Walking while Judging: Cognitive facilitation in younger and older adults during the concurrent performance of cognitive and sensorimotor tasks

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Abstract

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The current study evaluated the importance of attention in motor control. In a dual task paradigm, 24 younger ($M = 21$, $SD = 2.00$, range: 18-30 yrs) and 24 older ($M = 70.5$, $SD = 5.00$, range: 62-80 yrs) adults' attention was divided between walking on a treadmill and performing a semantic judgment. For the semantic task, words were presented auditorally and participants judged if the word was living or non-living. When walking, muscle preparatory activity was measured with electromyography (EMG). Performance was measured at two different levels of walking difficulty: level (0°), and downhill (-15°). Measures of single task performance were compared to measures of dual task performance, in order to derive a proportional dual task cost for each condition. When performing two tasks at once, it was expected that older adults (OA) would allocate more attentional resources to walking at the cost of slower responses to the semantic task. Further it was predicted that the preparatory muscle activity of OA would diminish under dual task conditions. Contrary to predictions, under dual task conditions, all participants significantly improved their response times, [$F\,(1, 46) = 29.13$, $p < .001$, $\eta = 0.39$] and experienced no changes in muscle activity. Across conditions, OA were slower at responding and had less muscle activity than the younger adults. In this study, the combination of tasks somehow facilitated a speedier response for the cognitive task. Cognitive capacity, task difficulty, and the demand characteristics of the testing are discussed.

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Walking is a motor skill that humans develop at a very young age. The repetitive use of this skill creates an activity that becomes highly automatic in nature. A simple example might be walking to the grocery store. There is little need to devote a great deal attention to the motor control of one's posture and limbs to walk to the store, since this has become an automatic process. Normative changes that occur with age have important implications for this automatic process. As we age, changes in muscle mass and strength affect the speed, accuracy, and variability of motor movements (Dierick et al., 2002). Beyond the changes in musculature that alter motor control, other research with older adults indicates that attentional capacity also plays a significant role in motor control (Wollacott & Shumway-Cook, 2002). This capacity is also one that declines with age (McDowd & Shaw, 2000). The increasing needs of motor control and the shrinking of attentional capacity create a scarce-resource model. In such a model an older adult may recruit or trade off attentional capacity in service of motor control. In attempt to prevent falling, an older adult may proceed with more caution, and pay more attention to the walking demands of the situation. Li et al. (2001) tested older adults under dual-task conditions and demonstrated that they choose to allocate their attention to the motor (walking) task over the cognitive (memory) task when asked to do these two tasks concurrently. The goal of the current study was to replicate and extend the findings of Li et al. (2001) by looking at possible changes in muscle preactivation under dual-task conditions.

The present research explores age differences in the role of attention during walking using a dual-task paradigm. When older adults have to do two things at once, do they prioritize walking over a concurrent cognitive task? If yes, *when* is attention most important to walking performance? Is there a point in the gait cycle where older adults need to allocate more attention to be able to maintain their walking performance? The current study addresses these main questions related to the cognitive and sensorimotor performance of older adults. To begin, this paper presents an overview of research involving attention, dual-task methodology, kinesiology, and musculature, in older adults.

Attention and changes with aging

Over a century's worth of research has been devoted to the topic of attention. In 1907, William James wrote: "Everyone knows what attention is. It is the taking possession by the mind in clear and vivid form of one out of what seem several simultaneous objects or trains of thought" (Posner, 1995, p.615). This definition of attention highlights the central theme that we are regularly bombarded with all kinds of information, tasks, and stimuli, which we have to process, and focus on what is most important.

What is most important? Given all the information that is processed, what is most likely to 'grab' our attention? Posner and Boies (1971) suggested that certain processes require more attention than others. Indeed they argued that certain tasks may be performed automatically and therefore liberate cognitive resources for the performance of other tasks, which may require more controlled processing. In their study, the primary task participants were asked to perform was letter matching. Participants were shown two letters, one after the other, and were asked to decide, as quickly as possible, if they were the same or different. The secondary task required the participants to respond to an auditory tone that was presented randomly during the letter matching task. When the first letter and the tone were presented concurrently, the letter matching did <u>not</u> disrupt the reaction time to the auditory tone. They therefore concluded that the processing of the letter occurred automatically, which allowed the available cognitive resources to be diverted to the processing of the auditory signals. In contrast, when the tone occurred after the first letter or immediately after the second letter, the reaction time to the tone slowed dramatically. In this case, the timing of the tone coincided either with the participants' rehearsal of the first letter or the matching decision. Both rehearsal and the matching decision required more processing on the part of the participant. The increase in cognitive demands reduced the amount of resources available to process the tone.

Kahneman (1973) supported Posner and Boies' (1971) proposal that some processes are considered "automatic" and have a limited effect on attentional capacity and that other mental processes are "effortful" and draw on available capacity. Kahneman further contends that we have a limited capacity to deal with all the incoming stimuli or task demands. Kahneman's (1973) cognitive capacity model asserts that people will be able to do more than two things at once as long as these two tasks do not exceed the number of available cognitive resources. In addition, the model posits that problems in doing two things at once are not caused by interference between the tasks but by the two tasks exceeding the available resources.

Limited capacity, automaticity, and controlled processing are all factors that become increasingly important as we age [For reviews see Kramer & Larish (1996) and Posner (1995)]. A common paradigm used to explore attention in cognitive research is the dual task paradigm (Baron & Mattila, 1989; Guttentag, 1989; McDowd et al., 1991; Park et al., 1989; Salthouse et al., 1984). In a dual task paradigm, participants are asked to divide their attention between two tasks while performing both tasks simultaneously.

Presumably, their performance on each task separately will be better than their performance under dual task conditions. Often when performing two tasks simultaneously, one of the single components of the dual task suffers. For example, if the two tasks are A and B, there is a dual task cost (of A or B) when performing task A and task B simultaneously. An example of divided attention conditions for an older adult might be driving while carrying-on a conversation with a passenger in the car. The dual task cost of performing these two tasks concurrently might be reflected in driving performance (they might miss their exit) or it might be reflected in their conversational style (they may talk less or stop talking).

As far back as 1977, Craik stated: "One of the clearest results in the experimental psychology of aging is the finding that older subjects are more penalized when they must divide their attention" (p.391). Current dual task research also supports the finding that older adults' performance suffers under dual task conditions (Kramer et al., 1995; Li et al., 2001; Fernandes & Moscovitch, 2002).

An overview of the dual task research seems to highlight a negative view of aging where older adults struggle to cope with competing demands on their attention. Using a dual task design, Li et al. (2001) revealed that despite normative declines (i.e. physiological and cognitive changes) there are ways of successfully aging. The study tested an older population on the difficult task of dividing their attention between walking and memorizing. Their results indicate that the older adults selected the maintenance of performance on the walking task as most the important goal and in order to successfully achieve this goal task they compensated by using a handrail. This study demonstrates that when faced with excessive attentional demands, older adults can choose to focus on the task most relevant to them and use the necessary means to succeed.

Baltes and Baltes (1990) propose that throughout the lifespan changes occur but that adaptations to these changes can be made and successful aging can occur. Successful aging refers to the adaptations an older adult may choose in order to maintain relevant goals. An older adult "may either try to alter or modify the course of personal development and in accordance with personal goals and aspirations ..., or adjust personal goals and standards to factual outcomes and constraints of development" (Brandtstädter & Wentura, 1995, p.86).Their model of selective optimization with compensation (the SOC model) has been applied to all age groups and puts forward the notion that "there is much opportunity for the continual optimization of development" (p.20).

The SOC model is a comprehensive view of human development that posits individuals can manage their lives successfully through: selection (S), optimization (O), and compensation (C). Selection refers to the setting of goals; optimization refers to attaining these goals; and compensation refers to being able to vary the means to attain these goals given potential changes across the lifespan (Freund & Baltes, 2002). With successful aging in mind, the normative cognitive and motor changes that occur when we age can be seen as developmental changes that can be adapted to. For example in the current study, it may be argued that although the maintenance of motor control may become more difficult for an older adult, the older adult may decide to select (S) between two tasks (i.e. choose to focus on walking over judging), optimize (O) the task of most importance (i.e. walking has survival value, therefore it will be of most importance) and use their available resources to compensate (C) for declines in one task domain (i.e., maintaining motor control may require the diversion of added attentional resources to the walking task).

Changes in musculature and movement with age

As mentioned previously, there are normative changes in aging that are beyond our control. Older adults tend to have less muscle mass and strength than younger adults. Muscle mass decreases as we age due to losses of muscle fiber numbers and a reduction in muscle fiber size. When tested on knee extensor strength tests, healthy older adults (70-80 years) are 20-40% weaker than the younger adults, and the very old (>80 years) show even greater reductions (50% or more: Roos et al., 1997). Dierick and colleagues (2002) proposed that one factor contributing to the overall slowing during gait in the elderly is the change in skeletal musculature.

EMG (electromyography) has been frequently used to measure changes in gait due to disorders (e.g. Parkinson's disease, Muscular dystrophy) and changes due to injury (e.g. Anterior cruciate ligament (ACL) injuries, amputations: DeMont et al., 1999; Dierick et al., 2002; Mulder et al., 2002; Woollacott & Shumway-Cook, 2002). Winter (1991) further argues that: "the alteration of the gait mechanism results from interaction changes between the neurological system and the mechanical demands of the locomotor task. From a neurological standpoint dynamic electromyography represents the neurological control of skeletal muscle during gait" (p.53).

The use of EMG in gait analysis allows for specific analysis of the timing of the motor response at the peripheral level of the muscle. In addition, the EMG data provide a time function of muscle related activity. This allows for concrete definitions of the timing and activity of the preparatory period (-150 to 0 ms), the motor response or swing phase (the execution of the motor response-contraction), and the stance phase (end of one gait cycle). Recent research by Mickelborough and colleagues (2004) demonstrated that healthy older adults had a more variable pattern of muscle activity in the preparatory phase of gait initiation. They concluded that the preparatory phase of gait initiation may be a point of difficulty for people with gait disorders.

Other research, with young women, by DeMont and colleagues (1999) suggests that women with ACL deficient knees have different patterns of muscle preparatory activity as compared to women who have had ACL reconstructive surgery and controls. This change in preparatory activity may reflect a cautious strategy or protective behaviour to avoid injury. As a person with an injury may implement a more cautious strategy when walking, so might an older adult who fears the repercussions of a fall.

On one side of the continuum, cognitive psychologists are employing the dual task paradigm to clarify the modulation of cognitive processes in the elderly. On the other side, researchers use kinematics to improve their understanding of overall movement slowing in older adults. The question of interest is: how do older adults perform different motor tasks?

Meyer et al. (1988) used kinematic analyses to evaluate the wrist-rotation of participants asked to turn a handle quickly and accurately from an initial position to a specified target position. The analyses revealed that the movement could be subdivided into a primary pre-programmed movement and a secondary, corrective submovement. The notion that some movements may be "pre-programmed" is analogous to certain cognitive processes being "automatic". Further, a secondary corrective submovement phase is indicative of controlled processing. Other kinematic research conducted by Pratt et al. (1994) compared the movement patterns of young and older adults. Their study revealed that older adults had longer overall movement durations and spent more time in the secondary corrective phase than did the younger adults, however the time spent in the primary or pre-programmed phase was the same between groups.

Recently, Ketcham et al. (2002) replicated these findings with a study that further explores age-related kinematic differences under varying conditions of task difficulty, target size, and movement amplitude. In this study, participants had to point (using a pen) to a specific location on a target (shaped like a bulls-eye) that was presented to them on a computer screen. The 'point' location changed and became increasingly difficult, on each subsequent trial. Further, the size of each target decreased and the amount of movement required to reach each 'point' location on the target was modified every trial. Their findings suggest that older adults are unable to effectively propel their arm to the target in a single step and they require multiple corrective submovements which make their movements less smooth and slower.

When it comes to balance and posture control again it seems that healthy older adults are not moving in the same way as younger adults. Woollacott and Manchester (1993) found that postural control is slower in the elderly which contributes to a loss of balance. When faced with postural disturbances, they found that older adults activated postural muscles later and that older adults exhibited less preparatory activity than did young adults.

