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Different motor tasks impact differently on cognitive performance of older persons during dual task tests

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ABSTRACT

Background: Dual task paradigm states that the introduction of a second task during a cognitive or motor performance results in a decreased performance in either task. Treadmill walk, often used in clinical applications of dual task testing, has never been compared to overground walk, to ascertain its susceptibility to interference from a second task. We compared the effects of overground and treadmill gait on dual task performance.
Methods: Gait kinematic parameters and cognitive performance were obtained in 29 healthy older adults (mean age 75 years, 14 females) when they were walking freely on a sensorized carpet or during treadmill walking with an optoelectronic system, in single task or dual task conditions, using alternate repetition of letters as a cognitive verbal task.
Findings: During overground walking, speed, cadence, step length stride length, and double support time (all with P value < 0.001) and cognitive performance (number of correct words, $P < 0.001$) decreased substantially from single to dual task testing. When subjects walked at a fixed speed on the treadmill, cadence decreased significantly ($P = 0.005$), whereas cognitive performance remained unaffected.
Interpretation: Both motor and cognitive performances decline during dual task testing with overground walking. Conversely, cognitive performance remains unaffected in dual task testing on the treadmill. In the light of current dual task paradigm, these findings may have relevant implication for our understanding of motor control, as they suggest that treadmill walk does not involve brain areas susceptible to interference from the introduction of a cognitive task.

1. Introduction

Many daily activities require performance of multiple tasks and involve the integration of cognitive and motor skills, on which the outcome of the performance depends. The ability to perform a second task while we are doing a first one is crucial in most daily activities, especially when some motor act is involved, for example when simultaneously walking and talking, or moving an object from one place to another while monitoring the surrounding environment. The current paradigm of the dual task (DT) interference states that the introduction of a second task during a cognitive or motor performance leads to a possible competition between the attentional resources available, resulting in a decreased performance in either task (Simpkins et al., 2004). The attentional demands of a task and the interference effects of concurrent tasks could be influenced by several factors, such as subject's age, level of skill, and the nature of the tasks involved (Huang and Mercer, 2001).

Because gait is of paramount importance in daily activities and is altered in many clinical conditions, it is the most used motor task in DT studies, whereas there is a wide variation in the choice of the associated cognitive task (CT) (Beauchet et al., 2009; Woollacott and Shumway-Cook, 2002). Both gait and posture undergo physiological alterations with normal aging, which in essence imply significantly increased attentional demands (Woollacott and Shumway-Cook, 2002); further deterioration is often caused by neurological diseases (Axer et al., 2010). DT tests may, therefore, reveal subtle age- and disease-related abnormalities in gait control, not evident in single motor task (SMT) tests, and this justifies the interest for clinical applications of DT tests. For example, the Walking While Talking test has been used to predict the risk of fall in older individuals: according to several authors, subjects who markedly reduce their walking speed (Verghese et al., 2002), or are unable to complete the task (de Hoon et al., 2003; Lundin-Olsson et al., 1997) in the DT condition, have an incidence of falls that significantly increased

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than those, whose motor performance remains unaffected by the co-administered cognitive task.

The overall effects of the DT interference change depending on the specific CT applied (Haggard et al., 2000) and, accordingly, neuroimaging studies have shown that verbal, arithmetic, or visuo-spatial tasks induce different working memory activation and spatial attention demand (Collette et al., 2005; Gurd et al., 2002; Sigman and Dehaene, 2008). Moreover, tasks belonging to the same cognitive domain, but of increasing difficulty, have progressively greater effects in DT tests (Verrel et al., 2009). On the other hand, the effects of different motor tasks on DT performance have been poorly investigated. In particular, to our knowledge, no previous studies compared DT tests based on either overground or treadmill walking. When performed as a single motor task (SMT), treadmill gait is qualitatively and quantitatively similar to overground gait, with only negligible differences in kinematic and kinetic parameters in matched comparisons (Riley et al., 2007). Nevertheless, it might be hypothesized that DT tests have substantially different outcomes when performed with overground walk, which leaves the subject free of modifying his speed and all other gait parameters, and treadmill walk, where speed is fixed and out of the walker's control: in this latter case, a greater impairment of cognitive performance is expected to represent the only detectable effect of DT interference.

The aim of the present study is to compare the effects of overground and treadmill walk while performing a DT test, in association with the same CT. To this purpose, we analyzed the preliminary data collected in an ongoing observational study, called MAIL ("La Marcia nell'Anziano Iperteso con Leucoaraiosi", which stands for "Gait in Older Hypertensives with Leukoaraiosis"), whose ultimate purpose is to investigate gait abnormalities and white matter brain lesions (leukoaraiosis) in uncomplicated hypertension.

