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Effect of Dual Tasking On Walking Over Even and Uneven Surfaces in Functionally Independent Community Older Adults

Olajide L. Kolawole
olajide.kolawole@shu.edu

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EFFECT OF DUAL TASKING ON WALKING OVER EVEN AND UNEVEN SURFACES IN FUNCTIONALLY INDEPENDENT COMMUNITY OLDER ADULTS

BY

OLAJIDE L KOLAWOLE

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OLAJIDE L KOLAWOLE

Dissertation Committee:

Dr. Genevieve Pinto Zipp, Chair

Dr. Raju K. Parasher

Dr. Terrence Cahill

Approved by the Dissertation Committee:

Genevieve Zipp Date: 12/9/14

Raju K Parasher Date: 12/9/14

Terrence F Cahill Date: 12/9/14

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One of my favorite scriptures in the bible that kept me going is Proverbs 3:5-6 (Trust in the LORD with all your heart and lean not on your own understanding; in all your ways submit to him, and he will make your paths straight).

DEDICATION

My deepest and warmest thanks go to my wife, Abimbola A Kolawole, whose love and support has kept me going. I express my gratitude and affection to my sons Kolade, Olaniyi and Oladipo to whom I dedicate this dissertation.

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Abstract

While several studies have reported a decrement in performance by older adults while walking and concurrently performing a dual task on even surfaces, to date the effects of dual tasking while walking on uneven surfaces commonly found in the community has received less attention. Thus, we sought to test the hypothesis that an incremental decrement in gait parameters will be observed, when walking on an uneven versus an even surface and furthermore, that this decrement would be dependent upon the concurrent performance of a secondary cognitive and/or motor task in functionally independent-living-community older adults.

Dynamic Gait Index assessed the subject's ability to modify gait in response to changing task demands and Mini Mental State Examination was used to screen cognitive function of the participants. Twenty-eight participants walked at a comfortable speed over the GAITRite^{TM} walkway placed over an even and uneven surface. Twenty-four strips of wood measuring 0.10 square meters and 0.05 meter high attached randomly under the smooth surface of an artificial grass mat measuring 6 meter long and 1.2 meter in width simulated a natural uneven surface. Each participant randomly performed a total of three (3) trials each under the following four task conditions as they walked over an even or uneven surface: 1) no secondary task (single task), 2) concurrent cognitive task, 3) concurrent motor task, 4) concurrent cognitive-motor task. The presentation of the task conditions were counterbalanced across subjects. Gait speed, cadence, stride time, and double support time were analyzed using a 2 x 4 repeated measures ANOVA. Also, to quantify subjects' ability for executing two tasks concurrently, we calculated the dual task costs. In addition, the cognitive, motor and

cognitive/motor tasks performances on even and uneven surfaces were assessed using Mann-Whitney U.

The results of these analyses revealed significant main effects for concurrent dual-tasking as well as surface for speed [$F(1.86,50)= 21.93$; $p \leq 0.05$; $F(1,27)= 24.3$, $p \leq 0.05$] , cadence [$F(1.85,50)=33.824$; $p \leq 0.05$. $F(1,27)= 22.2$, $p \leq 0.05$], stride time [$F(1.94,52.34)= 33.41$, $p \leq 0.05$; $F(1,27)= 23.49$, $p \leq 0.05$], and double support time [$F(1.99,53.62)= 7.4$; $p \leq 0.05$; $F(1,27)= 7.4$, $p = .011$]. It was observed that the elderly slow down, take a lesser number of steps per minute, increase their stride time and spend more time in double support when walking on uneven surfaces and when performing a concurrent dual-task. However, interaction effects failed to achieve significance. This study provides some preliminary evidence that independent, community living older adults use a default strategy that rely on making adjustments in gait that result in greater motor control. In other words the older adults err on the side of safety and focus their anticipatory resources towards controlling balance. It is important for clinicians to be aware of these strategies and incorporate them in the management of the elderly patient.

EFFECT OF DUAL TASKING ON WALKING OVER EVEN AND UNEVEN SURFACES IN FUNCTIONALLY INDEPENDENT COMMUNITY OLDER ADULTS

General Background

Growth of the older population in the United States is inevitable. There are now more older Americans than at any other time in U.S. history. According to a new Census Bureau report, there were 40.3 million older adults, ages 65 and over, on April 1, 2010, up 5.3 percent from 35 million in 2000. This population is projected to increase to 72.1 million by 2030 and will constitute 19.3% of the population. As this population increases, the probability of age-related disorders and disabilities will also increase proportionally. This increase will have a great impact on individuals, families and healthcare providers (US Census Bureau, 2010).

It has been well established that aging is associated with physiologic changes that naturally predispose the elderly to progressive weakening and functional decline (Hofer, Berg, & Era, 2003). One typical area of decline in the elderly is in the ability to balance. The loss of balance that accompanies aging may be due to sensory and/or motor changes, including decreases in muscle strength and power (Frontera, Hughes, Fielding, Fiatarone, & Evans, 2000; Johnson, Mille, Martinez, Crombie, & Rogers, 2004; Vandervoort, 2002).

Sensory information and its processing is fundamental to detecting a state of postural stability and initiating appropriate strategies to correct for instability (Silsupadol, Siu, Shumway-Cook, & Woollacott, 2006). Therefore, age-associated changes in the somatosensory, optic, and vestibular systems would most likely contribute to postural instability and the potential loss of balance. Decreases in velocity and accuracy in the processing of vestibular, visual, and proprioceptive information have been noted with aging (Silsupadol et al., 2006). These decreases affect the ability of the elderly to detect and react to disturbances in balance, leading to an increased risk for falls. Overall, the sensory impairments observed in the elderly have been associated with functional decline and fall risk, particularly when carrying out or performing functional tasks such as walking (Silsupadol et al., 2006).

Further compromising the functional status of older individuals is the fact that aging increases the elderly's need to cognitively attend to the task of walking (Sparrow, Bradshaw, Lamoureux &Tirosh, 2002). It has also been suggested that with increasing age the act of walking demands higher levels of control processing, and gait becomes less automatic (Woollacott & Shumway-Cook, 2002). So, greater attentional demand is needed in the older adults to perform the otherwise unconscious/subconscious act of walking.

Sparrow et al (2002) have suggested that this increase in attentional demands during walking would reduce the resources available for the performance of a concurrent dual task. Thus, in the case of walking while performing a cognitive task like reading, the primary task of walking is competing with the secondary task. This competition for cognitive resources can result in a change in walking-task performance, a decrease in the performance of the second task, and/or an increased likelihood of falling in the elderly.