Other researchers have found that normal aging seems to result in increased attentional requirement for balance during standing (Brown et al., 1999; Redfern et al., 2001). One study conducted by Redfern et al. (2002) explored the postural recovery of individuals dividing their attention between postural perturbations and their reaction time to visual or auditory stimuli. Although both young and older adults' reaction times slowed under the divided attention condition, older adults' reaction time was particularly slowed before and during the platform movement. This suggests that despite instructions that both tasks were important, older adults placed more importance on responding to the postural perturbations than on the visual or auditory stimulus.

Attention and Walking

In addition to the changes in musculature, locomotion or gait in the elderly tends to be slower. Older adults have shorter strides, less erect posture, and less range of motion at the hip, knee, and ankle joints (Romero & Stelmach, 2001). A closer look at kinematics, posture, musculature, gait, and cognitive processes in the elderly, results in a common theme. Attention is an important component in older adults' performance and behaviour during everyday activities. As a consequence, the automated and controlled processes of everyday activities of older adults have become the focus of current research.

Several components, which are often considered automatic, play a part in the everyday activity of walking (for review see Woollacott & Shumway-Cook, 2002). In the case of older adults, this everyday activity is often the origin of falls (Lipsitz et al., 1991). Falls that occur late in life can have serious repercussions. Research by Morley et al. (2002) reveals that, for older adults, falls are likely to lead to institutionalization, depression, and even death. Perhaps the assumption that walking is largely an "automated" process is not entirely true. Research by Lajoie et al. (1996), suggests that walking requires a great deal of cognitive processing and is far from "automated".

In clinical research, "stops walking when talking" has been proposed as a measure of fall predictability in older adults (Lundin-Olsson et al., 1997). In their sample of 58 residents who were able to walk with or without support, 12 participants stopped walking when talking. Of those 12, ten of them fell during the six month follow-up. Although the authors are not suggesting "stops walking when talking" is the best predictor of falls, they argue that it has a positive predictive value. The notion that talking while walking can disrupt walking performance implies that there is some association between cognitive function and motor function in old age.

Weerdesteyn and colleagues (2003) used a dual task paradigm, with a young sample, to explore how distraction affects obstacle avoidance during walking. The participants had to divide their attention between a cognitive task and avoiding obstacles falling randomly on the treadmill during walking. The results show that they were less able to avoid the obstacles and that they altered their gait (using smaller crossing swing velocities) under dual task conditions. Beauchet and colleagues (2003) also used a dual task paradigm to examine gait control. Both younger and older adults were tested on walking, counting backwards, and walking and counting backwards combined. Under dual task conditions only older adults' walking was altered, such that they had increased stride-to-stride variability.

Further, research by Lindenberger and Baltes (1994), proposes that a large percentage of variability in intellectual functioning late in life is mediated by sensorimotor functions, suggesting a strong connection between sensorimotor and cognitive functions in old age. If cognitive functions interact with sensorimotor functions then a closer look at the impact of cognitive functions and walking is needed.

Using a dual task paradigm, Lindenberger et al. (2000) examined the importance of cognitive control in walking and memorizing in younger and older adults. They asked participants to walk on two types of tracks (oval and aperiodic) and memorize words using the method of loci technique. The measures of walking performance were based on speed and accuracy and the measure of memory performance was the total number of words recalled. They found that performing the two tasks concurrently was more difficult for the older adults than for the young. In both walking performance and words recalled the older adults had higher dual task costs than the young.

Li et al. (2001) pursued the walking while memorizing research with the added dimension of compensatory behaviour. They examined the effect of dividing attention between a cognitive task (memorizing) and a sensorimotor task (walking), in younger and older adults. Consistent with their predictions, they found that when compared to young, older adults showed greater dual task costs in the memory domain, prioritizing walking over memorizing when their attention was divided. In addition, older adults were more likely to use an external aid to help them maintain walking performance and the young adults were more likely to use an external aid to maintain memory performance.

Research Overview

Taken together, the research points to a general trend in normal aging in which both cognitive and motor abilities are diminishing over time. If motor control requires more attention and attentional resources are shrinking then older adults should prioritize the activity that is most important to their survival. *Not* attending to walking could lead to a fall, which could have a huge impact on the life of an older adult. Given the importance of walking and the potential consequences of a fall, older adults should strategically allocate their attention in favour of motor control.

With the goal of improving on the existing sensorimotor and cognitive dual task research, a pilot study using a walking (sensorimotor) and tone identification (cognitive) tasks was designed. In the Li et al. (2001) study walking task difficulty was manipulated with obstacles on the walking track. In the pilot study, the walking task difficulty was manipulated by altering the inclination of the treadmill, such that there were three inclinations [level (0°), uphill (+15°), and downhill (-15°)]. The measure of walking performance was unique to the pilot study. Instead of measuring accuracy and speed, the speed was fixed and the electrical activity from the leg muscles was measured with an electromyogram (EMG). After testing a sample ($N = 17$) of young adults, the data analyses established that the tone identification task was not a challenging enough cognitive task. All the participants had ceiling effects on walking performance and tone identification, under dual task conditions. Given that there were no dual task costs for the entire sample a new cognitive task needed to be implemented.

Building on these results, with an emphasis on redesigning the cognitive task, the current study evaluated the importance of attention during the gait cycle. Electromyography (EMG) was used to investigate the effect of attention on muscle preparatory activity. This is an improvement over the Li et al. (2001) study, in which they measured walking speed and accuracy, because it directly measures the amount of electrical activity in the muscles. This EMG measurement allows for greater precision since the muscle activity during the entire gait cycle is evaluated temporally. Therefore, the effect of the secondary task is evaluated at the precise time it occurs during the gait cycle.

Due to the ceiling effects in performance on the pilot cognitive task, a new task was used for the current study. Simply making a distinction between a high or low tone was not challenging, therefore in the current study a semantic judgment task was used. Making a semantic judgment required deeper processing (for a review of levels of processing see Craik, 2002) as the participant monitored for the word and had to decide whether the word belonged in the category living or non-living.

Using a dual task design, younger and older participants' attention was divided between walking on a treadmill, at a set speed, and performing the semantic judgment task. When asked to walk and judge, older adults were expected to prioritize walking and therefore show an increased reaction time to the semantic task. In other words, when performing the two tasks concurrently, it was predicted that there would be a dual task cost for the older adults on the cognitive task. This finding would replicate the results of the Li et al. (2001) study.

Further, following the pilot study results, the manipulation of the walking difficulty was retained, with a focus on the level and downhill manipulations. It was anticipated that reaction time for older adults during dual task performance may be influenced by the degree of walking difficulty. Specifically, an increase in reaction time to the semantic task was expected on a downward slope (-15°), as compared to level (0°). Research by Leroux et al. (2002) demonstrated a slowing in walking pace and shortened steps when walking downhill. In the current study, participants had a set walking pace which they were not able to alter when walking downhill. Under dual task conditions, it was predicted that this set pace may lead to a higher dual task cost on the cognitive task. Also, since walking downhill places a slightly higher load on the knee (Kuster et al., 1995), which can affect postural stability, it was expected that there may be an increase in the perceived danger for the older adults and therefore they may have allocated more attention to the walking task.

The EMG measure of muscle activity will allow us to examine the different stages of the gait cycle (preparatory, swing, and stance). It is proposed that if attention is critical to preparatory muscle activity then having a participant walk and perform a cognitive task should also modulate the preparatory muscle activity. The activations of interest are single task (walking alone) and dual task (walking and making semantic judgments) for each of the different muscle groups. It was predicted that the peak amplitude would not change but that the area of muscle activation, within the pre-activation time frame (-150 to 0 ms), may shrink for the older adults as compared to the young, under dual task conditions. The literature on age differences in muscle preactivity is limited and finding altered muscle preactivity during dual task performance would significantly advance this new area of research. Measuring both the cognitive and motor components of dual-task performance in older adults may help to clarify the importance of attention during walking and add to the literature that argues a strong connection between sensorimotor and cognitive functions in old age.

Method

Participants

Twenty-four younger adults (*M* = 21, *SD* = 2.00, range: 18-30 yrs), and 24 older adults (*M* = 70.5, *SD* = 5.00, range: 62-80 yrs) were included in the study. Equal numbers of males and females were tested in both groups. All the participants were screened for medical or psychological problems that might have impaired their ability to perform either the walking or the cognitive tasks. In particular subjects were screened for neurological problems, such as stroke or physical problems such as hip or knee injuries, problems with balance, hearing impairment or recent heart attack (see Appendix A: Phone Screening Questionnaire). All subjects gave written informed consent (see Appendix B) and the experimental protocol was approved by the Ethics Committee of Concordia University. The young adults were recruited, on a volunteer basis, from Concordia University classrooms. The older adults were recruited using advertisements in the local newspapers. The older adults were remunerated $10.00 for their participation. Three participants were excluded from the final sample: Two younger participants who performed poorly on the semantic task were excluded from the study on day one; one older adult was excluded due to an inability to walk comfortably on the treadmill.

Tasks

Each participant completed a day of training and a day of testing on the walking and cognitive tasks under both single and dual-task conditions. The walking task required participants to walk on a treadmill at two different levels of difficulty (level and downhill slope). The cognitive task required making semantic judgments of a series of words (see Appendix C for complete verbal instructions for training and testing days).

Walking Task

Participants were asked to walk on a Biodex treadmill, at two different slopes, level (0°) and downhill (-15°). To ensure safety on the treadmill, a Biodex harness was used. Seventeen Medi-tace mini 133 brand electrodes were placed on eight points of maximum muscle density in the leg muscles to measure the electrical energy from the muscles during walking. Surface EMG activity was measured from vastus medialis oblique (VMO), medial hamstring (MH:semitendinosus and semimembranosus), and lateral hamstring (LH:biceps femoris) in the thigh, and the medial gastrocnemius (MG), lateral gastrocnemius (LG), tibialis anterior (TA) and peroneal longus (PL) of the leg. A reference electrode for the EMG system was placed over the tibia. The information from the electrodes was sent to a Myo-Pac transmitter box that was positioned at the waist of the participant with a belt. A shoe insert with footswitches was placed in the participants' shoe to record the heel-strike and toe-off times that were used to define the different phases of the gait cycle (preparatory, swing, and stance phases). The activity of each muscle and the footswitch signal for the dominant leg was registered via DATAPAC software onto the Dell laptop computer.

Cognitive: Semantic Judgment Task

For the semantic judgment task, participants were presented words at ten different inter-stimulus intervals (ISIs: 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000 ms) and were asked to judge whether the word they heard was living or non-living. All participants received the same pre-determined pseudo-random ISI order. The ISIs were varied to prevent predictability and to ensure that words would occur at different phases of the gait cycle under dual-task conditions. Murphy et al. (2000) provided the digitized word samples; the words were spoken in a female voice and consisted of two-syllable common nouns (e.g. spider, cello) with a frequency of more than 1 per million words according to the Kucera and Francis norms (1967). All the word samples were programmed using SuperLab Pro 1.74 Macintosh software. There were four lists for each day (see Appendix D for test lists). The practice lists consisted of 30 words and the test lists consisted of 62 words. Each list contained an equal number of living and non-living nouns. In both the practice and the test days the first two lists had a unique set of words and the last two lists were a re-randomized presentation order of the words in the first two lists. The words were presented auditorally through a Plantronics DSP-300 headset that also recorded the timing of the participants' response to the word stimuli. Reaction time (RT) of each response was recorded in SuperLab Pro. Participants' "yes" and "no" responses were recorded by the experimenter.

Dual task: Walking and making semantic judgments

Participants also performed the cognitive and walking tasks concurrently. During this dual task condition participants' vocal responses to the cognitive task were integrated with the motor performance on the walking task so that both sets of data could be considered in relation to one another. The onset of the word stimuli were sent via parallel connector to the computer recording the EMG muscle activations, and the footswitch signal. The RTs to the words were recorded in Superlab Pro and were subsequently merged with the EMG data in post-processing.

Subjective Questionnaires

During testing two subjective questionnaires were used (see Appendix E). One questionnaire asked the participants whether they emphasized walking or listening and to what percentage. The second asked them whether they felt safe and stable at a certain inclination. The purpose of these questionnaires was to see how the participants perceived the different components of the tasks.