2. Methods

2.1. Study design and participants

This is a cross-sectional study, approved by the ethics committee of the Azienda Ospedaliero-Universitaria Careggi, Florence. Participants were healthy volunteers aged 70 years or more, recruited in the outpatients' clinic of the Unit of Gerontology and Geriatric Medicine, University of Florence, or participating in community-based activities on healthy aging. They underwent an extensive evaluation, modeled on previous experiences by our group (Di Bari et al., 1999; Inzitari et al., 2008) to rule out the presence of diabetes, knee and hip osteoarthritis, and overt neurological, cognitive, psychiatric, and cardiovascular disorders, with the possible exception of uncomplicated hypertension. Absence of stroke was confirmed with brain MRI, a procedure that was part of the MAIL study protocol to assess the presence and extent of leukoaraiosis. Inability to walk for 400 m and to climb 10 steps of a stair, as well as very low education (inability to read and write), were further exclusion criteria.

2.2. Study protocol and data collection

General characteristics recorded were demographics, functional status (assessed with Basic Activities of Daily Living Scale (Katz, 1963) and Instrumental Activities of Daily Living Scale (Lawton and Brody, 1969), physical performance (assessed with the Short Physical Performance Battery (Guralnik et al., 1994), and cognitive and affective conditions (assessed with the Mini Mental State Examination (Folstein et al., 1975) and the 15-item Geriatric Depression Scale (Yesavage et al., 1983), respectively).

The treadmill testing was performed first, followed by overground testing between one and two weeks. In either testing (treadmill or overground), the sequence of tasks across CT, SMT, and DT was selected at random. Participants were given one or more practice trials on each task to familiarize with the procedure, but were not taught strategies (Watt et al., 2010).

Overground walk was analyzed with the GAITRite® system (CIR Systems, Inc., Hinckley, USA), including a portable electronic walkway mat, whose recording area (61 × 430 cm) contains 48 × 384 encapsulated sensors for the automated measurement of spatio-temporal gait parameters. The walkway mat was placed in the middle of a corridor 12.5 m long, to allow the participant to start walking before entering the recording area. To obtain a number of steps suitable for analysis, participants walked on the mat three times per condition (SMT and DT).

Treadmill walk was conducted on an apparatus equipped with a 1.4 × 0.4 m belt. To obtain comparability between subjects, in each participant walking speed was set according to the principle of dynamic similarity (Bullimore and Donelan, 2008), described by the formula $v = \sqrt{Fr * l * g}$, where v (m/s) is velocity, Fr is the Froude Number, an a-dimensional constant with five different values, l is the length of the leg (m) from the great trochanter to the external malleolus, and g (9.81 m/s^2) is the gravitational acceleration (Vaughan and O'Malley, 2005). Fr is the ratio between kinetic and potential energies adopted to characterize natural movements of animals, geometrically similar but of different sizes (Vaughan and O'Malley, 2005). A Fr value of 0.15 was selected in this study, because we judged that it would translate into a speed not too slow compared to overground walk, and not too fast to require use of handrails. After one or two trials, participants walked unsupported for at least 3 min to fully familiarize with treadmill walk (Dean et al., 2007) before a 30 s period of data acquisition. Gait parameters during treadmill test were obtained with an optoelectronic computerized system (ELITEplus® System, BTS, Milano, Italy), equipped with five cameras, at a sampling frequency of 100 Hz. Nine optic markers were placed on anatomical landmarks (sacrum and, bilaterally, prominence of the greater trochanter external surface, lateral epicondyle of the femur, lateral malleolus, fifth metatarsal head) (Haddad et al., 2006). Heel-strike and toe-off were identified using data from the foot markers, according to a previously described algorithm (Zeni et al., 2008). Event detection was performed with a custom written program using MATLAB 7.0 (MathWorks Inc., Natick, USA); duration of each gait phase was normalized to percent of total cycle duration.

Gait variables were collected over a total of 30 s walking, obtained as a whole walk duration over the treadmill or sum of consecutive GAITRite mat walks. An average of 57 and 14 steps were available for analysis with treadmill and overground walk, respectively; this difference stems from the limited extension of the recording area in the GAITRite mat, which does not allow for an extended time of acquisition. Variables produced by the system and considered for analysis were step and stride length, swing, double support, and stance duration, average speed, cadence (number of steps/s), and coefficient of variation of step duration (percent ratio between the standard deviation and the mean of the duration of all the steps recorded in 30 s).

The CT consisted in pronouncing alternate letters of the alphabet (i.e., skipping the letter in between), starting with a randomly selected letter. The total number of alternate letters correctly pronounced and the total number of errors during each condition were recorded. Cognitive performance was expressed as the number of correct answers per second.

2.3. Statistical analysis

Data were analyzed using the SPPS for Windows, version 18, statistical package. Continuous variables are expressed as mean (SEM), categorical variables as percentage frequencies. Means of gait and cognitive variables were compared with 2-way repeated measures ANOVA, checking for statistical significance of the interaction between walk condition (overground vs. treadmill) and task (SMT/CT vs. DT). When a significant interaction was found, differences between tasks or between walking conditions were checked separately; otherwise, only the main effect was reported. Pearson's r coefficient was used to analyze