Many activities of daily living involve performing dual tasks concurrently (i.e., walking and talking). Dual task paradigm is a procedure that requires an individual to perform two tasks simultaneously, in order to compare performance with single-task conditions. When performance scores on one and/or both tasks are lower when they are done simultaneously compared to separately, these two tasks interfere with each other, and it is assumed that both tasks compete for the same class of information processing resources in the brain. According to the dual-task paradigm, priority is typically given to one task while the other task suffers (Gerin-Lajoie, Richards, & McFadyen; 2005; Woollacott & Shumway-Cook, 2002).

Literature is emerging to suggest that a performer's characteristics, such as age and cognitive and/or motor impairments, may influence dual-task performance. The literature suggests that healthy adults walk slower when they are required to walk while performing another task (Abernethy, Hanna, & Plooy, 2002; Woollacott & Shumway-Cook, 2002). In addition, Gerin-Lajoie et al. (2005) reported that healthy, active older adults have greater difficulty than young adults in dividing their attention between walking and performing a relatively simple mental task, such as listening to an auditory passage. Walking and talking at the same time has been found to result in a lower rate of speaking (Williams, Hinton, Bories, & Kovacs, 2006).

Hollman, Kovash, Kubik, and Linbo, (2007) found that that gait velocity decreased by eight percent (8%) in young adults and by 20% in the elderly during dual-task walking. Similarly, Priest, Salamon, and Hollman, (2008) reported a reduction of 18% and 30% respectively in stride velocity when younger and older adults performed a dual task. This suggests that older adults need increased sensorimotor control to perform dual tasks while walking in order to maintain balance, as additional attentional resources are required to complete the task successfully (Lajoie, Teasdale, Bard, & Fleury, 1996).

In summary, the evidence suggests that there is a significant decrease in the elderly compared to young adults in performing the primary task of walking and/or in performing secondary tasks when they concurrently perform the two tasks at the same time. Thus, recognizing that the inclusion of an additional attention-demanding secondary task can affect gait performance (Li, Lindenberger, Freund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000) makes it imperative that we further investigate the effects of dual-tasking on gaiting in the older adults, given the strong link between gait disturbances and fall prediction (Verghese, Holtzer, Lipton, & Wang, 2009).

In addition to the decreases seen in the elderly in gait on level-surface walking when concurrently performing a secondary task, changes in gait characteristics on different walking surfaces have also been reported. Menz, Lord and Fitzpatrick (2003) evaluated the gait pattern of young and elderly subjects while walking on an even and an uneven walking surface. The study found that elderly participants exhibited reduced velocity, shorter step length and increased step-timing variability compared to the young. These differences were more pronounced when walking on an uneven surface. Previous studies that have investigated the effects of age on the ability to walk on uneven terrain have also reported increases in step variability and decreases in trunk and head variability in older adults (Thies, Richardson, & Ashton-Miller, 2005; Menz, Lord, & Fitzpatrick, 2003). More recently, Marigold and Patla, (2008) examined the effects of aging on gait variability over uneven and solid ground, and found that the elderly walked more slowly and took shorter steps compared to the young adults.

Although limited information exists regarding uneven surface demands in the elderly population when dual tasking, it appears that as task demands become more challenging additional adjustments need to be made while walking, particularly in the elderly.

Several theories have been proposed in the literature as a means to explain the observed dual-task effects, including bottleneck, capacity sharing and crosstalk (Kanheman, 1973; Pashler, 1994). The capacity-sharing theory (Kanheman, 1973) suggests that humans have a limited amount of processing capacity available when performing tasks. Thus, the ability to perform two or more tasks successfully depends on how much demand the tasks make on a limited capacity processor. Tasks requiring less processing capacity for successful execution leave additional attention available for carrying out another task at the same time. Alternately, difficult tasks, which require more processing capacity, may limit the available attention needed to carry out simultaneous tasks effectively. Thus, performing even a simple secondary task while walking would necessitate additional processing capacity, leading to an overload on the capacity processor and, consequently, to a decrease in the performance of one or both tasks in the elderly.

The question of how to define task complexity is one that has been discussed in the literature (Peng & Zhizhong, 2012) and can be looked at from a variety of perspectives. The taxonomy of tasks proposed by Gentile (1987) provides a theoretical framework to understand the processing complexities of tasks performed individually as well as concurrently. There are two dimensions of Gentile’s taxonomy: environmental context (open/closed or inter-trial variability/no inter-trial variability) and function of actions (stability/transport or manipulation/no manipulation). Gentile (1987) purports that the environmental conditions and the goal of the action regulate how a person must execute his or her movements in order to successfully negotiate the demands of the task and achieve the goal. Thus, walking and manipulating an object would require consistent attention, resulting in more complex processing than standing or walking down an uncluttered pathway. When the primary task requires an excessive deal of attention, performance of the secondary task would be expected to suffer because the remaining attentional resource for the secondary task is minimized. On the other hand, when the primary task requires less attention, a better secondary task performance would be expected.

Statement of the Problem and Purpose

Several studies have established the effect of dual-task performance in healthy young and elderly adults while walking on level surfaces (Abernethy et al., 2002; Woollacott & Shumway-Cook, 2002) and uneven surfaces (Thies et al., 2005; Menz et al.,, 2003; Lindenberger, et al., 2000). However, much less is known about the gait adaptations made by the elderly while walking on either even or uneven surfaces and simultaneously performing a cognitive and/or a motor task. Understanding the ways in which these conditions affect the gait of older adults may be important to the study of adaptive control mechanisms used by the elderly and, in turn, may have implications for fall prevention. Thus, the purpose of this study was to examine the effects of performing a motor and/or cognitive dual-task on the spatio-temporal characteristics of gait in the elderly as they ambulate on even and uneven surfaces. More specifically, the research questions of the study were:

1) Are there changes in spatio-temporal gait characteristics in functionally independent, community living older adults as they walk on *even surfaces* compared to *uneven surfaces,* regardless of the tasks?
2) Are there changes in spatio-temporal gait characteristics in functionally independent community living older adults as they perform different tasks regardless of the surfaces?
3) If there are changes in spatio-temporal gait characteristics in functionally independent community living older adults as they walk on either an even or uneven surface, are these changes influenced by (or dependent upon) the type of secondary dual task (cognitive, motor, cognitive/motor) being performed, i.e., is there a surface-type x dual-task-type interaction?