Procedure

Participants were tested for two hour and a half sessions on two separate days (either two consecutive days or one day apart). Day one involved practice on each of the tasks in a set order and various paper and pencil tests. Day two was the testing day which involved a balance test and testing in each of the tasks at both walking difficulties.

Day one: Practice: The purpose of the practice phase on Day 1 was to familiarize the participant with walking on the treadmill and performance of the semantic task and performance under dual-task conditions. Basic health, physical activity, hearing, and cognitive testing were all measured during day one. Participants were asked their age, height, weight, and questions about their typical level of physical activities, in particular, participants were asked about their experience using a treadmill. Subsequently, each participant's word comprehension was tested with a shadow task that mimicked the word presentation used in the testing phase. The shadow task was another screening technique used to insure that the participants were able to respond during the hearing conditions that would be in effect during dual task testing. In the shadow task participants were seated beside the treadmill while the treadmill was operating. In this environment, participants had to repeat the words that they heard through the headset, as quickly and as accurately as possible. Word comprehension of 90% accuracy and above was considered sufficient for inclusion in the testing phase.

Participants were given practice on the walking and cognitive tasks under single and dual-task conditions. For the walking task, the dominant leg was assessed by recording the desired foot used for the initiation of a step. Participants were asked to step towards the experimenter three times, and the experimenter recorded the leg used most often to initiate the step. The EMG transmitter box was attached to the participant's waist during practice but it was not recording any muscle activity. This was done to familiarize the participant with all the equipment before testing.

Prior to walking on the treadmill, the experimenter demonstrated several ways to stop the treadmill and all participants self-selected their walking pace using the BORG rating of perceived exertion scale (RPE: Borg, 1982). Participants were shown the scale and asked to set their walking pace to a score of 12, on the RPE scale (range: 6 -19). A perceived exertion rating of 12 on the RPE scale represented a walking pace set between the descriptors "Fairly light (11)" and "Somewhat Hard (13)". The purpose of having participants' aim for a 12 was to set a pace that they would not perceive as under or over exerting. The participants were blind to the speed of the treadmill as the experimenter manipulated the speed until the participant felt that they had reached their comfortable walking pace. The participant would walk for two minutes familiarizing themselves with the treadmill and the set pace. The pace set during practice was the pace used throughout all subsequent trials.

Once walking pace was set the participant was introduced to the cognitive task alone. When practicing the semantic task, participants were wearing the headset and stood beside the treadmill while it was in operation. They were answering as quickly as possible "Yes" to living words and "No" to non-living words. Vocal reaction time to the semantic task was recorded with a unidirectional microphone and "yes", "no" responses were recorded by the experimenter.

Upon completion of the semantic task alone, the participant returned to the treadmill and walked, on a level slope, for 1.5 minutes. Then the treadmill was stopped and the participants' were given the instructions for the dual task. They were instructed to perform both walking and semantic judgments simultaneously. They were informed that both tasks were equally important, that they should respond quickly and accurately to the words, and that they should walk looking straight ahead as they would if they were normally walking on a sidewalk. In addition, to ensure that they did not miss a word, they were told not to correct their responses and not to respond to words that they were unsure of. They then completed the dual task on a level slope. The same order of tasks (semantic task alone, walk alone, and semantic and walking tasks concurrently) was repeated on a downhill slope.

On day one, not only did the participants become familiarized with the basic tasks but they also completed a hearing test and various cognitive tests for the purpose of having more detailed background information about the sample. Their auditory acuity was measured with a Maico-MA 39 audiometer. Three cognitive tests were administered: the Digit Symbol (Weschler, 1981), the Montreal Cognitive Assessment (MOCA; Nasreddine et al., 2003), and the Trail Making Test (Spreen & Strauss, 1998). At the end of the practice session, each participant was given a four page demographic questionnaire to complete at home and return on the test day.

Day two: Test: On day two, the Sharpened Romberg (SR) balance test was administered (Brigg et al., 1989). Participants were asked to stand in the most difficult position for this test. The goal of the test was to maintain balance as long as possible in a tandem stance (one foot directly in front of the other- heel to toe), with head-up, eyes closed, and arms placed at the sides of the torso. Using a stopwatch, the experimenter measured how many seconds the participant was able to retain this position. Participants were given two practice trials and then they were given three timed trials. Of the three trials, the longest time was retained as the participants' SR score. A score above 30 seconds was considered a normal balance score.

After the balance test, EMG electrodes were placed on the muscles of the dominant leg. Each muscle group was tested for their maximum voluntary contraction (MVC). The experimenter then placed the participant into the harness and placed the footswitch in the shoe of their dominant leg. All this equipment was attached via fiber-optic cable to the computer.

Prior to testing, each participant completed another practice trial of the dual task, on a level slope, as a refresher from day one. Each participant was then given a different random order of semantic task alone (single task), walking (single task), and walking and semantic task (dual task). Each participant performed approximately 2.5 minutes of each task, under a counterbalanced order of level and downhill conditions (see Appendix F, for counterbalancing procedure). Questions from the two subjective questionnaires were asked upon the completion of all the tasks at each level of walking difficulty.

Results

The main goal of the current study was to evaluate the importance of attention during the preactivation phase of the gait cycle, in samples of young and old participants. In the current study, there were two dependent measures of performance: (1) one that addresses the cognitive component of the study, reaction time in milliseconds to the semantic task (correct responses only); and (2) one that focuses on the walking component of the study, percentage muscle preactivation. Separate analyses were conducted to evaluate the effects of age group (young and old), type of task (single and dual), and walking difficulty (level and downhill) on each dependent measure.

Cognitive data

For the cognitive data, only correct responses to living and non-living words were assessed. Data analyses were conducted using SPSS 11.5. Prior to the analyses, screening for outliers was carried out. Reaction times (RTs) above or below three standard deviations from the mean for both groups were excluded from the analyses. Standard deviations values were determined per individual and per word list, thus outliers were not identical across participants. For the entire sample there was a possibility of 11,904 responses to living and non-living words. Only 94 of these responses were outliers that were removed from the dataset (0.008 %). There were no significant age differences in the number of outliers discarded (younger adults: $M = 1.83$, $SD = 1.61$; older adults: $M = 2.08$, $SD = 1.64$).

Mean RTs were calculated for each condition (single-level; dual-level; single-downhill; dual-downhill). Difference scores (dual-single) were also calculated for level and downhill conditions. Further, these difference scores were used to calculate proportional dual-task costs (pDTCs: dual-single/dual). The pDTCs allow for the analysis of each individuals performance on dual-task in reference to their baseline performance on single task. Given that each individual is compared to his/her baseline, any age differences in the data should be directly related to the concurrent performance of the tasks and not due to methodological design. Mean RTs for living and non-living words were also calculated, with the goal of verifying that there were no systematic differences in responding to the different categories. Finally, accuracy scores (correct responses/total responses) were calculated for each age group under each condition (semantic task alone and dual task). These scores were further split into accuracy for living and non-living responses. The accuracy scores were measured to test if there was a speed (RT) versus accuracy trade-off.

In order to explore whether age group (young and old), walking difficulty (level and downhill), or type of task (single and dual), have an effect on semantic judgment reaction times a 2x2x2 mixed factorial ANOVA was conducted. The within subjects factors were walking difficulty and type of task, and the between subjects factor was age group. With the goal of replicating the results of Li et al. (2001), it was predicted that the interaction between age, type of task, and walking difficulty, would be significant. In other words, it was hypothesized that mean RTs, and pDTCs for the cognitive component would be greater in the older adults as compared to younger adults and that this difference would be augmented as the walking difficulty level increased.

Counter to predictions, the ANOVA (using mean RTs) revealed that there was a main effect of task, such that both age groups mean RTs were faster under dual-task conditions, $F(1, 46) = 29.13$, $p < .001$, $\eta = 0.39$ (see Figure 1). There was also a main effect of age, $F(1, 46) = 5.29$, $p = .03$, $\eta = .103$, such that younger adults were faster ($M = 634.86$, $SD = 86.49$) than older adults ($M = 695.27$, $SD = 95.24$) in responding across all conditions (see Appendix G). There were no significant interactions for age, type of task, or walking difficulty. Proportional dual-task costs were examined and there were no significant findings (see Appendix H).

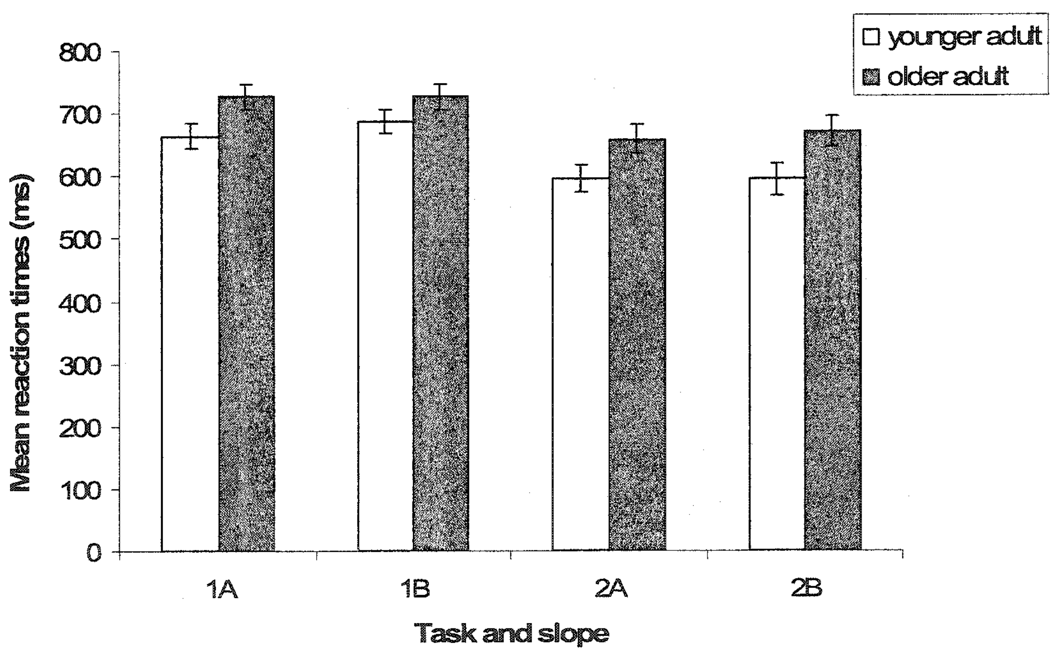

Figure 1. Mean reaction times in milliseconds for single and dual task conditions. 1A = single task/level; 1B = single task/downhill; 2A = dual task/level; 2B = dual task downhill.

With the goal of verifying if there was any speed/accuracy trade-off, the total accuracy of responses was assessed with another 2x2x2 mixed factorial ANOVA. There were no significant effects. Overall accuracy was very high (94% and above), with both groups answering correctly to living and non-living words for all conditions (single-level, dual-level, single-downhill, dual-downhill). Upon closer examination of the RTs for living versus non-living words, a main effect of category, $F(1, 46) = 84.84$, $p < .001$, $\eta = .648$) emerged. RTs to non-living words were longer on average ($M = 692.23$, $SD = 107.70$) than RTs to living words ($M = 637.33$, $SD = 87.12$).

For each participant there were also some missed responses. These missed responses represent either the participant choosing not to respond, the participant responding too late, or the microphone not registering the participants' response. Another 2x2x2 ANOVA was conducted to evaluate if there were any significant effects or interactions between the three variables (age, type of task, and walking difficulty). There was a main effect of task, $F(1, 46) = 37.25$, $p < .001$, $\eta = .447$, such that both groups had more missing responses on dual-task ($M = 16.62$, $SD = 9.35$) as compared to single task ($M = 9.75$, $SD = 5.33$). There was no main effect of group or interactions, indicating that older adults did not have particular trouble with the apparatus or with hearing the stimuli. There was a significant type of task and walking difficulty interaction, $F(1, 46) = 10.13$, $p = .003$, $\eta = .180$, such that there were more missed responses on single-task downhill ($M = 10.52$, $SD = 6.66$) as compared to single task level ($M = 8.98$, $SD = 6.06$), but fewer missed responses on dual-task downhill ($M = 15.5$, $SD = 9.76$) than on dual-task level ($M = 17.72$, $SD = 10.88$).

