conditions. The few studies that have combined walking with a visuospatial secondary task focused on only one of the two tasks (Bock and Beurskens, 2011; Thomas and Seiffert, 2011). Furthermore, the use of a secondary task that mimics keeping track of objects or persons while walking, which commonly occurs in everyday life, adds ecological value to our task although the walk–MOT task is not as similar to daily life as a recent dual-task study on street crossing behavior in a virtual environment in aging (i.e., Neider et al., 2011).

Second, performance in the newly designed visual tracking MOT task decreased with increasing task complexity. This decrease in the ability to track targets among distractors as the number of targets or the moving speed of the discs increases is commonly reported in studies using MOT tasks (e.g., Alvarez and Franconeri, 2007; Sekuler, McLaughlin, & Yotsumoto, 2008). In this study, it was observed in all participants. The easy manipulation and quantification of the magnitude of attentional demand is considered to be the main advantage of the MOT paradigm (Scholl, 2009). In this study, the decrease in the MOT performance with increasing task complexity was found in each of the three groups investigated and in both the single- and the dual-task conditions, which emphasizes the reliability of our MOT task in assessing visuospatial attention.

Third, regarding our dual-task results, although no difference between single and dual task was detected for the cognitive performance, we found that both young and older adults walked significantly slower under the dual-task condition. A decrease in performance in one of the two tasks is common in dual-task studies (e.g., Shumway-Cook et al., 1997). In this study, it seems that the participants maintain their tracking performance by slowing down their walking pace. The lack of reduction in the MOT performance while walking contrasts with the results of Thomas and Seiffert (2011). However, their methodological procedure largely differs with, notably, a higher number of targets to track than in this study (1–5 vs 1–3, respectively). In addition, the reported difference between single and dual conditions concerned high tracking load only (≥3 targets), whereas we used a maximum of three targets. Our results are, nevertheless, consistent with reduced gait speed or postural performance under dual-task condition compared with single-task condition (Doumas & Krampe, 2013; Yogev-Seligmann et al., 2008). Thus, the well-recognized deleterious effects of a secondary task on gait also apply when the secondary task involves tracking moving objects.

Finally, as expected, we found impaired performance in aging in the walk–MOT dual task as well as in the gait and multiple objects tracking tasks assessed separately. In both the single- and dual-task conditions of the MOT task, the global performance was significantly worse in older adults than in young participants, in agreement with an age-related decline in tracking multiple moving objects (Kennedy, Tripathy, & Barrett, 2009; Sekuler et al., 2008; Trick, Perl, & Sethi, 2005; Trick, Hollinsworth, & Brodeur, 2009), and more generally with the visuospatial attentional deficit in the elderly people (see McDowd & Shaw, 2000 for a review). Furthermore, although both young and older adults attained more than 95% correct responses when tracking a single target, increasing the number of tracked targets up to three significantly impaired tracking performance in older compared with young adults. This finding is consistent with the well-known worse performance in visuospatial attention when increasing the attentional load in the elderly people (Sekuler et al., 2008; Trick et al., 2005). As for gait performance, we found slower walking with age in both the single- and dual-task conditions, as classically reported (see Al-Yahya et al., 2011), together with a more marked decrease between single- and dual-task conditions in older than in young adults (about 24% and 12%, respectively). Although age-related deficit is usually observed in gait-related dual tasks when the secondary task involves executive or memory function (see Yogev-Seligmann et al., 2008 for a review), this is the first report of a greater dual-task cost in older adults than in young adults when walking while tracking multiple objects. Our walk–MOT dual task is thus very sensitive to age-related decline in cognitively intact older adults, which makes it very suitable for aging investigations.

In this context, our second objective was to determine whether impaired performance in aging would differ between older adults younger than and older than 75 years in a dual task that engaged visuospatial attention while walking. Interestingly, we found that the two groups of older participants performed similarly or differently depending on the task and task condition. A gradual decrease in performance from young adulthood to the young-old and then to the old-old adults was most frequently observed in multiple objects tracking and in walking. However, unexpected results were also found.