The hypotheses of the current study were:

1) It is hypothesized that there will be changes in spatio-temporal gait characteristics in functionally independent community living older adults as they walk on *even surfaces* compare to *uneven surface*s regardless of the tasks.
2) It is hypothesized that there will be changes in spatio-temporal gait characteristics in functionally independent community living older adults as they perform different tasks regardless of the surfaces.
3) It is hypothesized that there would be a greater decrease in gait speed, and increased cadence, stride time and double support time in functionally independent community living older adults with the addition of a secondary task while walking on uneven surfaces compared to even-surface walking.

Chapter II

Review of the Literature

As the number of Americans over the age of 65 increases, so does the problems and challenges related to the aging process. As this population ages, some individuals experience physical limitations, such as flagging muscle strength, weakening vision, decreased coordination and decreased reflexes. Furthermore, aging is associated with physiological and neurological changes that naturally predispose the elderly to progressive weakening and functional decline (Hofer et al., 2003). This functional decline includes but is not limited to impaired gait characteristics and deficits in static and dynamic balance. Consequently, with a decrease in functional capacity, the proportion of elderly needing assistance with everyday activities increases with aging. It has been reported that nine (9) percent of those between ages 65 and 69 need personal assistance, while up to 50 percent of elderly Americans over the of 85 need assistance with everyday activities (US Census Bureau, 2010). Importantly, these physical changes and deficits in functional status may result in falls. According to the National Safety Council (2010), one in every three subjects above the age of 65 is in danger of falling. Furthermore, falls are a leading cause of comorbidities, such as hip fractures, which lead to an additional decline in functional status (National Safety Council 2010). Falls can cause the elderly to lose confidence in their abilities to function safely, which can then contribute to an increased fear of falls. Half of the people who have fallen admit to restricting activities subsequently, which leads to increased periods of immobility and subsequent morbidity. Furthermore, a decrease in activity levels, in turn, leads to physical complications similar to the aging process itself, e.g., muscle weakness, osteoporosis, and more fall risk (Tinetti, 2003).

At a sensorimotor level, age-related changes in the elderly include increased reaction times, decreased auditory acuity and decreases in the processing and response to vestibular, visual, and somatosensory stimuli (Prince, Corriveau, Hebert, & Winter, 1997). These deficits have been shown to impact significantly on gait characteristics. Thus, compared to young adults, the older adults walk with a higher cadence, shorter stride length, and increased double support phase (both limbs are on the ground simultaneously) while walking at self-selected velocities. These changes make gait-related disorders the second most prevalent disorder in the elderly population (Rubino, 1993). Furthermore, it has been reported that sensorimotor impairments potentially decrease stability while walking, contributing to the large number of falls in the elderly population (Rubino, 1993).

Elderly adults also demonstrate decreases in muscle strength and power (Frontera et al., 2000; Johnson et al., 2004; Vandervoort, 2002). Because of aging, the average adult aged 50 to 70 years loses 30% of muscle strength (Butler, 2000). The maximal cross-sectional area of the quadriceps is on average 25% lower in 70 year olds compared to 20 year olds (Young, Stokes, & Crowe, 1985). Furthermore, declines in muscle strength are attributed to decreases in the number and size of muscle fibers and the loss of entire motor units (Spirduso et al., 2005). Furthermore, Lexell, Taylor, and Sjostrom, (1988) have suggested that the denervation and re-innervation process resulted in a smaller cross-sectional area, which included a loss in the total number and size of the type II fibers. The older adults, age 60 and older, rapidly lose functioning motor units, while surviving units are typically enlarged and are slow in twitch nature, suggestive of a loss of fast-twitch fibers. These changes in musculature in the older adults lead to adaptations during walking. The focus of the following sections will be on age-related changes in gait as the older adults negotiate different surfaces and perform dual tasks.

Gait Changes with Aging

Gait or walking is a very complex task that requires several muscles and joints to work in a synchronized pattern of coordinated movements. A continuous task involves the alternate and cyclical movements of the legs as the body is linearly displaced through space. A gait cycle is initiated when one foot contacts the ground and ends when the same foot contacts the ground again.

During normal walking, there are two phases: a stance and a swing phase. In self-paced walking, 60 percent of the gait cycle for one limb is spent in stance and 40 percent in swing. Furthermore, approximately 20 percent of the total time during which both limbs are on the ground simultaneously is termed double support.

A person’s walking velocity is defined by the spatial parameter of step length (distance from one heel to the next at one point in time) and the temporal parameter cadence (step frequency). Walking velocity is increased by increases in both step length and cadence until physiological limits of step length is reached. As the velocity increases or decreases, the proportion of time spent in stance and swing phases changes (Shumway-Cook & Woollacott, 2001). The comfortable walking velocity for elderly adults, based on an average reported in the literature is 1.16 m/second. This is 13.5% slower than the average of 1.34 m/second in young adults (Hausdorff, Edelberg, Mitchell, Goldberger, & Wei, 1997).

The older adults slow down as a strategy to minimize loss of balance, and this slowing down has been shown to be directly related to decreased stride length (Scott, Menz, & Newcombe, 2007; Kavanagh, Barret, & Morris, 2004; DeVita & Hortobagyi, 2000) (Table 2 & 3). Scott et al. (2007) reported normalized walking velocity of young participants (mean age 20.9 ± 2.6 yr.) mean of 1.19 ± 0.14 m/s compared to 0.94 ± 0.18 m/s for elderly participants (mean age 80.2 ± 5.7 yr.). Similarly, elderly participants (mean age 67.4 ± 5 yr.) exhibited a slower (1.21 m/s) walking velocity when compared with young participants (mean age 28.2±5 yr.) (1.32m/s) walking as they walked on a six-meter walkway at a self-selected velocity (Ostrosky, VanSwearingen, Burdett, & Gee, 1994). This decrease in velocity has been associated with less likelihood of falling. Montero-Odasso et al. (2005) reported that older adults with low walking velocity of less than 0.7 m/s have 72% chance of falling compared with 34% of those with median velocity (0.7–1 m/s), and 20% with high walking velocity (>1.1 m/s).

Another strategy used by the elderly to compensate for decreased dynamic balance is to spend less time in swing phase and spend more time with both feet in contact with the ground, that is, increase time spent in double support. It has been observed that when walking velocity is controlled the elderly spend more time in double limb support than the young do. This occurs twice during the gait cycle, at the beginning and end of the stance phase. DeVita, & Hortobagyi (2000) reported that elderly participants spent on average 64.2% in double limb support as compared to 61.2% for young participants. This study also found that the elderly generally preferred to walk at a slower velocity, take shorter strides, have a higher cadence, and increase time spent in double support as compared to young adults (DeVita & Hortobagyi, 2000) (Table 5).