EMG data

For the walking component of the study, the EMG data were the focus of analyses. EMG was used to measure any changes in muscle preactivity during dual task. The data from eight muscle groups were compiled into integrated electromyographic (IEMG) activity. IEMG provides the researcher with an area measure of the muscle activity to be used in comparisons. The eight sites measured were: the vastus lateralis (VL), the vastus medialis oblique (VMO), medial hamstring (MH:semitendinosus and semimembranosus), and lateral hamstring (LH:biceps femoris) in the thigh, and the medial gastrocnemius (MG), lateral gastrocnemius (LG), tibialis anterior (TA) and peroneal longus (PL) of the leg and footswitch signals were recorded during single and dual task at both walking difficulties (level and downhill). IEMG activity was normalized to the mean amplitude of the individual and analyzed for area and mean amplitude for 150 milliseconds prior to heelstrike (considered the preactivation phase of muscle activity). The preactivation phase was identified manually by inserting markers that coincided with the heelstrike signal. Each preactivation measure was reported as a percentage of the mean.

In order to explore whether age group (young and old), walking difficulty (level and downhill), or type of task (single and dual), have an effect on the preactivation activity of each muscle group a 2x2x2 mixed factorial ANOVA was conducted. Measures of muscle activity when the participant was walking (single task) were compared to measures of muscle activity when the participant was walking and responding to words (dual task). In line with Lindenberger and Baltes' (1994) proposal that sensorimotor and cognitive functions are linked in older adulthood, it was hypothesized that the percentage area of muscle activation, within the pre-activation time frame (-150 to 0 ms), would be smaller for the older adults as compared to the young, under dual task conditions.

Contrary to predictions, there were no significant age differences in muscle preactivation for single versus dual task. However, when individual muscle groups were examined, significant age differences in preactivation were found for three particular groups: VMO, LH, and TA. In all three muscle groups the younger adults had more preactivition than the older adults. In the TA there was a significant effect of age, $F(1, 46) = 5.99$, $p = .018$, $\eta = .117$, such that younger adults had greater percentage preactivation ($M = 54.82$, $SD = 25.70$) than older adults ($M = 38.70$, $SD = 19.14$) (Figure 2). In the LH there was a significant effect of age, $F(1, 46) = 10.49$, $p = .002$, $\eta = .189$), such that younger adults had greater percentage preactivation ($M = 87.77$, $SD = 42.63$) than older adults ($M = 54.01$, $SD = 27.53$) (Figure 3). In the VMO, there was a significant slope by group interaction, $F(1, 46) = 7.63$, $p = .008$, $\eta = .145$, such that younger adults had more muscle preactivation on a level slope in this muscle (Figure 4). In this study, higher preactivation in these muscle groups reflects better preparation at heel strike. In other words, when compared to older adults, younger adults have better control before they put their foot down.

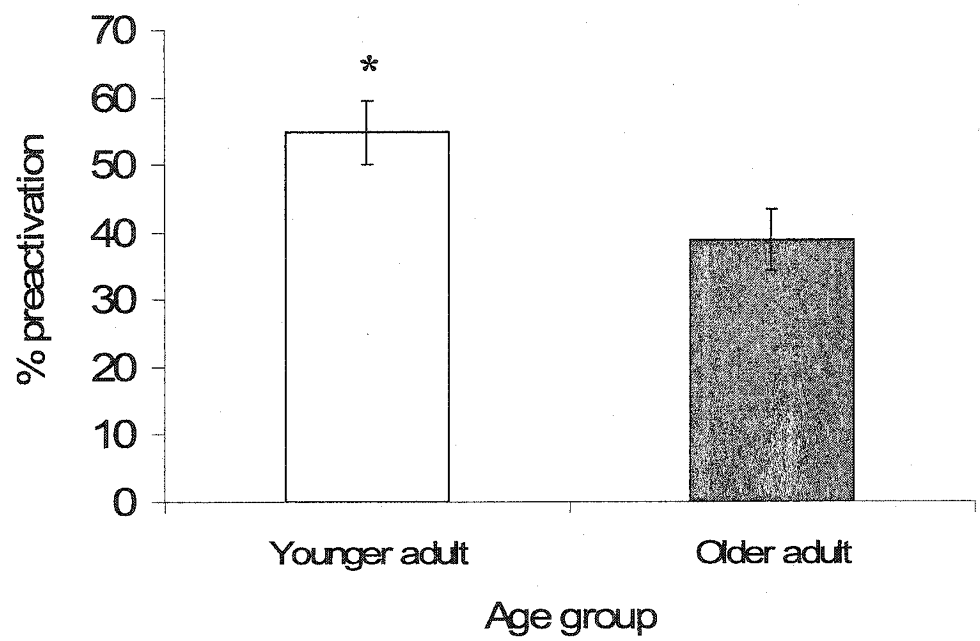

Figure 2. Age differences in the percentage muscle preactivation of the tibialis anterior (TA). Note: * $p = .018$.

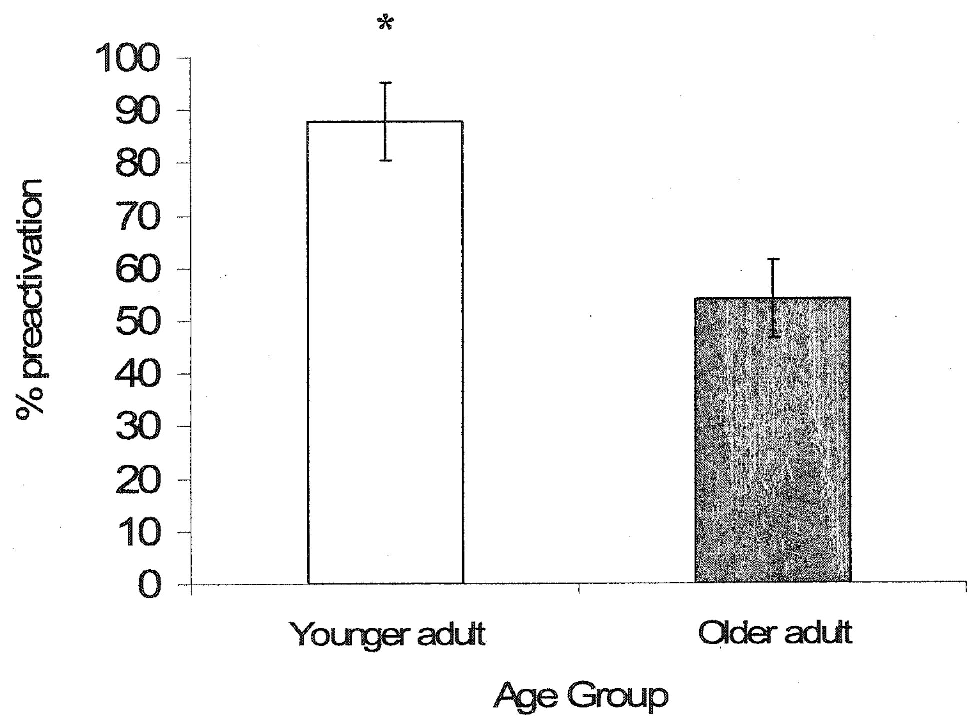

Figure 3. Age differences in the percentage muscle preactivation of the lateral hamstrings (LH). Note: * $p < .001$.

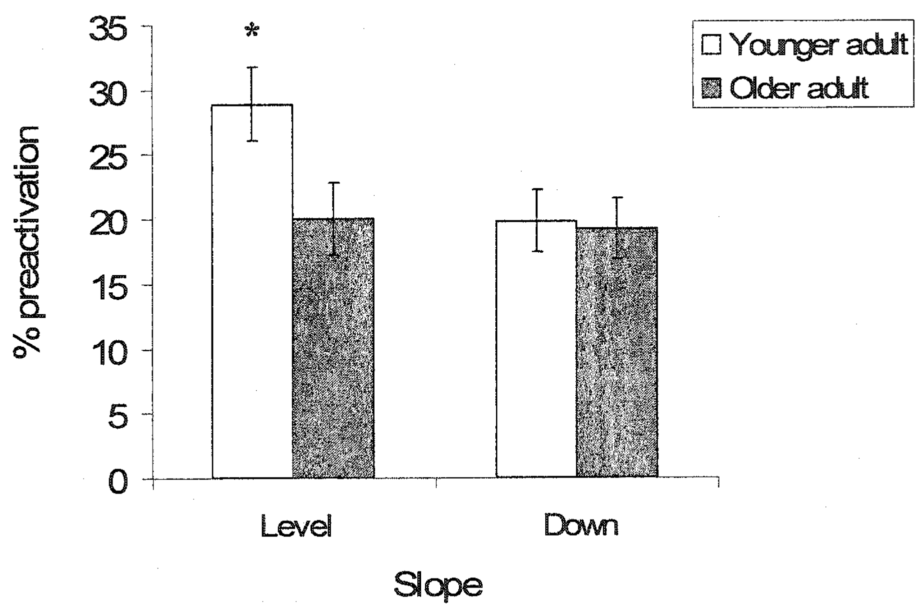

Figure 4. Age differences in the percentage muscle preactivation of the vastus medialis oblique as a function of slope. Note: $*p = .008$ for interaction of age group and slope.

Subjective Questions

Participants responded to three separate questions; one addressing where they placed their emphasis during the dual task condition, and two others that focused on the walking safety and stability during level and downhill walking conditions.

In general the emphasis question asked: "If you had 100% to split between the emphasis you placed on walking versus the emphasis you placed on listening…how would you divide it?" (See Appendix C for exact wording). Overall, both groups placed more emphasis on listening than walking, $F(1, 46) = 77.62$, $p < .0001$, $\eta = .633$, even during downhill walking. Both groups decreased the amount of emphasis that they placed on listening during the downhill walking condition and gave a bit more emphasis to walking. Despite this, a significant walking difficulty by task interaction, $F(1, 46) = 10.20$, $p = .003$, $\eta = .185$, revealed that the older adults placed more emphasis on listening on a downhill slope than the young.

Participants were also asked to rate how safe and how stable they felt on the treadmill in both level and downhill conditions. A rating closer to five reflects an endorsement of very unsafe and unstable. Overall, both groups felt less safe ($M = 1.77$, $SD = .75$) on a downhill versus a level slope ($M = 1.33$, $SD = .56$), $t(47) = 16.35$, $p < .001$ (two tailed). Similarly, both groups felt less stable on a downhill ($M = 2.04$, $SD = .85$) as compared to a level slope ($M = 1.50$, $SD = .80$), $t(47) = 16.65$, $p < .001$ (two tailed). However, both the stability and safety ratings are in the safe to very safe or stable to very stable range. A one-way ANOVA revealed a significant age difference in the ratings of stability with respect to walking difficulty, $F(1, 46) = 11.43$, $p < .001$,

$\eta = .199$, such that older adults felt more stable on a downhill slope (*M* = 1.67, *SD* = .565) than younger adults (*M* = 2.42, *SD* = .929). Another one-way ANOVA was conducted for subjective ratings of safety and there was also a significant age difference in safety ratings with respect to walking difficulty, $F(1, 46) = 7.05$, $p = .011$, $\eta = .133$, such that older adults felt more safe on a downhill slope (*M* = 1.50, *SD* = .59) than younger adults (*M* = 2.04, *SD* = .81).

Treadmill Use, Speed Setting and Balance Data

All participants' self-selected speed for treadmill walking was recorded to verify if there were any age differences in preferred treadmill speed. A t-test was conducted to compare younger and older adults' self-selected walking speed on the treadmill. Speed was set in miles per hour (mph). A significant age difference was found such that younger adults set a much higher speed (*M* = 2.31, *SD* = .52) than older adults (*M* = 1.72, *SD* = .34), $t(23) = 33.26$, $p < .001$ (two tailed). In addition, given that balance is important to motor control during walking all participants were measured on their balance control with the Sharpened Romberg balance test (SRT). A t-test comparing how long younger and older adults were able to maintain their balance during the SRT revealed a significant age difference, such that younger adults were able to maintain their balance much longer (*M* = 54.19, *SD* = 15.55) than older adults (*M* = 23.41, *SD* = 20.23), $t(23) = 17.07$, $p < .001$ (two tailed). Interestingly, an overview of the SRT and the speed setting for the older adults revealed a pattern for those older adults that had never been on a treadmill before. Seven out of the sample of 24 older adults had never been on a treadmill before. Of those seven the majority (six out of seven) had lower than average balance scores on the SRT, and also chose to set their pace on the treadmill lower than the average of their age group (below 1.72 mph). This pattern of results suggests that a less active sample of older adults may have more difficulty with the conditions of this experiment.