In the multiple object tracking task, a gradual decrease in global performance was observed with increasing age in both the single- and the dual-task conditions, with a significant difference between young and older adults, as well as between both groups of older adults. Progressive changes in tracking processes that continue late in life is consistent with studies concerning other forms of visuospatial attention, e.g., searching for visual targets that differ in color and shape from distractors (Potter, Grealy, Elliott, & Andrés, 2012).

In contrast, a gradual decrease in performance with age was not found when taking into account the attentional load of the multiple objects tracking task. Indeed, the oldest participants were significantly impaired in the single condition of the MOT task as soon as they have to simultaneously track two targets, but the young-old adults still performed as well as the young participants for tracking two objects. The difference between the two groups of older adults does not seem to be explained by differences in visual abilities because these abilities were very similar in both groups. The similar performance of adults aged 20–29 and 60–74 years when the attentional load is low suggests that, as opposed to the older adults older than 75 years, those younger than 75 years are able to compensate for the attentional decline related to age, at least when the task is relatively easy. These findings in young-old adults are consistent with neuroimaging studies that reported different patterns of brain activation despite similar performance in young and older adults (Bennett, Sekuler, McIntosh, & Della-Maggiore, 2001; Cabeza, Anderson, Locantore, & McIntosh, 2002), including in low-load conditions (Ansado, Monchi, Ennabil, Faure, & Joanette, 2012).

In the walking task, the gradual decrease in gait velocity that we observed from the youngest to the oldest participants during single walking is consistent with the linear relationship between gait velocity and aging (Schimpl et al., 2011). However, the young-old adults did not differ significantly from the young adults, favoring the hypothesis of well-preserved gait velocity in healthy adults up to 75 years old when walking requires no or very few attentional resources. Again, it can be hypothesized that, unlike the old-old adults, the young-old adults are able to compensate for their reduced abilities, in sensorimotor functions in order to continue walking at normal speed during a simple walk. In contrast, young-old adults walked significantly slower than young adults while simultaneously performing the tracking task, and this slowing resulted in young-old adults walking at the same speed as the old-old adults. Although we cannot exclude that our small sample size may have hampered the detection of intergroup differences, a similar lack of difference in gait performance during dual tasking was found in the rare studies that compared adults from middle to old age (Camicioli et al., 1997; Lindenberger, Marsiske, & Baltes, 2000). Our findings of the same magnitude of impaired gait velocity in the walk–MOT dual task in both groups of aged participants, relative to young adults, indicates that, as early as 60 years, attentional interference can greatly disturb gait performance. This may place young-old adults at a substantial risk of falling in challenging conditions. Reducing gait velocity in the presence of attentional overload nonetheless reflects appropriate strategy for minimizing falls risk in older adults, cognitively intact and non-fallers, aged 60–74 years.

The age-related functional loss in visual tracking and gait in old-old adults would easily explain their significant decreased abilities in dual-task conditions. In contrast, older adults younger than 75 years of age seem able to compensate for their less-marked functional loss under single-task conditions, at least when the task involves only low attentional load. However, these compensations would no longer be efficient when cognitive interference occurs while walking. Nonetheless, both young-old and old-old adults would accurately prioritize safe walking in case of attentional interference, or at least adopt a conservative walking strategy to allow parallel processing of visual information.

In conclusion, the age-related deficit found in older adults in this study indicates that the walk–MOT task is a valuable dual task for investigating the interference between visuospatial attention and gait in both young and older adults. It could thus be usefully applied to other populations with gait disorders (e.g., fallers and patients with Parkinson's disease). In addition, the ability to modulate the task's complexity makes it a tool of choice for falls prevention programs. This original dual task also revealed unexpected differences in gait performance and visuospatial abilities between older adults aged younger than and older than 75 years. This issue of a differentiation in dual-task performance between young-old and old-old adults requires further investigation to improve our understanding of the role of interference in the age-related decline in dual-task performance.

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Correspondence

Correspondence should be addressed to Kristell Pothier, PhD student (and Neuropsychologist) School of Medicine, Institut national de la santé et de la recherche médicale, U1075 COMETE, Caen 14032, France. E-mail: pothier-k@phycog.org

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