Another gait parameter that changes in the elderly is step length. Step length is the distance between corresponding successive points of heel contact of the opposite feet. Specifically, it is the distance from initial contact of one foot to the following initial contact of the same foot. It has been reported that step length is decreased in the elderly compared to young adults (DeVita & Hortobagyi., 2000; Ostrosky et al., 1994). Associated with this shortened stride, the elderly increase their cadence and reduce their forward velocity as they walk (Himann, Cunningham, Rechnitzer & Paterson, 1987).

Gait Changes in the Older Adults While Walking on Different Surfaces

Successful walking in a community requires gait adaptations to avoid obstacles, negotiate uneven terrain, and accommodate for changes in velocity and direction. It has been reported that significant changes occur when an elderly individual is exposed to different walking surfaces (Thies et al., 2005). The elderly have been shown to exhibit greater step width variability compared to the young participants when they walk on an uneven surface at a self-selected walking velocity along a ten-meter walkway. Thus, surface type (even vs. uneven) had significant effects on the average step width and step width variability in the elderly compared with the young. In addition, the elderly exhibited increased step time variability as they walked on an uneven surface compared to an even surface (Thies et al., 2005). Similarly, Menz et al (2003) found that elderly participants (mean age 79 ± 3.0 yr.) exhibited a significant reduction in step length and increase in step timing variability compared a group of young participants (mean age 29 ± 4.3 yrs.) when walking on uneven surfaces (Menz et al., 2003).

Dual Task and Gait in the Older Adults

Many activities of daily living involve performing dual tasks concurrently, such as talking on the phone and walking. Ebersbach, Dimitrijevic, and Poewe, (1995) reported that a significant change in gait pattern was induced by various concurrent secondary tasks in young adults aged 25-42 years. They reported that young participants increased their double support time as they walked while performing a concurrent cognitive and motor task. Furthermore, the researchers found that as the complexity of the task increased there was a concomitant increase in their double support time, which they suggested was a strategy used to control balance during the performance of an attention demanding tasks (Ebersbach et al., 1995).

Similarly, the effects of aging on ambulation while performing a dual task have also been studied using a foot-targeting task that required subjects to place one of their feet on designated targets on the floor while walking (Sparrow,et al., 2002). The authors of this study found that the elderly had significantly longer visual and auditory reaction times while walking and performing dual tasks.

Hollman et al. (2007) compared healthy elderly participants to the young, as they walked and concurrently performed a cognitive task. The researchers found that gait velocity decreased by 8% in young adults and by 20% in the elderly under the dual-task condition. Additionally, they found that in the elderly the impaired walking performance was associated with impaired cognitive performance as well.

Priest et al. (2008) examined if gait velocity and variability-in-stride velocity differed in community-dwelling elderly women (80 ± 9 years) compared to healthy young women (23 ± 2 years) during dual-task walking. Participants walked under the following two conditions: (1) a self-selected velocity and (2) a self-selected velocity while incrementally counting backwards. They found a reduction of 30% and 18% in walking velocity while concurrently performing the dual tasking in the older and young adults respectively. The study also reported an increase in walking velocity variability in both groups in the dual-task condition. The researchers suggested that this increase in variability is indicative of a relatively more unstable gait (Priest, et al., 2008). Similarly, in a study in which elderly participants had to pay attention to auditory messages while walking, the results suggested that older adults have a decreased ability to walk while performing mental tasks simultaneously (Gerin-Lajoie et al., 2005).

According to the dual-task paradigm, priority is typically given to one task, while the other task suffers (Gerin-Lajoie et al., 2005; Woollacott & Shumway-Cook, 2002). Evidence in the literature suggests that healthy adults walk slower when they are required to walk while performing another task (Abernethy et al., 2002; Woollacott & Shumway-Cook, 2002). In addition, Gerin-Lajoie et al. (2005) have reported that healthy active elderly individuals have greater difficulty than young adults do in dividing attention between walking and performing a relatively simple mental task, such as listening to an auditory passage. Also walking and talking at the same time result in a slower rate of speaking (Williams et al., 2006). Taken together, it appears that a combination of cognitive and motor tasks and negotiating even and uneven surfaces may have a deleterious effect on the primary task, the secondary task, or both.

In summary, walking and performing other tasks have become an important part of today’s life style. it is also true that individuals need to walk on different types of surfaces, such as concrete walkways, grass etc that create an uneven walking surface to function independently in the community. Uneven walking surfaces afford the performer different conditions from that of a even walking surface and, thus, may require additional attention afforded to the surface characteristics.

Dual task performance has been identified as a predictor of fall risk (Beauchet, Annweiler, Allali, Berrut, Herrmann, & Dubost, 2008). It is purported that performing a dual task increases the risk of falling among the frail elderly or those elderly who suffer from recurrent falls without any known organic reason as compared with non-fallers (Springer, Giladi, Peretz, Yogev, Simon, & Hausdorff, 2006). Also, Lundin-Olsson, Nyberg, and Gustafson, (1997) have suggested that many falls in balance-impaired elderly individuals do not typically occur during normal walking conditions but rather when they are walking and simultaneously performing a secondary task such as talking. Thus, it appears that the addition of a secondary task while walking results in a decrease in gait. Accordingly, understanding how the elderly adapt to walking on multi-surface terrains while performing a dual task may provide useful information that may help design fall-prevention programs for the elderly population.

Dual Task Theoretical Framework

Several theoretical frameworks have been applied to understand the attentional processes involved during the performance of dual tasks. The first such theory put forward was that of a strict processing bottleneck or the ‘bottleneck theory’ (Pashler, 1994). This refers to the idea that critical mental operations are carried out sequentially manner. Simple operations may require a single mechanism to be dedicated to them for a short period. However, when two or more tasks need the same mechanism at the same time, a bottleneck results, and one or both tasks will be delayed or otherwise impaired. This kind of framework is generally referred to as a bottleneck or single-channel model. Only one task stimulus can be process at a time. Thus, performing two tasks simultaneously creates difficulties because only one task can be concentrated on at a time.

