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The interacting effect of cognitive and motor task demands on performance of gait, balance and cognition in young adults

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ABSTRACT

Mobility limitations and cognitive impairments, each common with aging, reduce levels of physical and mental activity, are prognostic of future adverse health events, and are associated with an increased fall risk. The purpose of this study was to examine whether divided attention during walking at a constant speed would decrease locomotor rhythm, stability, and cognitive performance. Young healthy participants ($n = 20$) performed a visuo-spatial cognitive task in sitting and while treadmill walking at 2 speeds (0.7 and 1.0 m/s).Treadmill speed had a significant effect on temporal gait variables and ML-COP excursion. Cognitive load did not have a significant effect on average temporal gait variables or COP excursion, but variation of gait variables increased during dual-task walking. ML and AP trunk motion was found to decrease during dual-task walking. There was a significant decrease in cognitive performance (success rate, response time and movement time) while walking, but no effect due to treadmill speed. In conclusion walking speed is an important variable to be controlled in studies that are designed to examine effects of concurrent cognitive tasks on locomotor rhythm, pacing and stability. Divided attention during walking at a constant speed did result in decreased performance of a visuo-spatial cognitive task and an increased variability in locomotor rhythm.

1. Introduction

Successful aging has become one of the most important aspects of health care in the 21st century. As people live longer risks of cumulative illness, chronic disability increase [1,2]. Mobility limitations and cognitive impairments, both common with aging, reduce levels of physical and mental activity, are prognostic of future adverse health events, and are associated with an increased fall risk [2]. Importantly, the link between cognitive impairment, mobility limitations and the tendency to falls is recognized in the literature [3].

Maintaining stability during walking through the environment is a complex, multi-dimensional process requiring higher level motor control, and cognitive flexibility to address balance threats, while attending to environmental demands and concurrent cognitive tasks [2]. A key factor in locomotor control is executive cognitive functioning and deficits are associated with increased risk of falling [3,4]. Various dual task (DT) studies have affirmed that difficulty in assigning attention to each task simultaneously may contribute significantly to increased fall risks. Poor DT performance in either the motor or cognitive task could be caused by altered prioritization between the two tasks [5]. The most common and consistent finding of DT studies has been the reduction of gait speed [3], likely as a strategy for concurrent task processing or to avoid stability threat. Reduced speed is commonly observed in elderly, and when negotiating obstacles, irregular or unpredictable terrain [6].

Dual-task studies have utilized cognitive tasks, like animal enumeration or number subtraction that are typically only assessed qualitatively, do not involve the visuomotor system and are limited in recruitment of individual brain areas. Visual–spatial processing of object locations/motions and their spatial relations with respect to body and space are key aspects of balance and locomotor skills, and evidence supports visual–spatial processing as an important aspect of cognition to explore in mobility decline [7,8].

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Virtual environments, viewed during treadmill walking, have been used as an ecological approach to rehabilitation [9]. Computerized cognitive tasks and games have received interest from researchers and clinicians, both as a model for learning a broad range of cognitive tasks and as a means to examine training and transfer of skills to daily life activities [10–12]. A treadmill rehabilitation platform (TRP) was designed around a treadmill as it is an excellent choice for conducting gait training with dual-tasks. It can incorporate walking skills while interacting with computer-generated cognitive activities viewed on a standard LCD display [9]. DT treadmill walking has important advantages versus over ground walking as gait variables are significantly influenced by walking speed [13,14] and reduced gait speed is a highly consistent strategy used during dual-task over-ground walking [3]. It is a convenient method to determine steady-state walking speed. It also allows gathering hundreds of consecutive steps in a few minutes. Data from 5–10 strides (i.e. in gait laboratories or during repeated walks over short, instrumented walkways) may reliably measure gait speed, but is not sufficient for measures of gait variability or periodicity, particularly during dual task walking and for older adults with mobility limitations [15,16].

The purpose of this study was to further explore the interplay between cognitive and walking demands on task performance. Since previous studies have shown that gait speed is an important factor affecting gait parameters, the treadmill speed is held constant to prevent a strategy of slowing walking speed. The first objective was to evaluate the effect of walking speed on temporal gait parameters and measures of walking stability, amplitude and variation of center of foot pressure (COP) displacements and trunk motion. The objective was to examine whether divided attention during walking at a constant speed would decrease locomotor rhythm, stability, and cognitive performance. This study addresses three hypotheses:

(1) Walking speed has a significant effect on temporal gait variables, and measures representing walking stability.
(2) Stability, locomotor, and cognitive performance will significantly decline from single task to DT conditions during constant speed.
(3) Cognitive performance will decline with increasing treadmill speed.

