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EFFECT OF TYPE OF COGNITIVE TASK AND WALKING SPEED ON COGNITIVE-MOTOR INTERFERENCE DURING DUAL-TASK WALKING

P. PATEL,[a] M. LAMAR[b] AND T. BHATT[a*]

[a] University of Illinois at Chicago, Department of Physical Therapy, 1919 West Taylor Street, 4th Floor, Chicago, IL 60612, United States

[b] University of Illinois at Chicago, Department of Psychiatry, 1601 West Taylor Street, M/C 912, Chicago, IL 60612, United States

Abstract—*Objective:* We aimed to determine the effect of distinctly different cognitive tasks and walking speed on cognitive-motor interference of dual-task walking.
***Methods:* Fifteen healthy adults performed four cognitive tasks: visuomotor reaction time (VMRT) task, word list generation (WLG) task, serial subtraction (SS) task, and the Stroop (STR) task while sitting and during walking at preferred-speed (dual-task normal walking) and slow-speed (dual-task slow-speed walking). Gait speed was recorded to determine effect on walking. Motor and cognitive costs were measured.**
***Results:* Dual-task walking had a significant effect on motor and cognitive parameters. At preferred-speed, the motor cost was lowest for the VMRT task and highest for the STR task. In contrast, the cognitive cost was highest for the VMRT task and lowest for the STR task. Dual-task slow walking resulted in increased motor cost and decreased cognitive cost only for the STR task.**
***Conclusions:* Results show that the motor and cognitive cost of dual-task walking depends heavily on the type and perceived complexity of the cognitive task being performed. Cognitive cost for the STR task was low irrespective of walking speed, suggesting that at preferred-speed individuals prioritize complex cognitive tasks requiring higher attentional and processing resources over walking. While performing VMRT task, individuals preferred to prioritize more complex walking task over VMRT task resulting in lesser motor cost and increased cognitive cost for VMRT task. Furthermore, slow walking can assist in diverting greater attention towards complex cognitive tasks, improving its performance while walking. © 2013 IBRO. Published by Elsevier Ltd. All rights reserved.**

Key words: cognition, gait, attention, multi-tasking, healthy adults.

INTRODUCTION

Walking is one of the most common circumstances during which people fall (Sartini et al., 2010). Irrespective of having any sensory or motor impairments, individuals with cognitive deficits pose relatively higher risk of falling compared to those without cognitive deficits (Axer et al., 2010). These findings have raised interesting questions about cognitive-motor interference (CMI) during walking. Thus, increasingly, investigators are attempting to understand the underlying mechanisms of CMI during walking and design dual-task paradigms for rehabilitation directed towards meeting demands of ‘real life’ situations.

The CMI of dual-tasking refers to deterioration of either motor or cognitive task performance when they are attempted simultaneously (Plummer-D’Amato et al., 2008). While walking, CMI has been demonstrated either by alteration of walking pattern—such as reduced gait velocity or increased gait variability or by decline in cognitive task performance across domains such as visuomotor processing, verbal fluency (e.g., word list generation (WLG)), and working memory (e.g., serial subtraction (SS)). A general observation of CMI is that, when confronted by two attention-demanding activities, humans explicitly prioritize one task over the other based upon counterbalancing capabilities and available cognitive and/or motor reserves (Yogev-Seligmann et al., 2012). However, the diverse range of cognitive tasks employed across CMI studies make conclusions about prioritization (i.e., cognition versus walking) difficult to discern.

The nature of CMI across these varying cognitive domains has been studied in both younger and older adults. Dubost et al. (2008) observe that the verbal fluency task did not show any effect on stride velocity in a cohort of young healthy adults, nor did verbal fluency differ between walking (dual-task) versus sitting (single-task) conditions in this same sample. In contrast, an arithmetic task instigated a decline in gait speed and the ability to enumerate numbers while dual-task walking compared to single-task conditions in another cohort of young healthy adults (Beauchet et al., 2005). Furthermore, some researchers have proposed that the effect of concurrent cognitive task on walking also differs with age. For example, reaction times of the older adults when responding to visual (but not auditory) stimuli while walking are greater than that of young adults (Sparrow et al., 2002). Older adults also show

*Corresponding author. Address: University of Illinois at Chicago, Department of Physical Therapy, 514-E, 1919 West Taylor Street, Chicago, IL 60612, United States. Tel: +1-312-355-4443.
E-mail address: tbhatt6@uic.edu (T. Bhatt).

Abbreviations: ANOVA, analysis of variance; CMI, cognitive-motor interference; SS, serial subtraction; STR, Stroop; VMRT, visuomotor reaction time; WLG, word list generation.

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greater decline in gait speed while dual-tasking compared to young adults (Li et al., 2001).