In contrast to the bottleneck, the cross-talk theory purports that in the performance of dual tasks the interference produced might be critically dependent not on what sort of operation is to be carried out but on the content of the information actually being processed. Thus, when two tasks are more similar, performing them together will cause more interference than would be the case with very different tasks (Pashler, 1994). This suggests that the interference depends on the similarity or confusability of the task.

The third theory that attempts to explain the attentional demand associated with dual task performance is the capacity-sharing theory. This theory assumes that processing capacity is shared among tasks. When more than one task is performed at any given moment, mental processing capacity needs to be shared among the tasks, leading to a decrease in attentional resources and, therefore, potential task performance impairments (Kanheman, 1973). For instance, people who carry out several different activities at once will routinely exhibit difficulty in their performances as more and more activities are required to be completed concurrently. As a result, the performer requires more effort during dual tasking, which usually results in one or all of the activities being affected negatively. Exactly how attention is divided between the two tasks relies on several factors, including task complexity, familiarity, and importance. With the capacity-sharing model, dual task interference occurs only if the available resource capacity is exceeded, resulting in a decline in performance on one or both of the tasks. This theory provides information as to allocation of resources and if the task-required capacity is exceeded, the performance of the task is degraded. Based on Gentile's taxonomy (Gentile, 1987) which classifies tasks based upon environmental context and the function of action the capacity-sharing theory represents a suitable theoretical framework to address dual-task performance (Tombu & Jolicoeur, 2003).

Taxonomy of Tasks

The taxonomy of tasks proposed by Gentile (1987) provides a comprehensive framework with which to understand the processing complexities of tasks, performed individually as well as concurrently. Moreover, the framework helps understand the biomechanical and information-processing demands imposed by the task in the context of the performer as well as the environment. Gentile (1987) suggested that the constraints imposed by the task and environment affect motor performance. For example, walking patterns are likely to demonstrate different kinematics and kinetics to accommodate walking on uneven surfaces such as sand when compared to walking over a level surface such as concrete (Patla, 1997). In addition, size and/or compliance of the standing support surface alters the balance strategies used by healthy participants (Nashner 1989). Accordingly, walking along a carpeted, well-lit and empty corridor would require less processing than walking in a similar corridor filled with chairs, pillars, moving objects/people and different floor surfaces (Gentile, 2000). Like with complex environments, Gentile (2000) suggested that processing requirements are also dependent upon a second dimension, that of the functional demands of the task. For example, does the task necessitate body stability/transport or object manipulation?

It is purported that the information processing requirements will be greater if the task requires transport as well as manipulation of the object (Gentile 1987).

Gentile's taxonomy classifies skills based on degree of difficulty and environmental factors. She proposed that a task would be more difficult when the body is moving during the task performance. Tasks that require body transport and object manipulation are more complex than no body transport and no object manipulation because of the greater number of variables to deal with to complete the tasks.

In summary, the need to process information related to the task and environment may compete for limited central resources and, hence, performance may be influenced by the complexity of the environment and/or the functional requirements of the task. Gentile's taxonomy provides a basis for categorizing motor tasks in relation to the environmental context (Magill, 2007). Thus, simply walking in an uncluttered corridor would necessitate the utilization of less information processing than walking in a cluttered corridor while dialing a number on one's cell phone. It has been shown that elderly participants and patient groups have difficulty walking and carrying objects (Lundin-Olsson et al 1997). Outwardly paced activities, dual-task performance and changing environments provide a greater challenge in information processing (Lundin-Olsson et al 1997). This decrease in performance has been shown to affect the elderly greatly.

Another mean to assess the effects of dual tasking is by calculating dual task cost (Bock, 2009; Cossette, Ouellet, & McFadyen 2014). Dual task cost is use to determine the relative change between single and dual tasks. Dual task costs can be calculated using the mean value of each task using the following formula:

$$\text{Dual Task Costs (\%)} = \frac{\text{Single task} - \text{Dual task} \;\square\; 100}{\text{Single task}}$$

A high dual task cost value indicates a poorer performance under dual-task conditions compared with single-task conditions (Bock, 2009; Cossette, Ouellet, & McFadyen 2014).

Effects of Cognitive Dual Tasking on Gait

Based upon the taxonomy of tasks, one might infer that the difference in the effects of dual-task performance is influenced by the type of task performed, which can be defined by the degree of attention required: e.g. cognitive-based task, motor-based task, or cognitive-motor-based task.

The concurrent-performance of a cognitive-based task such as counting backward while walking has been shown to decrease performance on one or both tasks. Fifty independent-functioning older adults in an institution were able to walk and follow simple instructions were recruited by Lundin-Olsson et al (1997). The elderly participants were observed by a physical therapist as they were accompanied from their living accommodations to an assessment room. Unbeknownst to them, they were assessed on the number of times they stopped when involved in a conversation. The results showed that of the 58 elderly participants, 12 stopped walking with initiation of a conversation and 12 participants fell during a six-month follow-up.

Verghese, Holtzer, Lipton, and Wang (2007) reported decreases in velocity and cadence and increases in double support time in elderly participants when they walked while reciting alternate letters of the alphabet (skipping the letter in between) on a walkway. Furthermore, it was observed that when subjects were asked to pay more attention to reciting the letters than to their walking, the velocity and cadence decreased even more and double support time increased.

Bootsma-van der Wiel et al. (2003) evaluated the effect of performing a cognitive task while walking in the elderly population. Walking time over a 12-meter distance was measured, as well as the verbal fluency to recite names of animals or professions during a 30-second period. The authors found that walking time and the number of steps taken were significantly higher and the number of words recited significantly lower when performing dual tasks.

Shumway-Cook, Brauer, and Woollacott (2000) asked elderly community-dwelling participants to stand up, walk 3 m (10 ft.), turn, walk back, and sit down. Interestingly, they found that the time taken to complete the test strongly correlated with the level of functional mobility. Each participant was asked to complete three trials of this test while counting backward by threes from a randomly selected number between 20 and 100. The authors demonstrated that elderly individuals with a history of falls take more time to complete the test by 25% compared with 16% in the elderly without a history of falls. Similarly, Lindenerger, et al, (2000) found that the elderly had greater decrease in gait velocity than young participants when they needed to memorize a list of 16 item words while walking. They suggested that decreased walking velocity can be attributed to a compensatory strategy that the elderly use when their attention is divided.

It is generally assumed that self-paced walking is said to require minimal cognitive involvement and relies on automatic motor control processes that require minimal attentional resources (Mesure, Darmon, & Blin, 2001). However, with the introduction of additional cognitive demands during walking, attentional resources have to be shared between both the cognitive and the motor task as reflected by reductions in gait performance. In the elderly with limited attentional resource, reallocation may result in postural instability and an increase in risk for falls (Woollacott & Shumway-Cook, 2002).