2. Methods

Twenty healthy young adults aged 20–30 years (mean age 26.3 ± 3.2 years) participated. Participants were excluded if they had past neurological impairment, musculoskeletal disorder or were taking medications that may have influenced their walking.

3. Instrumentation and data recording

Fig. 1 illustrates the experimental set-up. Participants were positioned on the treadmill 100 cm from the 30-inch monitor connected to a computer running the cognitive game. Vertical foot contact pressures were recorded from each foot using in-shoe pressure insoles. (Vista Medical Ltd, WPG. MB). The pressure insoles each consist of an array of 128 piezo-resistive sensors, calibrated to 300 mm Hg (12-bit). Pressure signals from left and right insoles were recorded at 35 Hz. The 3D Track STAR (Ascension Tech, Burlington, VT, US) was used to record the position of the trunk (80 Hz). The track STAR sensor was secured to the skin at the second thoracic spinal process. A commercial motion mouse (Gyration Air Mouse, USA) was secured to a head band and used as the computer input device to control on-screen cursor motion with head rotation (left–right). This Air Mouse has inertial sensors used to derive angular position signals. With this simple method, seamless and responsive hands-free interaction with the computer application is made possible. In a similar manner, a number of studies have used reaching or pointing tasks to evaluate perception, attention, and higher-level cognitive decision-making [17,18]. Visually guided head movements are among the most natural, therefore these tasks are easily performed with minimal

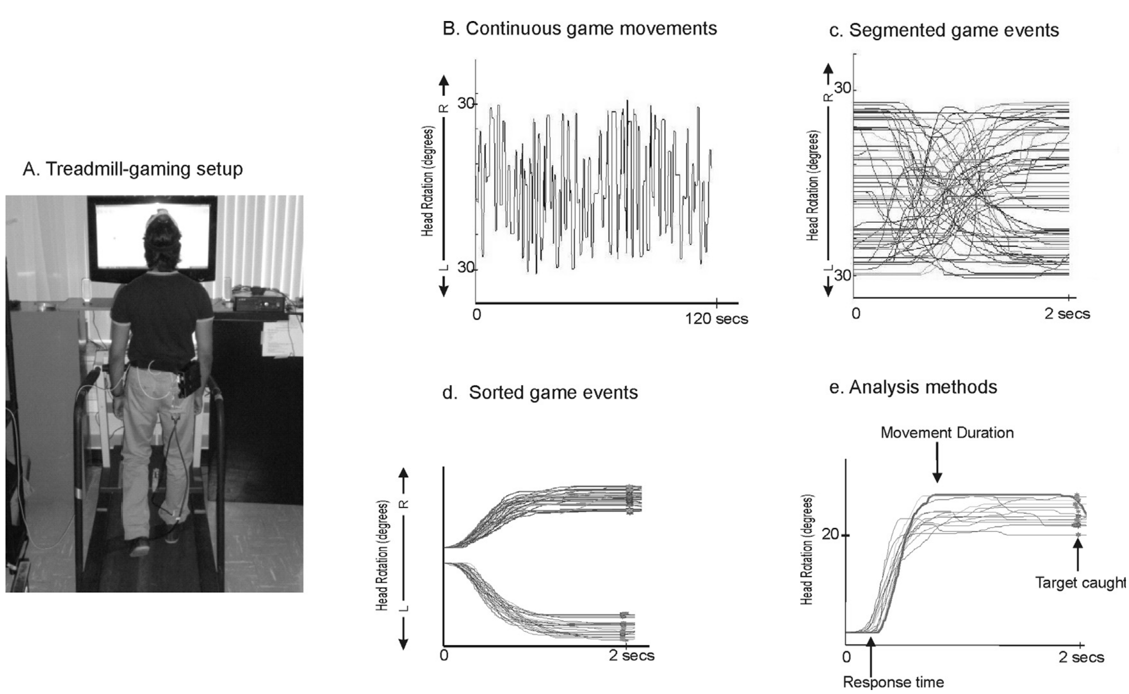

Fig. 1. Experimental set-up. Participant is shown walking on treadmill while viewing a computer monitor and using head rotation (motion mouse) to interact with cognitive game. Panel B presents trajectory of game paddle movements for one logged game file, 120 s duration. Each game event is 2 s in length; thus, recording includes a total of 60 game events (random presentation of different amplitudes and directions). Panel C presents overlay of individual game events segmented based on index times of target appearance and disappearance Time zero is onset of target appearance, end of event is time when target disappears. Panel D: segmented game events shown in D are sorted grouped in functional bins, which in this case represent medium amplitude player movements in leftward direction (upward trajectories), and rightward direction (downward trajectories). Panel E illustrates analysis methods to quantify response time and movement time.