Discussion

The current study had the goal of replicating and extending the findings of Li et al. (2001). Under dual task conditions, it was expected that older adults would not perform as well as the younger adults in both the cognitive and motor tasks. Contrary to expectations, younger and older adults were faster at responding under dual task conditions compared to single task and their motor control (as measured by EMG) did not change significantly across conditions.

Separate analyses were carried out on the two dependent variables: reaction time to the words presented and percentage muscle preactivation for eight muscle groups of the leg. For the reaction time measurement of semantic judgments, the findings of interest were: (1) that younger and older adults were faster at responding during dual task as compared to single task; (2) across all conditions, younger adults' response times were quicker than those of the older adults. In general, under dual task conditions, the improvement of all participants and the lack of age differences may either reflect a combination of tasks that do not exceed cognitive capacity or that the performance of the cognitive and motor tasks simultaneously results in a facilitation of response for the cognitive task. The finding that the younger adults had a faster response time than the older adults is a common finding in dual task research (Hartley, 1992; Guttentag, 1989), which reflects a general slowing in older adults. The analyses of muscle preactivation revealed significant age differences in three muscle groups: the VMO, TA, and LH, such that younger adults had greater preactivation than older adults in these muscle groups. This suggests greater preparatory motor control in the younger sample.

Cognitive Findings

No age differences in dual task performance were found, however consistent with the literature on age differences in reaction time measures (Benton, 1977; Spirduso & Clifford, 1978) older adults were slower at responding to the words than younger adults. This is a common finding related to a general slowing with age (Birren et al., 1980; Buckles, 1993; Cerella et al., 1980) and does not interact with any of the conditions of this particular study. When interpreting the cognitive findings an important point to note is that the absence of an age group effect or any interactions with age indicates that older adults did not have particular trouble with the apparatus, or with perceiving the stimuli.

In this study, having participants perform two tasks concurrently, one that was sensorimotor and one that was cognitive, was expected to significantly alter performance, such that dual task performance would be inferior to the performance of each task alone. In developing the methodology, it was expected that the combination of the walking task and semantic task would exceed cognitive capacity and cause dual task costs (DTCs) in performance in one or both tasks, for both age groups. Further, following the theory of Lindenberger and Baltes (1994), which posits that normative aging creates a stronger link between sensorimotor and cognitive functions and the results of the Li et al. (2001) study where older adults prioritized walking over memorizing, the DTCs for the semantic task were expected to be larger in the older sample. While walking performance remained unchanged under dual task conditions, both age groups improved their cognitive performance. Participants were faster at responding to the words when walking, than when responding to words alone. Somehow, performing the two tasks simultaneously facilitated the performance of the cognitive task. There are two possible interpretations of this finding: (1) that walking may be more automatic and involve less controlled processing than predicted, (2) that both tasks were relatively easy to perform and concurrent performance did not exceed participants' cognitive capacity, which left participants with extra resources to allocate to the performance of the cognitive task.

The notions of limited capacity, automaticity, and controlled processing (Kahneman, 1973; Kramer & Larish, 1996; Posner & Boies, 1971) are relevant for the interpretations of overall improved performance under dual task conditions for both age groups. Posner and Boies (1971) make a case for certain tasks being performed automatically which liberates cognitive resources for the performance of other tasks. In this study, the lack of change in muscle activity (from single to dual task conditions) suggests that the walking task was performed automatically and that the majority of attention was devoted to responding quickly and accurately to the cognitive task. In fact, when asked where they placed their emphasis (on walking or listening) one older participants' perception of the tasks is reflected in the statement: "Walking is easy, automatic, the listening (to the words) takes more effort. I suppose it depends on where you are walking."

The automaticity and the perception of the walking task as "easy" may have been a result of the harness that all participants wore during testing. The harness may have provided a sense of security that influenced participants' perception of the walking task. Indeed, the participants' ratings of safety and stability indicate a general perception of very safe to safe and very stable to stable for level and downhill walking during dual task. Interestingly, many of the older adults expressed that they did not need to worry about the walking component of the study because they felt that the harness was supporting them.

At the end of testing, one participant said: "I felt very secure with the harness. I closed my eyes at one point to focus on the words."

The ease of walking due to the harness coupled with a fear of appearing cognitively fragile may have led the participants to emphasize their semantic judgment performance under dual task conditions. The cognitive task was actively being measured by the experimenter. When the participant responded to a word, the experimenter marked on a sheet the category endorsement (living or non-living). In addition, the participants were instructed to answer quickly and accurately to the cognitive task. In comparison, the walking task was passively measured by electrodes placed on the leg and walking speed was set at a self-selected pace prior to testing. Therefore, despite being instructed to equally emphasize both tasks, participants may have perceived the cognitive task as more important.

When asked subjectively where they placed their emphasis (on walking or listening), both older and younger adults placed significantly more emphasis on responding to the words. One would expect that older adults, who have greater health consequences if they fall, would place more emphasis on their walking performance especially on a downhill slope. This was not the case, as the older adults still placed more emphasis on listening than younger adults on a downhill slope. The importance the older adults placed on swiftly and correctly responding to the cognitive task, even on a downhill slope, suggests that they perceived the cognitive task as more important. Successfully mastering the cognitive task allows the older adults to demonstrate that their cognition is intact.

An alternate interpretation of the cognitive facilitation during dual task trials is that neither task overly taxed the participants' cognitive capacity. As stated earlier, walking performance was unchanged under dual task conditions. Further, when examining the accuracy on the cognitive task, it is clear that not only were participants able to respond quickly but they were also highly accurate in their responses. If both tasks can be considered relatively easy to perform then it is possible that under dual task conditions, the participants had additional attentional capacity left over that they could allocate to the cognitive task. In comparison to single task performance, where participants devoted their attention solely to responding to the words, the dual task condition may have forced participants to respond even faster to the words in order to manage both tasks well. Despite the ease of the walking task, walking still required some attentional capacity; consequently performing the cognitive task rapidly would simplify the management of the attentional resources shared between the two tasks. Along the same lines, the performance of the single task (cognitive) may not have been challenging enough for participants to make a real effort (Kahneman, 1973). The combination of the two tasks may have proven a bit more challenging to the participants and they rose to the challenge by responding faster than they did when responding to the words alone.

Although not statistically significant ($p = .18$), both groups slightly increased their reaction time when performing the cognitive task on a downhill slope as compared to a level slope. When asked the safety and stability questions, one older adult stated: "It's harder going downhill". When asked subjectively where they placed their emphasis (on walking or listening), both older and younger adults reduced the amount of emphasis they placed on listening during the downhill dual task. During the downhill walking manipulation, the reduction of emphasis on the cognitive task and the slight increase in reaction time likely reflects the downhill slope requiring a bit more attention devoted to walking. This suggests that a more difficult walking scenario might significantly influence their cognitive performance. In the Li (2001) study, for example, participants were asked to walk without a harness, on a walking track with random obstacles. Under dual task conditions, they had to walk avoiding the obstacles and memorize words with the method of loci. Both tasks threaten stability (Maylor & Henson, 2000; McKenzie & Brown, 2004) and likely led to the prioritization of the walking task for the older adults in this study. The tasks chosen in the Li and colleagues (2001) (memorizing and stepping over obstacles) can be considered more challenging than the tasks chosen in the current experiment. This idea of not challenging the participants enough is in line with "Kahneman's (1973) suggestion that subjects simply cannot harness as much effort in easy tasks as they can in difficult tasks" (McDowd & Craik, 1988, p.277).

Further, when comparing younger and older adults self-selected speed settings on the treadmill, there was a significant difference between the groups. Younger adults (M = 2.31 mph, SD = .34) set a much higher speed than older adults (M = 1.72 mph, SD = .52). Not only could the harness be considered a compensating factor for walking performance but it could also be the case that older adults self-selected a slower walking pace in preparation for the dual task condition. The slower walking pace would ease the demands of the walking task and allow the older adults to more easily manage both tasks concurrently. Research by R. L. Craik et al. (1992) suggests that "free speed walking velocities" may not be the best indicator of age-related changes in walking performance. In their study, comparing younger and older men, there were no significant age differences in the free speed but the slow and fast walking conditions produced significant age differences. They argue that older adults need to be carefully screened for walking tasks in order to provide a walking task that will "better challenge the declining neuromusculoskeletal system" (p. 244).

The notion that a set walking pace may have influenced the speed of response to words was also considered. In research by McIntosh et al. (1997), auditory stimuli presented at a specific pace speeded motor responses due to a sensorimotor synchronization. This begs the question: Could a set motor speed influence verbal responses? In the current study, all participants self-selected their walking pace in the practice session of testing and kept their chosen pace throughout testing. When performing the cognitive task alone all participants stood beside the treadmill. Under dual task conditions, their verbal response was coupled with their set walking pace on the treadmill. Given that the words were presented randomly (750-3000 ms intervals), it is unlikely that the walking pace would synchronize and facilitate participants' responses to the words.

EMG Findings

It was hypothesized that muscle preactivation would be smaller in older adults, as compared to younger adults, during dual task performance. Contrary to expectations, performing two tasks at once did not influence the muscle preactivition of either group. In line with the cognitive findings, it is likely that the combination of tasks did not exceed the available resources. As indicated earlier in the text, the harness and self-selected walking pace may have influenced the walking performance of participants, such that the harness and a slower walking pace may have made the walking task a very simple, automatic task. In the case of the younger adults who are familiar with and frequently use a treadmill, it could be the case that the walking task had a very low demand on their attentional capacity.

Although dual task performance did not affect muscle activity, there were interesting findings in three of the muscle groups [vastus medialis oblique (VMO), lateral hamstrings (LH), and tibialis anterior (TA)]. Each of these muscle groups showed age differences in muscle preactivition. In all cases older adults had less muscle preactivity than younger adults. There are mixed interpretations of high and low levels of muscle activity. The literature on muscle preactivity with older samples is lacking as most of the research has focused on kinematic measures, where slowing in gait, decreases in stride length and changes in stepping patterns are all common findings in an elderly sample. Certainly the changes in musculature that occur with normal aging (Dierick et al., 2002) reduce the output (in activity) that older adults make.

In terms of general muscle activity, Laughton et al. (2003) argue that "high levels of muscle activity are characteristic of age related declines in postural stability" (p.101). Lamontagne et al. (2000) found that their elderly stroke patients had *less* muscle activity on their paretic side and that *increased* activity on the non-paretic side compensated for this decline. Dietz et al. (1981), tested young adults on their preparatory activity in proximal arm muscles for self-initiated forward falls and the findings suggest that *higher* muscle preactivity reflects *greater* preparatory control. The current study's findings correspond most closely to Dietz et al. (1981). Since each individual is compared to his or her baseline, it is appropriate to infer that the *lower* preactivity (VMO, LH, and TA) in the older sample indicates *less* preparatory motor control at heelstrike than the younger sample. In an everyday walking situation, people are faced with changes in terrain. The findings from the older adults in this sample suggest that they would not be as prepared for uneven ground as their younger counterparts. In this study, having less preparatory activity in these three muscles did not affect the older adults' gait but perhaps, in future studies, implementing tasks that are more demanding would exacerbate this difference and cause dual task costs in performance.

The debate as to the amount of controlled processing necessary for walking is ongoing (Schmidt & Lee, 1999). It could be that walking is so automatic that the spinal cord is responsible for the repetitive movements necessary for locomotion and that higher cortical brain areas are not necessary. Alternately, it could be that simple walking without obstacles in an unchanging environment requires only spinal cord actions, whereas more complicated environments, with obstacles and changing environmental demands may require quick changes in movement which could necessitate higher levels of processing.