Effects of Motor Dual Task on Gait

It has been suggested that the mechanisms that regulate motor tasks are similar to those that regulate cognitive tasks and might share similar attentional resources (Ebersbac et al., 1995). It has been observed that when a driver (regardless of age) has to perform a simulated driving task and use a cellular phone at the same time, which is motor-based as it requires object manipulation, there is an increase in the probability of error and the driver missing a target (Rakauskas, Gugerty, & Ward, 2004). Similarly, when community-dwelling elderly participants were required to stand up, walk 3 m (10ft), turn, walk back, and sit down while carrying a full cup of water, there was a decrease in their performance. Also interestingly, elderly participants classified as fallers increased their performance time by 22% as compared to 15% in non-fallers (Shumway-Cook et al., 2000).

Shkuratova, Morris, and Huxham (2004) examined the effects of aging on balance control while walking and concurrently performing a motor task. Twenty healthy elderly individuals (mean age 72 years) and 20 healthy young subjects (mean age 24 years) were asked to walk in a figure-eight path in a clockwise direction at a comfortable velocity while performing a coins transfer from the right to the left pocket, using the right and left hand alternatively. The results showed that elderly participants walked more slowly and demonstrated higher cadence rates and reduced stride lengths than did young adults while they concurrently performed the second task.

Effects of Concurrent Cognitive and Motor Tasks on Gait

Ebersbach et al. (1995) tested a group of young adult participants by measuring their gait while they performed four different secondary tasks. They found a significant decrease in stride time when the subjects were required to perform a concurrent fast finger-tapping movement. They also found that the memory of how many digits that a subject tapped within one trial decreased significantly during gait as compared to quiet standing.

Eleven community-dwelling elderly individuals (mean age 76 years) and 13 young participants (mean age 26 years) participated in a study that required them to walk along a figure-of-eight track at a self-selected velocity while concurrently performing an arithmetic task and/or carrying a tray holding a cup filled with water. It was found that the stride variance coefficient was 61% higher when the elderly performed both the cognitive and the motor tasks compared to the walking task only; it was only 57% higher when walking and performing the motor task (Laessoe, Hoeck, Simonsen & Voigt, 2008). Furthermore, their gait velocity compared to just walking was 21% slower when they concurrently performed both the cognitive and the motor tasks, 14% slower with just the cognitive task and 8% lower with solely the motor task.

Thus, it appeared that the added processing and attentional resource requirements of concurrently performing cognitive and motor tasks contributed to the inability of the elderly to control dynamic balance during gait in a graded manner. Taken together, current evidence suggests that dual-task performance negatively affects gait characteristics in the elderly. To date, it appears that no study has directly examined how spatio-temporal gait parameters are affected on uneven surfaces while performing a dual task. The available evidence suggests that there are significant reductions in the performance of the primary task as well as the secondary task in healthy elderly adults when they perform dual tasks and walk over a level surface. Thus, supporting the hypothesis that attention-demanding secondary tasks can affect gait performance (Li et al., 2001; Lindenberger et al., 2000). In order to function independently in the community, the elderly must have the ability to multitask. Therefore, an elderly person whois unable to perform two or more tasks efficiently may have limitations in his or her functional independence, and may fall more frequently and thus need to depend on others. Additionally, these findings are of particular importance given that disturbances in gait are a strong predictor of falls (Verghese et al., 2009).

In the literature, gait changes have been noted in the walking patterns of the elderly when walking over different uneven surfaces, although these findings did not include the observations of dual tasking. These studies examined gait deficits while the elderly simply walked on uneven surfaces, i.e., they did not perform a concurrent dual task. Menz et al (2003) evaluated the gait pattern of young and elderly subjects when walking on even and uneven walking surfaces. They found that elderly participants exhibited reduced velocity, shorter step length and increased step-timing variability when compared to the young. Importantly, these differences were particularly pronounced when walking on uneven surfaces. Similarly, previous studies that have investigated the effects of age on the ability to walk on uneven terrain have also reported increases in step variability and decreases in trunk and head variability in older adults (Thies et al., 2005; Menz et al., 2003). More recently, Marigold and Patla (2008) examined the effects of aging on gait on uneven and on solid ground and found that the elderly walked more slowly and took shorter steps compared to the young adults. Hsieh and Cho (2012) reported that gait performance on two floor surfaces (hard and soft) while performing dual tasks resulted in increased stance time and decreased swing time when walking on the soft floor. Thus, taken together it appears that as task demands associated with the walking surface become more challenging additional adjustments need to be made while walking, particularly in the older adults.

Recently, Ferraro, Pinto Zipp, Simpkins, & Clark, 2013 examined the spatio-temporal adaptations that occur when healthy elderly subjects walk up and down inclines. From this work, the authors suggested that the spatio-temporal changes that occur while walking on inclines could be loosely and indirectly characterized as being similar to those that occur while walking on uneven surfaces in that it similarly challenges the sensorimotor and attentional control processes. This work demonstrated that cadence, step length and velocity all decreased on inclines, while the Gait-Stability ratio (GSR) increased on inclines relative to subjects' level ground walking patterns. Pinto Zipp et al. (2013) expanded upon Ferraro et al. (2013)'s work and explored the effect of dual task performance in the elderly while they walked on inclines. Pinto Zipp et al. (2013) observed that, in order to successfully complete the requirements of both tasks concurrently, healthy older adults adapted a more stable pattern on inclines, particularly while walking and performing the cognitive task of color association. The researchers observed *a* decrease in gait velocity as well as notable errors in performing the secondary cognitive task. Inclines can be considered only one type of uneven walking surface that older adults must walk over to continue to remain independently functional in the community.

In this current study, the authors propose that uneven walking with or without an incline is extremely important, as older adults in the community must be able to walk on uneven surfaces such as grass, sand, and carpets daily, while they perform a number of secondary tasks, like talking to a friend or carrying a grocery bag etc. Thus, studying the effects of these surface types on walking patterns in the elderly while dual tasking is imperative as one cannot assume that what was found in the level or incline surfaces is transferable. Therefore, this study will not only be an extension of the prior work conducted but will meaningfully add to the evidence-based literature on dual tasks and walking on uneven surfaces in the elderly.