Dual-tasking paradigms have also been applied to individuals with neurological conditions in order to develop a more comprehensive understanding of fall risk in these vulnerable populations. Studies on CMI have shown that individuals with stroke (Haggard et al., 2000), or multiple sclerosis (Hamilton et al., 2009) present with poor ability to divide attention between motor and cognitive tasks compared to age-matched healthy adults. The digit span task significantly affected gait in those with Alzheimer's disease, but it did not affect gait in young adults (Ebersbach et al., 1995). Across these studies, results are often attributed to declines in cognitive function associated with the underlying neurological condition in question (Logie et al., 2004).

It is evident the CMI pattern varies largely based on the population being studied and the methodology being used. For example, the choice of cognitive task can heavily influence the CMI pattern in young and older adults as well as individuals with cognitive and/or motor impairments (Ebersbach et al., 1995). Thus, it follows that one specific task may be inadequate to explain CMI in its entirety or to determine whether individuals prefer prioritizing cognitive tasks over walking or vice versa.

On the same lines, manipulation of walking speed may alter such cognitive prioritization. For example, while increased gait speed may be indicative of safe travel under dual-task conditions (e.g., crossing lights while talking over the phone), Dennis et al. (2009) demonstrated that walking at a faster speed resulted in more number of errors on the concurrent cognitive task compared to that while walking at preferred speed. Other evidence suggests that walking at a slower speed improves walking stability (Bhatt et al., 2005; England and Granata, 2007). It is thus likely that the increase in stability gained while walking at a slower speed might provide additional neural resources for processing of the cognitive task. As such, the beneficial effects of slow walking to enhance cognitive-motor performance in dual-task condition have not received much attention.

This study attempts to determine the differences in CMI when performing cognitive tasks targeting different cognitive functions at varying walking speeds. Thus, the twofold aim of this study was (1) to examine the effect of visuomotor, memory recall, working memory, and executive function tasks on motor and cognitive costs of dual-task walking and (2) to determine the effect of slow walking versus preferred-speed walking on cognitive cost of dual-task walking. The cost was determined by computing the difference between single- and dual-task performance. We hypothesized that a higher motor cost will be associated with a particular cognitive task. Higher motor cost would indicate requirement of greater attentional resources for that cognitive task, under dual-task conditions. Tasks showing higher cognitive cost would indicate prioritization of motor task (walking) under the respective dual-task condition and lower cognitive cost would indicate prioritization of cognitive task under respective dual-task condition. We further hypothesized that compared to preferred-speed walking, slow walking while dual-tasking would improve the performance on the cognitive tasks i.e., decrease the cognitive cost of dual-task walking.

EXPERIMENTAL PROCEDURES

Participants

Fifteen healthy young adults (M = 25.6, SD = 5.23 years, 14 females, one male) participated in the study. Subjects were recruited from the University of Illinois at Chicago and informed consent was obtained. We chose to focus on younger adults to determine the typical pattern of CMI while performing varied cognitive tasks while walking. To understand the pattern of CMI of dual-task walking, subjects performed four different cognitive tasks while sitting and walking at preferred and slow speeds.

Gait Speed

Gait speed was recorded using an electronic mat GaitRite (CIR Systems, Inc., Sparta, NJ, USA). It consists of sensors embedded into 12×2 feet mat which measures spatial and temporal gait parameters via the accompanying GaitRite software (GaitRite Gold, Version 3.2). To record the steady state gait speed, subjects were instructed to begin walking about 1 m before stepping on the mat and to keep walking about 2 m beyond the mat. Gait speed was recorded and defined as the distance walked in the walking time for that specific trial. Gait speed was selected to evaluate the change in motor function, as the effect of a concurrent cognitive task has shown to be most evident on this variable (Al-Yahya et al., 2011) and is consistently linked with functional outcomes (Verghese et al., 2011; Holtzer et al., 2012).

Cognitive tasks

Subjects were asked to perform four different cognitive tasks in randomized order while sitting and walking. (1) *Visuomotor reaction time (VMRT) task:* In a sitting position, subjects were shown two visual stimuli that were flashed on a screen. The first (red) stimulus was a preparatory signal followed by a second (green) stimulus. Subjects responded to the second stimulus by pushing a push-button in their hand. The VMRT response was recorded as the amount of time (milliseconds) taken to press the button upon presentation of second stimulus. To maintain the position of the hand consistent under single- and dual-task conditions, subjects were asked to sit in a chair without an armrest and place their hand, unsupported, by the side of their body. (2) *Word list generation (WLG) task:* Subjects were asked to generate words beginning with a specific letter, and the total number of words generated in 10 s was summed (Dubost et al., 2008). This task focused on verbal fluency and semantic memory. (3) *Serial subtraction (SS) task:* In this task targeting working memory, subjects were instructed to