Sample Characteristics

When discussing the findings of this study, it is important to mention that the sample tested in this study was a highly functioning one. The younger adults, for the most part ($n = 20$), were students from the Exercise Science department. These individuals exercise regularly and are very familiar with treadmills. In the case of the older adults, all were healthy individuals of which the majority ($n = 17$) had been on a treadmill before and all but one regularly exercised. Research by Toole et al. (1993), argues older adults who have been physically active for at least three years are faster at responding to simple and complex cognitive/motor task than those who have not been involved in aerobic activity. In future studies, a more varied sample including physically active and sedentary individuals might yield interesting performance differences.

Future Directions

With the goal of replicating and extending the findings of Li et al. (2001) a future design should include a more challenging walking task. As stated by a participant in this study: "Walking is easy, automatic, the listening (to the words) takes more effort". It is in the designs such as Li et al. (2001) where walking has a more demanding component (i.e. obstacles) that dual task costs are found. In other dual task research by Weerdesteyn and colleagues (2003), obstacles were used with a sample of younger adults. Their goal was to see if kinematic parameters of walking were affected by dual task performance. Participants had to avoid an obstacle dropped on the treadmill in front of one of their legs and perform a cognitive task simultaneously. The cognitive task was considered a secondary task and reaction time was not measured. The kinematic data revealed that, when only a short response time was available, the young adults' suffered drops in obstacle avoidance performance and smaller crossing swing velocities during dual task trials. Chen et al. (1996) tested younger and older adults on obstacle avoidance using virtual obstacles and found that dividing attention significantly decreased both groups' obstacle avoidance, with older adults showing a greater decrement.

In follow ups to the current study, the speed of the treadmill could be manipulated to increase the difficulty of the walking task. Participants could perform a block at their self-selected pace, then another block at their self-selected pace plus some fixed speed increase (i.e. add half a mile per hour). Alternatively, the speed of the treadmill could be increased and decreased during a block. Having walking speed vary during a block will make the walking task more unpredictable in nature, much like the presentation time of the words was unpredictable. Participants will have to adapt to the speed changes during the block which would change the attentional demands of the walking task.

Measurement of the walking component could also be altered. For this study, all participants were given a practice day prior to testing. During the practice muscle activity was not measured. In addition, when testing, collection of EMG data started several seconds after participants' started walking and there was a delay before participants heard their first word. Ideally, subsequent studies of this nature would record EMG data during practice and compare practice day walking performance to test day walking performance. Further, measuring walking when participants initiate gait (the first 30 ms) before they have adapted an automatic cyclical walking pace might give a clearer picture of preparatory muscle activity. Careful timing of gait initiation and the cognitive task, such that both would commence simultaneously might also offer new insights into the current findings.

Following the interpretation that both tasks were easy to perform, the cognitive task could be switched to a task that is more cognitively demanding. A follow-up study might use a 1-back task. A 1-back task requires participants to listen to a series of numbers (i.e. 4 and 9) and repeat the number that is 1-back (i.e. 4). This task requires working memory (Dobbs & Rule, 1989) and might place a heavier load on cognitive capacity than the semantic task of deciding whether an item is living or not.

Future research that implements the proposed changes in design might help clarify the importance of attention during the gait cycle. Until then, the current study suggests that some cognitive and motor tasks can easily be performed concurrently by younger and older adults. In this case, they were performed so well that their performance when executing two tasks at once was better than their performance of one task alone.

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Appendix A

Phone Screening Questionnaire

Hi! My name is ____________ and I am calling from the Psychology department at Concordia University.

(Student...) We came into your class and you expressed an interest in participating in our summer research.
(Older adult...recently participated in another study...) You came in recently for a study on ____________ and mentioned that you would be interested in other studies.

Would you like to hear about a new study that we are currently conducting at the Loyola campus?

[If "NO", then ask them if it would be Ok if we call them back another time for another study]

[If Yes...] First let me tell you a little bit more about the study. We are interested in how people are able to do more than one activity at the same time. We are investigating how people walk and listen simultaneously. The study involves walking on a treadmill while verbally responding to words that you will hear through head-phones. While you're walking, we will measure energy from your muscles using sensors on your legs. We need you to come two days in a row, for one hour each day, would you be interested in volunteering?

[If yes...] Before we book an appointment, I have a few general health questions that are relevant to this study. **[If yes to any of the following then suggest that this study may not be good for them but perhaps they wouldn't mind if we called them for another study]**

(1) Have you had any injuries in the leg or hip in the last 3 years? (e.g. break, sprain, tendons, knee surgery, etc.)

(2) Is there any other injury or medical illness that would affect your movement? (e.g. Parkinson's disease, MS, arthritis, etc.)

(3) Have you had a stroke?

(4) Have you ever experienced dizziness or fainting?

(5) Do you have any difficulties hearing? Do you wear a hearing aid?

(6) How old are you?

Phone Screening Questionnaire (contd.)

Everything sounds good. When you come in for the study, you will need to bring a pair of shorts and running shoes. Sensors will be placed on one of your legs to measure the muscle energy-it is possible that we will need to shave the hair on small areas on your leg in order to apply the sensors. It is important to NOT put any lotion on your legs the day that you come in and it is preferable that you do not have more than one alcoholic drink the night before testing.

When would you be available to come in (2 days in a row)? [take note of appointment-give directions]
Thank-you very much-we'll see you on (repeat dates). We'll call you the day before to confirm. If you have any other questions or need to reach us, you can call **848-2424 (2247).**
****If people are comfortable with the security desk CC building-then I will meet them there.**

Appendix B

CONSENT FORM TO PARTICIPATE IN RESEARCH

This is to state that I, ______________________________ agree to participate in a program of research being conducted by Sarah Fraser of the Psychology department at Concordia University.

A. PURPOSE

I have been informed that the purpose of this research is to measure muscle activation patterns in the legs of healthy individuals during treadmill walking under walking and walking and listening conditions. This research is a step in determining the role of attention in controlled walking.

B. PROCEDURES

You will be tested in two sessions each lasting approximately 1 hour. All procedures will be explained to your satisfaction, and you will be asked to fill out a brief questionnaire regarding activity level, previous injury, and demographic data. Any previous leg injury within six months, or current lower extremity injury or pain syndrome will exclude you from participation. Your auditory acuity will be tested to ensure that the auditory task is presented well within your hearing range.

The electrical activity of 8 muscles around the knee will be measured via electromyography (EMG). A total of 8 pairs of adhesive sensors and 1 ground sensor will be attached to your skin after it has been cleaned, shaved (if required) and slightly abraded. You will also be fitted with a device that fits in your shoe and signals your foot contact with the ground. A harness will be used as a safety measure. With this equipment in place, you will be asked to do three activities: treadmill walking on level and downhill grades; a listening while stationary; and walking while performing listening. All procedures are completely non-invasive, and should be painless. There are no adverse reactions except a possible minor irritation from the tape and bandages holding the equipment in place and possible muscle fatigue.

You will have the opportunity to ask questions throughout the study, and are free to discontinue at any time throughout data collection.

C. CONDITIONS OF PARTICIPATION

- ☐ I understand that I am free to withdraw my consent and discontinue my participation at anytime without negative consequences.
- ☐ I understand that my participation in this study is CONFIDENTIAL (i.e., the researcher will know, but will not disclose my identity)
- ☐ I understand that the data from this study may be published.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOLUNTARILY AGREE TO PARTICIPATE IN THIS STUDY.

Name (please print): ____

Signature: ______________________________________

Witness Signature: __________________________ Date: ________________________

Appendix C

Verbal Instructions: Walking while judging study
Practice Phase: Day one

(When the participant enters offer them a seat)

- Hi! Welcome to the lab before we start I'd like to briefly explain to you what is involved in this study. Today I will be explaining the two parts of this study and allowing you to practice each. One part is simply listening through earphones to words that are presented to you. Once you have heard the word, you have to judge, as quickly as possible, if it is living or not. If the word is living you will say "yes", and if the word is non-living you will say "no".
  The other part is walking on the treadmill, on a level and downhill inclination, at your own pace. We will ask you to do these two parts separately and concurrently. The next day you come in, I will remind you of the parts of the study and then we will measure your performance on both of these parts. For the walking part, there will be sensors placed on your leg that will record the energy from your muscles. Now that I have explained the study, I would like to have you to please read this consent form and sign it if you agree to participate in this study. If anything is unclear please feel free to ask questions.

(Once the consent form is signed...) **Start with the audiogram.**

- First, we are going to start with an auditory test.
  (If asked: The purpose of this test is to verify that you have a normal range of hearing.)
  SEE AUDIOMETER INSTRUX: How to conduct a threshold audiogram (standardized instructions for the MAICO audiometer)

When the audiogram is complete do the <u>Trail Making test –Part A</u>.

- *Sample A. When ready to begin the test, place the Part A sheet in front of the subject, give the subject a pencil, and say:* "On this page (*point*) are some numbers. Begin at number 1 (*point to "1"*) and draw a line from one to two, (*point to "2"*), two to three (*point to "3"),* and three to four *(point to "4"),* and so on until you reach the end (*pointing to the circle marked END*). Draw the lines as fast as you can. Do not lift the pencil from the paper. Ready! Begin!

- *If the subject makes a mistake on Sample A, point it out and explain it. (e.g. "please keep the pencil on the paper and continue on to the next circle, or You started with the wrong circle. This is where you start (point to "1")).*

- *If the subject completes the sample item correctly, and in a manner which shows that he or she knows what to do say* "Good! Let's try the next one." Turn the page and give
  Test A.

- *Test A. Say:* "On this page are numbers from 1 to 25. Do this the same way. Begin at number one (*point*) and draw a line from one to two (*point to 2*), two to three (*point to 3*) and three to four (*point to 4*), and so on, in order until you reach the end (*point*). Remember work as fast as you can. Ready! Begin!

- *Start timing. If the subject makes an error, call it to his/her attention immediately, and have the subject proceed from the point where the mistake occurred. DO NOT STOP TIMING. Record the time in seconds. Then say:* "That's fine. Now we'll try another one."

<u>Trail making test-Part B.</u>

- *Sample B. When ready to begin the test, place the Part A sheet in front of the subject, give the subject a pencil, and say:* "On this page are some numbers and letters. Begin at number 1 (*point to "1"*) and draw a line from one to A, (*point to "A"*), A to two (*point to "2"),* and two to B *(point to "B"),* B to three (point to 3), three to C (point to C), and so on, in order until you reach the end (*pointing to the circle marked END*). Remember first you have a number (*point to "1"*) and then a letter (*point to "A"*), then a number (*point to "2"),* then a letter *(point to "B"),* and so on. Draw the lines as fast as you can. Ready! Begin!

- *If the subject makes a mistake on Sample A, point it out and explain it. (e.g. You skipped this circle (point to the one omitted). You should go from one (point) to A (point), A to two (point), two to B (point, B to three (point), and so on until you reach the circle marked END (point)).*

- *After the mistake has been explained, the examiner marks out the wrong part and says:* "Go on from here" *(point to the last circle completed correctly in the sequence).*

Trail making test Part B (continued..)

- *If the subject completes the sample item correctly, and in a manner which shows that he or she knows what to do say:* "Good! Let's try the next one." Turn the page over and proceed immediately to Part B and say: "On this page are some numbers and letters. Do this the same way. Begin at number 1 (*point to "1"*) and draw a line from one to A, (*point to "A"*), A to two (*point to "2"),* and two to B *(point to "B"),* B to three (point to 3), three to C (point to C), and so on, in order until you reach the end (*pointing to the circle marked END*). Remember first you have a number (*point to "1"*) and then a letter (*point to "A"*), and so on. Do not skip around, but go from one circle to the next in the proper order. Draw the lines as fast as you can. Ready! Begin!

- *Start timing. If the subject makes an error, immediately call it to his or her attention and have the subject proceed from the point at which the mistake occurred. DO NOT STOP TIMING. If the subject completes part B without error, remove the test sheet. Record the time in seconds.*

Scoring Trails

- *For both forms, scoring is expressed in terms of the time in seconds required for Part A and Part B of the test. Some examiners also calculate a Trails B/Trails A ratio.*

After Trails proceed with the Romberg test

- Now I would like you to stand over here

(lead the participant to the center of the floor space away from tables/counters)

INSTRUX FOR SHARPENED ROMBERG TEST (SRT):

- What I am going to do is get a measure of how long you can maintain your balance in a specific position, without moving your arms and your legs, or opening your eyes.