Additionally, while several studies have shown that there is an increase in attentional demands and consequent changes in gait parameters when performing a dual task while walking on even surfaces, few studies have looked at the effects of both cognitive and motor dual tasks while walking on different surfaces within the same study. Dual tasking depends on the efficient and accurate integration of cognitive and motor skills. Increasing the load in one or both of these areas for any given task may lead a decline in task performance due to the limited capacity of the control systems.

Thus, the purpose of this study is to examine the effects of concurrently performing a secondary cognitive and/or motor task on the gait characteristics (spatio-temporal) in functional, independent-community older adults as they simultaneously ambulate on even and uneven surfaces. It was proposed that information from this study will provide much needed evidence about elderly gait while multitasking on different surfaces and thus add to the body of knowledge in the area of geriatrics. Since research has not yet provided any normative data on elderly walking on uneven surfaces while performing a secondary cognitive or motor task, the information gained from this study will also provide baseline data for future research. Finally, participation in this study may benefit the participants by providing them greater insight into their abilities as they continue to dual task on uneven surfaces.

Chapter III

Method

Participants

Twenty-eight community-dwelling older adult men and women aged 65-75 years who met the set inclusion criteria volunteered to participate in the study. Recruited participants were informed verbally (by the primary investigator) regarding the experimental protocol and were notified verbally as to the testing location, date and time.

Inclusion Criteria

The study participants were between the ages of 65 to 75 years with systolic blood pressures of 90-130 mm Hg, diastolic 60-90 mm Hg, and pulse rates of 60-100 beats per minute were included in the study. Each participant self-reported as being able to walk independently in the community without an assistive device for at least 50 feet and as free from falls in the last six months.

Exclusion Criteria

The exclusion criteria was as follows: (1) Participants with neurological conditions (e.g., Stroke, Parkinson disease, Multiple Sclerosis, etc.); (2) participants that reported a fall in the last six months; (3) participants suffering from severe musculoskeletal pathologies or medical conditions that would affect participation; (4) participants that scored less than 19 on the DGI, and (5) participants that scored below 23 on the MMSE.

Design

The design used for this study was a repeated measures or a within subjects design. There were two *conditions*: (1) type of surface–even versus uneven–and (2) type of tasks—no task (control condition), cognitive, motor and cognitive/motor. The GAITRite was used to measure the *dependent* variables - gait speed, cadence, stride time and double support time.

Instrumentation

GAITRite. GAITRite^{TM} (GAITRite GOLD, CIR Systems, PA, USA) is an electronic walkway with embedded pressure sensors connected to a computer via an interface cable measuring 4 meters (13 feet). In walks over the mat, the sensors close under pressure, enabling collection of spatial and temporal parameters. The standard GAITRite electronic walkway contains seven sensor pads encapsulated in a roll up carpet to produce an active area 61cm wide by 427cm long. The walkway is connected via a serial port to an IBM computer using GAITRite GOLD software running on Windows 7 operating systems. Data was collected at a sampling rate of 80 Hz. The GAITRite software controls the functionality of the walkway, processes the raw data into footfall patterns, and computes the temporal and spatial parameters of gait. The resultant information was electronically stored in the software's data files.

The GAITRite^{TM} system is reliable and valid for measuring spatial and temporal gait parameters in both young adults and the elderly. Reliability coefficients ranging from 0.95 to 0.99 have been reported in the literature (Webster, Wittwer, & Feller, 2005; McDonough, Batavia, Chen, Kwon, & Ziai, 2001; Van Uden & Besser, 2004). The concurrent validity of the system is also high (ICC=0.99) when compared to another common gait analysis tool, the in-sole Clinical Stride Analyzer (Bilney, Morris, & Webster, 2003). It is a widely used standard measurement tool used by physical therapists to assess spatial temporal parameters of gait.

Uneven surface. An uneven walkway created to simulate a natural uneven surface by attaching twenty-four strips of wood, measuring 0.10 square meters and 0.05 meter high, under a smooth surface of artificial grass, measuring 6 meter long and 1.2 meter in width, in a random sequence (Appendix H). The GAITRite^{TM} system mat was placed on top of this walkway to allow for measurements of the spatio-temporal variables.

To the best of our knowledge, there is no study to date that has established reliability of GAITRite on an uneven surface (like the one used in this study), intra-rater reliability (across trials) of GAITRite when placed on an uneven surface was established. The data from the first six participants were used to establish reliability on uneven surfaces (reliability on uneven surfaces ranged from .91 to .99 for all the independent variables).

Tally counter clicker. A tally counter is a mechanical device used to maintain a linear count. A tally counter is usually made of metal and is circular in shape. Inside the counter are a number of rings that range from zero to nine in descending order going clockwise. Most counters have four such rings, allowing the user to count up to 9999.

The Mini-Mental State Examination: The Mini-Mental State Examination (MMSE–Appendix E) is a simple way to quantify cognitive function and screen for cognitive loss. It is a standard assessment tool used by entry-level physical therapists. It tests an individual's orientation, attention, calculation, recall, language and motor skills. A maximum possible score on the MMSE is 30/30. Good test–retest and inter-rater reliability with the correlation coefficients being 0.8 have been reported (Folstein, Folstein, & McHugh, 1975). A score of 23 or lower is indicative of cognitive impairment. The MMSE takes only 5-10 minutes to administer and is therefore practical to use repeatedly and routinely. For the purpose of this study, each participant had to have a score of 24 or above. Those falling below the score of 23 were not eligible.

Dynamic Gait Index: The Dynamic Gait Index (DGI–Appendix G) is a standardized clinical assessment tool that asses a person's ability to modify gait in response to changing task demands (Whitney et al., 2003). This is a standard assessment tool used by entry-level physical therapists. DGI is a performance-based test developed as part of a profile of tests and measurements that are effective in predicting the likelihood for falls in community-dwelling older adults. The DGI consists of different gait tasks that include walking at different velocity, walking with head movements, walking around and over objects, turning and stopping quickly, and ambulation on stairs and rates performance from zero (poor) to 3 (excellent) on these tasks. Scores on the Dynamic Gait Index range from zero to 24. Scores of 19 or less are related to an increased incidence of falls in the elderly. The DGI has been shown to have excellent Inter-rater reliability (ICC = 0.98) and Intra-tester (ICC = 0.76-0.98) (McConvey & Bennett, 2005). Those scoring below 19 were not eligible.