- To start, I will demonstrate the position that I would like you to stand in.

Here the experimenter models the Romberg tandem position for the participant.
(SRT-eyes CLOSED)

- Place your feet one in front of the other, toe to heel, like so.
  Place your hands at your sides.
  Make sure that you are facing straight ahead and then close your eyes.
  Try and maintain this position as long as you can.
  The moment that you move your arms or feet or open your eyes, I will stop the timer.
  Keep in mind that this position is unnatural, and will cause you to sway a little.
  The other researcher is nearby if you feel you need assistance-and we encourage you to use your arms and legs to steady yourself if you feel unbalanced.
  Do you understand? Any questions?
  OK. Before I start timing you-why not practice the position a couple of times- just so that you get the feel of it.

Let the participant practice twice.

- Now you have an idea what it is like, I am going to ask you to take this position three times and I will time you each time. When you move your arms or feet or open your eyes-I will say "stop" and I will stop timing you. When you hear stop-you can relax and stand in a comfortable standing position. When you are in position-say "ready" and I will start timing you.

Record the time (with stopwatch) for the Romberg eyes closed tests (3) on the testing package.

If the person is wearing badly worn shoes-make a note of this on the testing package

After the Romberg...the participant will be tested for ***leg dominance****.*

- What I am going to ask you to do next is to stand in the centre of the floor, with your feet together, and then take three steps towards me.

The researcher marks down which foot the participant took their first step with and then has the participant repeat this task twice more. Of the three trials evaluate the first step-

the foot that most often is chosen for the first step is considered the dominant choice (left/right). Mark the participant's dominant leg on the testing package.

After testing leg dominance proceed with the Shadow Task

SHADOW TASK

***Here** have the participant perform the **Shadow Task**: (if able to repeat the words (90% correct) then they pass the shadow task. Sitting in a chair facing the same direction as during testing, Say:*

- Now in this sitting position I am going to play some words through this headset, some words will come quickly and some slowly. After you hear "ready", you will hear words presented one at a time. As soon as you hear a word, repeat it out loud, and then listen for the next word. For each word that you hear, repeat the word out loud as quickly as possible.

Once the instructions are understood place the headphones on the participant (making sure hair and earrings are not in the way). Then verify voice threshold with the microphone-options-USB audio.

- Can you please say "yes" and "no" for me so that I can verify that the microphone is picking-up your voice Ok?
- *Once set say*: That's good.
-

In some cases if the participant speaks very softly you may have to ask them to speak a little louder. Tell the participant when you are about to start.

Scoring: *" √ " Is for a correct response and "X" is for incorrect. If you have time, for the incorrect responses mark down what the participant said. Then count the number of incorrect answers, subtract from 62. Divide the number you get by 62, then multiply by 100 = % correct.*

*(If you notice the participant has problems with **either** hearing test say:* I noticed some discrepancies with your hearing-Did you notice any problems? Since this is not an official hearing test, I would recommend that you see your doctor and get your hearing tested. In this study, the test may end up being harder for you and it wouldn't be fair. **Instead of continuing on to the treadmill would you mind filling-out a questionnaire? (SOC)** *(This is a suggestion: at least this way the participant feels that they have contributed to the research)*

After Shadow Task proceed with Digit Symbol.

- Now we have to go back to paper and pencil.

DIGIT SYMBOL

Place the digit symbol page in front of the participant point to the coding key at the top and say:

- Look at these boxes. Notice that each has a number in the upper part and a special mark in the lower part. Each number has its own mark.

Point to 1 and its mark in the key, then 2 and its mark. Then point to the seven squares located to the left of the heavy black line and say:

- Now look down here where the squares have numbers in the top part but the squares at the bottom are empty. In each of the empty squares put the mark that should be there. Like this.

Point to the first sample item, then point back to the key to show its corresponding mark, and say:

- Here is a 2; the 2 has this mark. So I put it in this empty square, like this.

Write in the symbol. Point to the second sample item and say:

- Here is a 1; the 1 has this mark (*point*). So I put it in the square (*write down*).
- Now you will fill in the squares up to this heavy line.

If the participant makes an error on any of the sample items, correct the error immediately and review the use of the key. Continue to provide help if needed. Do not proceed with the subtest until the participant clearly understands the task.

- Now you know how to do them. When I tell you to start, you do the rest of them.
- *point to the first square to the right of the heavy line and say:* Begin here and fill in as many squares as you can, one after the other without skipping any. Keep working until I tell you to stop. Work as quickly as you can without making any mistakes.
- *Sweep across the first row with your finger and say:* When you finish this line, go on with this one *(point to the first square in the second row). Bring them back to the start point and say:* Go ahead.
- *If they skip any point this out say:* Do them in order. Don't skip any.
- *After 120 seconds say:* Stop!

Scoring

Count the number of correctly drawn symbols (not including the sample items). Do not give credit for items completed out of sequence. A response is scored as correct if it is

clearly identifiable as the keyed symbol, even if it is drawn imperfectly or if it is a spontaneous correction of an incorrect symbol. [Max score 133]
Proceed with the MOCA: Follow standardized verbal instructions for this test.
Finally ask the participant the questions about physical activity on the front page of the test booklet. Then ask the participant to change into his/her shorts, t-shirt, and running shoes.
(Prepare the EMG transmitter box)

- First, I am going to attach this box around your waist. When we measure the activity in your muscles tomorrow, the wires from this box are attached to sensors that will be placed on your leg. For today's practice we won't be putting any sensors, only simulating that you have all the equipment on. Also I am going to clip this little microphone to your t-shirt; it will record your vocal responses.

(How to stop at any point)

- Before we put the harness on, I would like to show you a few different ways to stop the machine or straddle it if you want to stop.
  If you feel uncomfortable at all, just say "STOP!" in a loud voice- I will stand behind you so that I do not distract you, but I am always ready to stop the machine for you. You can also straddle the machine.

(Here the experimenter models straddling the treadmill-while it is running, pressing the emergency stop button, and how to signal the researcher if they want to stop).

- When you are walking on the treadmill, you should walk as if you were walking on the sidewalk, looking straight ahead with your arms at your sides, but if you should need to steady yourself please grab hold of the parallel bars on either side of the track. *(demonstrate)*

*(On the treadmill-have the participants' facing **away** from the monitor/control panel of the treadmill AND PUT THE TREADMILL IN REVERSE) Show the BORG scale (verbal instructions and the scale follow). All participants will practice on **LEVEL 1st**.*

- What we would like you to do is to set your walking pace to somewhat light **SHOW BORG SCALE** (a normal walking pace for you). Please start walking, looking straight ahead, and I will increase and decrease the pace of the treadmill until it is at a pace that you feel comfortable with.

At this point the experimenter manipulates the speed of the treadmill…asking:

- How is that pace? Would you prefer a little faster? A little slower?

Increase and decrease in increments, keeping track of the comfort/exertion level of the participant, until the participant feels that they are walking at a comfortable pace. Once you have found that speed record it on the participant information sheet.

- Ask the participant if they feel that they are walking at a pace that would reflect **'12'** on the BORG scale
- Now I am going to let you walk at this pace for a couple of minutes.
  You still find that a comfortable pace? Good.
  Now I would like you to straddle the treadmill.

(Experimenter stops the treadmill)The participant can stand at ease in the middle of the treadmill.

Verbal instructions for the BORG scale:

During the exercise test we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try and concentrate on your total, inner feeling of exertion. Try not to underestimate or overestimate your feelings of exertion; be as accurate as you can.
We would like you to aim for an exertion rate that is a 12 on this scale. Which means your exertion should be somewhere between fairly light and somewhat hard.

BORG SCALE

6	
7	VERY, VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY, VERY HARD
20	

- **WAIT FOR THE BEEP-BEFORE STARTING A TRIAL WITH LISTENING**

Introducing the word judgments:

- At this point, I am going to introduce the listening part. What I need you to keep in mind is the question: "Is _____ living?" Through the earphones you will hear two syllable nouns that you will have to judge as living or not. If the noun is living say "yes" if it is non-living say "no".

- You should try and answer as quickly as possible. Sometimes the words will come faster sometimes slower.

- For example, you may hear the word "doorknob" you would say "no" then you may hear the word "doctor" you would say "yes". Do you understand? Ok now I am going to give you the practice words, you will hear the word "ready" and then the words will start, answer as quickly as possible. Do not worry about making a mistake, if you do just continue on to the next word and do not correct your response. Do not correct yourself because you may not hear the next word. When you hear a word that is unfamiliar you can skip it. Any questions? Please put on the headphones-adjust them if you need to-be prepared to start when you hear the "ready" signal.

The experimenter runs the 1st practice list.

(Dual task)

- Ok, now that you understand both parts of the study, we are going to put them together. You are going to walk and judge the words as living or non-living, at the same time. Both tasks are equally important. First, I will start the treadmill and bring it to the same pace as you had before and then you will hear "ready" in the earphones and you will have to walk and judge the words at the same time. Please look straight ahead and answer as quickly as possible "yes" or "no" to the words. Don't worry about making a mistake, if you do just continue on to the next word and do not correct your response.

The experimenter runs the 2nd practice list.

Have the participant straddle the treadmill again and stop it.

- Now you are going to practice the same two parts, this time on a **downhill** inclination.

Increase the slope of the treadmill to the max.
Start the treadmill and have the participant walk on it when it is at a slow pace.

- Please start walking on the treadmill and I will slowly increase the speed to the same walking pace that you set earlier. How is that?
  Now I am going to let you walk at this pace for a couple of minutes. *(2 mins)*
  You still find that a comfortable pace? Good.
  Now I would like you to straddle the treadmill. *(Experimenter stops the treadmill)*

(Single task: Downhill)

- At this point, I there is another listening part. The same idea as before, but with different words. What I need you to keep in mind is the question: "Is _____ living?" Through the earphones you will hear two syllable nouns that you will have to judge as living or not. If the noun is living say "yes" if it is non-living say "no".
  You should try and answer as quickly as possible. Sometimes the words will come faster sometimes slower.
  For example, you may hear the word "doorknob" you would say "no" then you may hear the word "doctor" you would say "yes". Do you understand? Ok now I am going to give you the practice words, you will hear the word "ready" and then the words will start, answer as quickly as possible. Do not worry about making a mistake, if you do just continue on to the next word and do not correct your response. Do not correct yourself because you may not hear the next word. When you hear a word that is unfamiliar you can skip it. Any questions? Please put on the headphones-adjust them if you need to-be prepared to start when you hear the "ready" signal.

The experimenter runs the 3rd practice list.
(Dual task)

- Again I'll get you to start walking downhill and then you are going to walk and judge the words as living or non-living, at the same time. Both tasks are equally important. First, I will start the treadmill and bring it to the same pace as you had before and then you will hear "ready" in the earphones and you will have to walk and judge the words at the same time. Please look straight ahead and answer as quickly as possible "yes" or "no" to the words. Don't worry about making a mistake, if you do just continue on to the next word and do not correct your response.

The experimenter runs the 4th practice list.
When the list is complete have the participant straddle the treadmill, stop the treadmill, and bring it down to a level inclination. Remove headset.

- That was the practice session. Did you find it OK? Tomorrow we will be the same as today, only this time the parts of the study will not be in the same order and we will be placing the sensors on your leg to record your muscle activity. *Remove all the gear.* Before you go, I have a short History questionnaire to give you that can be completed at home and brought in tomorrow. All your answers are confidential.
  Thank-you for coming today, we'll see you here tomorrow at ________(time) (*reconfirm appointment)*

Verbal Instructions: Walking while listening study (2003)
Test Phase: Day two

- Welcome back....Do you have the History Questionnaire-which you filled-out at home? Ok first, could you please change into your shorts, t-shirt, and running shoes. *(show them to the nearest bathroom)*

- Just to remind you of the parts of the study: One part is simply listening through earphones to words that are presented to you. Once you have heard the word, you have to judge, as quickly as possible, if it is living or not. If the word is living you will say "yes", and if the word is non-living you will say "no".
  The other part is walking on the treadmill, on a level and downhill inclination, at your own pace. We will ask you to do these two parts separately and concurrently. Today, we are going to be measuring the activity in the muscles of your dominant leg, so we will be placing sensors on the muscles of that leg.

Christina/Melissa places the sensors on the participants' leg and places the footswitch in their shoe.
The EMG transmitter box is attached at the waist.

- Now we move back to the treadmill.

Attach the harness.
Remind the participant of the safety measures and how to stop.

Participants getting Condition orders 1-6 always start level.

Participants getting condition orders 7-12 always start downhill.

Word lists A & C are always presented 1st and B & D are always presented 2nd.

The order of task that the participant receives depends on the condition-check condition order sheet to verify what order the participant will be completing and then arrange your verbal instructions accordingly (i.e. if dual task, walk alone, semantic alone-then place the verbal instruction sheets in this order

<u>Testing phase (Day 2):</u> <u>Single task-Semantic Judgment</u>

- At this point, I am going to introduce the listening component. What I need you to keep in mind is the question: "Is _____ living?" Through the earphones you will hear two syllable nouns that you will have to judge as living or not. If the noun is living say "yes" if it is non-living say "no".

- You should try and answer as quickly as possible. Sometimes the words will come faster and sometimes slower.

- For example, you may hear the word "doorknob" you would say "no" then you may hear the word "doctor" you would say "yes". Do you understand? Ok now I am going to give you the test words, you will hear the word "ready" and then the words will start, answer as quickly as possible. Do not worry about making a mistake, if you do just continue on to the next word and do not correct your response. Do not correct yourself because you may not hear the next word. When you hear a word that is unfamiliar you can skip it. Any questions? Please put on the headphones-adjust them if you need to-be prepared to start when you hear the "ready" signal.

Testing phase (Day 2): Single task-Walking

The experimenter will introduce which slope (level or downhill) depending on the condition order.

- When you are walking on the treadmill, you should walk as if you were walking on the sidewalk, looking straight ahead with your arms at your sides, but if you should need to steady yourself please grab hold of the parallel bars on either side of the track. I am going to start-out the pace slowly and then increase it to the pace that you set yesterday.
  Then I will let you walk at this pace for two and half minutes…when the time is up I will ask you to straddle the treadmill and I will stop the treadmill.

Testing phase (Day 2): Dual task-Walking and judging

The experimenter will introduce which slope (level or downhill) depending on the condition order.

- Ok, now that you understand both parts of the study, we are going to put them together. You are going to walk and judge the words as living or non-living, at the same time. Both tasks are equally important. First, I will start the treadmill and bring it to the same pace as you had before and then you will hear "ready" in the earphones and you will have to walk and judge the words at the same time. Please look straight ahead and answer as quickly as possible "yes" or "no" to the words. Don't worry about making a mistake, if you do just continue on to the next word and do not correct your response.

At the very end of level and down conditions ask the participants to subjectively judge both treadmill inclinations and what they felt they emphasized under dual task conditions

**See the testing package for the question sheets*
After all conditions ask the participant to answer the emphasis question (did you emphasize one part (walking or judging) over another?)

- When you had to walk and listen at the same time, on a _________(level, downhill) slope, did you find that you emphasized walking over listening, listening over walking, or placed equal emphasis on both tasks? Out of 100%, what percentage would you give to walking and what percentage would you give to listening

At this point the experimenter shows the participant the question sheet and fills in the participants' choice of percentages.

Also, give the participant the question sheets that ask them how they felt about the inclination of the treadmill (stable/unstable; safe/dangerous).

Debriefing

- The purpose of this study is to see how to people manage to do two things at once. Some evidence shows that dividing a persons' attention can have consequences on their performance.
  In this study, we expect that people will pay attention to walking in order to avoid falling, if people focus on the walking part than they are likely to have a drop in performance on the word judgments when doing the two tasks simultaneously.
  We will also be able to compare the activity level in the leg when walking alone and when walking and judging the words. We hope that this will allow us to pinpoint more clearly when during walking attention is most important.
  Do you have any questions?
  Thanks so much for coming in…

Older adults will be paid $10.00 for their time. Give them the $10.00 then have them sign the honorarium.

If questioned about the results:
For younger adults-the general results will be available sometime in the fall-if you would like to drop-by the Li lab PY-017…I will be glad to discuss them with you(or Sarah will be glad to..)

For older adults-the general results will be available in the fall-we will send you a summary (in the mail) of the study some time after that.

If someone asks: Is it better not to walk and talk at the same time?
Answer: There is no strong evidence that it is dangerous to walk and talk at the same time. It really comes down to your personal preference and perhaps the terrain that you are walking on. If you are walking on a hiking path with lots of rocks and tree roots to trip over, then it is advisable to pay attention to where you put your feet but in other circumstances you may not need to pay close attention to where you place your feet.

Appendix D

Word Lists

	LIST A	LIST A (cont'd)			LIST B	LIST B (cont'd)	
Trial	WORD	Trial	WORD	Trial	WORD	Trial	WORD
1	insect	38	beaver	1	cello	38	layer
2	shepherd	39	cheetah	2	check-up	39	attic
3	wrinkle	40	eagle	3	bedroom	40	postman
4	robber	41	binder	4	infant	41	value
5	collar	42	camel	5	cobra	42	uncle
6	chimney	43	waitress	6	counter	43	water
7	seamstress	44	victim	7	parrot	44	pleasure
8	sheriff	45	poodle	8	farmer	45	turtle
9	moisture	46	sunshine	9	sparrow	46	pilot
10	cobalt	47	hiker	10	python	47	raven
11	liquid	48	gangster	11	habit	48	monkey
12	wallet	49	cousin	12	ranger	49	triumph
13	mayor	50	picnic	13	father	50	absence
14	usher	51	content	14	temper	51	student
15	signpost	52	buyer	15	language	52	basket
16	minnow	53	parcel	16	welcome	53	quarrel
17	prison	54	product	17	maiden	54	witness
18	music	55	jewel	18	tractor	55	copy
19	author	56	women	19	lady	56	butter
20	tuna	57	table	20	player	57	windmill
21	baker	58	sorrow	21	double	58	haircut
22	pony	59	barber	22	widow	59	lawyer
23	squirrel	60	haddock	23	neighbour	60	cockroach
24	formal	61	cannon	24	husband	61	marvel
25	errand	62	kitten	25	hammer	62	butcher
26	dumbbell			26	sailor		
27	subway			27	sabre		
28	unit			28	carriage		
29	herring			29	movement		
30	donkey			30	partner		
31	anthem			31	linen		
32	mother			32	salmon		
33	lightbulb			33	anchor		
34	cinder			34	dentist		
35	blanket			35	tailor		
36	concert			36	journal		
37	handle			37	poet		

Word Lists (cont'd)

	LIST C	LIST C (cont'd)			LIST D	LIST D (cont'd)	
Trial	**WORD**	**Trial**	**WORD**	**Trial**	**WORD**	**Trial**	**WORD**
1	baker	38	parcel	1	ranger	38	turtle
2	author	39	hiker	2	double	39	copy
3	usher	40	picnic	3	player	40	witness
4	minnow	41	content	4	tractor	41	lawyer
5	errand	42	sorrow	5	habit	42	postman
6	squirrel	43	lightbulb	6	father	43	butter
7	anthem	44	cheetah	7	widow	44	uncle
8	herring	45	cinder	8	cello	45	dentist
9	subway	46	mother	9	sailor	46	poet
10	chimney	47	cousin	10	neighbour	47	windmill
11	seamstress	48	camel	11	welcome	48	pleasure
12	wrinkle	49	product	12	hammer	49	butcher
13	prison	50	eagle	13	maiden	50	pilot
14	signpost	51	waitress	14	sabre	51	absence
15	formal	52	concert	15	temper	52	journal
16	tuna	53	kitten	16	farmer	53	attic
17	dumbbell	54	haddock	17	parrot	54	quarrel
18	pony	55	binder	18	carriage	55	anchor
19	liquid	56	blanket	19	language	56	salmon
20	mayor	57	sunshine	20	sparrow	57	raven
21	sheriff	58	table	21	partner	58	tailor
22	wallet	59	gangster	22	husband	59	basket
23	unit	60	barber	23	cobra	60	water
24	donkey	61	handle	24	movement	61	monkey
25	cobalt	62	beaver	25	check-up	62	counter
26	moisture			26	bedroom		
27	shepherd			27	python		
28	insect			28	infant		
29	robber			29	lady		
30	collar			30	linen		
31	music			31	value		
32	jewel			32	triumph		
33	women			33	layer		
34	cannon			34	marvel		
35	buyer			35	cockroach		
36	poodle			36	haircut		
37	victim			37	student		

Appendix E: Subjective Questionnaires

Verbal Instructions for the Emphasis Questionnaire

"When you had to walk and listen at the same time, on a _________(level, downhill) slope, did you find that you emphasized walking over listening, listening over walking, or placed equal emphasis on both tasks? Out of 100%, what percentage would you give to walking and what percentage would you give to listening?"

At this point the experimenter shows the participant a table (on the following page) and fills in the participants' choice of percentages.

ON A **LEVEL** SLOPE:

Emphasis placed on Walking	Emphasis placed on Listening
%	%

ON A **DOWNHILL** SLOPE:

Emphasis placed on Walking	Emphasis placed on Listening
%	%

1) When you were walking on a **level** slope, how stable or unstable did you find it was? Circle the number that best represents your answer.

VERY STABLE	STABLE	NEITHER	UNSTABLE	VERY UNSTABLE
1	2	3	4	5

2) When you were walking on a **downhill** slope, how stable or unstable did you find it was? Circle the number that best represents your answer.

VERY STABLE	STABLE	NEITHER	UNSTABLE	VERY UNSTABLE
1	2	3	4	5

3) When you were walking on a **level** slope, how safe or unsafe did you find it was? Circle the number that best represents your answer.

VERY SAFE	SAFE	NEITHER	UNSAFE	VERY UNSAFE
1	2	3	4	5

4) When you were walking on a **downhill** slope, how safe or unsafe did you find it was? Circle the number that best represents your answer.

VERY SAFE	SAFE	NEITHER	UNSAFE	VERY UNSAFE
1	2	3	4	5

Appendix F

Counterbalancing Procedure

Participants getting these orders always get LEVEL first and DOWN second:

Block	Order #1	Order #2	Order #3	Order #4	Order #5	Order #6
1	single cognitive A→C	single walk	dual A→C	dual A→C	single walk	single cognitive A→C
2	single walk	dual A→C	single cognitive B→D	single walk	single cognitive A→C	dual B→D
3	dual B→D	single cognitive B→D	single walk	single cognitive B→D	dual B→D	single walk

Participants getting these orders always get DOWN first and LEVEL second:

Block	Order #7	Order #8	Order #9	Order #10	Order #11	Order #12
1	single cognitive A→C	single walk	dual A→C	dual A→C	single walk	single cognitive A→C
2	single walk	dual A→C	single cognitive B→D	single walk	single cognitive A→B	dual B→D
3	dual B→D	single cognitive B→D	single walk	single cognitive B→D	dual B→D	single walk

A = word list 1
B = word list 2
C = word list 1, in re-randomized order
D = word list 2, in re-randomized order

***Participants will be tested on one level of walking difficulty, the three levels of task (single, single, dual) and versions A & B of the word list.

The same participant will be tested on the other level of walking difficulty, the three levels of task and versions C & D of the word list.

***Two participants per order, per age group. Total $N = 48$.

Appendix G

Table 1

Analysis of Variance for Mean Reaction Times

Source	*df*	*F*	η	*p*
		Between subjects		
Age	1	5.29*	.103	.03
Error	46	(33101.32)		
		Within subjects		
Slope	1	1.43	.030	.24
Slope x Age	1	.09	.002	.76
Error (Slope)	46	(2335.76)		
Task	1	29.13**	.388	.001
Task x Age	1	.48	.010	.49
Error (Task)	46	(8244.78)		
Slope x Task	1	.28	.006	.60
Slope x Task x Age	1	2.43	.050	.13
Error (Slope x Task)	46	(1637.43)		

Note. Values in parentheses represent mean square errors.
$^{*}p < .05$. $^{**}p < .01$

Appendix H

Table 2

Analysis of Variance for Proportional Dual Task Costs (pDTCs)

Source	*df*	*F*	η	*p*
		Between subjects		
Age	1	.009	.000	.92
Error	46	(.019)		

Note. Values in parentheses represent mean square errors.