Procedure

Upon arrival to the testing site, participants read and signed the informed consent. The primary investigator (PI) answered all questions posed by the participants. The primary investigator assessed blood pressure and pulse rates. The primary investigator (PI) then administered the Mini-Mental State Examination (MMSE) followed by the Dynamic Gait index (DGI), both of which are valid and reliable assessment tools commonly used by physical therapists. The PI was well versed in the use of these tools. These tests provided objective measures of the participants' eligibility to participate in the study. The minimum cut-off for the MMSE and DGI are 23 and 19 respectively. Both tests were administered as described in the testing manuals as noted respectively in appendices E and G.

Each qualified participant was assigned an alphanumeric code to maintain anonymity. All participants were randomized into testing protocol bins to ensure counterbalancing. Counterbalance was ensured by having subjects randomly pick a folder (A or B) in which the order of testing was randomized. Participants who chose the folder 'A' started on an even surface while concurrently performing either no task, a cognitive task, a motor task, or a cognitive-motor task in random order. Participants were subsequently tested while they walked on an uneven surface as they randomly performed the same tasks outlined above. In contrast, subjects who chose folder 'B' started on an uneven surface followed by testing on an even surface.

Participants were randomly tested across all secondary task conditions during a single session that lasted approximately 90 minutes. Adequate rest intervals were provided as needed. Prior to testing, the participants received verbal instructions as to what they needed to do and engaged in no more than 3 practice trials, if needed, under each condition to familiarize themselves with the testing procedure.

White tape was attached to the floor 0.9 meters before and after the edge of the electronic walkway, which served as start and end points respectively to ensure consistency, as well as to establish constant gait speed while the data were recorded (Grabiner, et al., 2001). Standardized verbal instructions were provided to all participants via a script. Participants walked at a comfortable speed over the GaitRite walkway when they heard the command “start” and continued until they reached the “stop” white line. Each trial consisted of walking the length of the GAITRite^{TM} on the walkway. Participants performed three (3) trials under each of the following four task conditions in random order: 1) without performing any secondary task (single task), 2) while concurrently performing a cognitive task, 3) while performing a motor task and 4) while performing a cognitive/motor task.

To ensure safety, a standard gait belt, routinely used by physical therapists and occupational therapists, was placed around the subject’s waist, allowing the primary investigator to follow the participant along a walkway and assist, if necessary, without interfering with the participant’s walking pace. The lab assistant trained by the primary investigator in the use of the GaitRite computer assisted during data collection.

All quantitative gait evaluations were conducted using the GAITRite^{TM} system. When the GAITRite switched from an even to an uneven surface or vice versa, the participants were asked to wait and rest in a comfortable, secured chair in the waiting room.

Secondary task descriptions and attentional demands. According to Gentile's Taxonomy, every action we carry out is a result of the complex interactions between the performer, the task and the environment. Therefore, the no task and cognitive task were categorized, according to Gentile's Taxonomy, as body transport, no manipulation, and stationary no inter-trial variability on an even surface. The same tasks were categorized on the uneven surface as body transport, no manipulation, and stationary inter-trial variability. The cognitive and cognitive-motor tasks on even surfaces were categorized as body transport, manipulation, and stationary no inter-trail variability. On the uneven surface, cognitive and cognitive-motor tasks were categorized as body transport, manipulation, and stationary inter-trail variability.

Task 1 (no task).—Walking without performing any task— Based upon Gentile's Taxonomy, this task requires body transport with no limb manipulation in a stationary environment and no inter-trial variability while walking on an even surface. However, there is an inter-trial variability in addition to body transport, manipulation in a stationary environment on uneven surface.

Task 2 (cognitive). Testing on the cognitive task consisted of asking the participant to count backwards, from100 by fives (5), aloud. Correctness was ensured by asking the assistant to check for correctness and note the score achieved at the end of each walking pass. (Appendix D). Based upon Gentile's Taxonomy, this task required body transport with no limb manipulation in a stationary environment and no inter-trial variability while walking on an even surface. However, there is an inter-trial variability in addition to body transport and manipulation in a stationary environment on an uneven surface.

Task 3 (motor). For the motor task, participants were to press the button repeatedly on the tally counter clicker they held in their preferred hand while walking on the walkway. The dominant hand was used to press the numbers. Task accountability was determined by the PI through noting the total number recorded on the tally counter at the completion of the task and recording it on the appropriate data sheet (Appendix D). Based upon Gentile's Taxonomy, this task required body transport with limb manipulation in a stationary environment and no Inter-trial variability while walking on an even surface. On the uneven surface, cognitive and cognitive-motor tasks were categorized as body transport, manipulation, and stationary inter-trail variability.

Task 4 (cognitive-motor). For the concurrent cognitive motor tasks, participants were to perform task 1 and 2 simultaneously. Based upon Gentile's Taxonomy this task required body transport with limb manipulation in a stationary environment and no Inter-trial variability while walking on an even surface. On the other hand, there was an inter-trial variability with a stationary environment on an uneven surface.

Data analysis

The Statistical Package for the Social Science (SPSS) software (IBM, version 19) was used to conduct the statistical analysis on each dependent variable. To ensure Intratester reliability, Intra-class correlation (ICC) coefficients were used across trials for each of the dependent variables when participants walked on the GAITRite walkway that was placed on either the even or uneven surfaces. The data from the first six participants was used to establish intra-tester reliability. This reliability on uneven surfaces for all the independent variables Cronbach's Alpha ranged from .91 to .99.

A repeated measure's ANOVA is an appropriate statistical test for comparing differences when the same group of subject were measured under several conditions (Portney & Watkins, 2009). The level of statistical significance will be set to p</0.05.

To determine relative change between single and dual tasks, dual task costs were calculated using the mean value of each task. The following formula was used:

$$\text{Dual Task Costs (\%)} = \frac{\text{Single task} - \text{Dual task} \square 100}{\text{Single task}}$$

Chapter IV

Results

Subjects and Demographics

Twenty-eight older adults aged 65-74 years old met the inclusive criteria and consented to participate in this study. All of the participants included in this study were healthy, active older adults living in the community.

Participant demographics, Dynamic Gait Indices (DGI) and Mini Mental State Examination (MMSE) scores are presented in Table 1.The mean age of the sample was 68.39 (± 3.04) in this study. The mean age for males was 69(± 3.3) and for females was 67 (± 2.8). Sample Size: G* power software was used to calculate the appropriate sample size. With a small effect size (0.2) it was determined that a minimum of 36 participants were necessary to demonstrate significance with 0.05 (Portney &Watkins, 2009).

Contrary to the calculated sample size of 36, the actual number of participants was twenty-eight. Post-hoc power analysis resulted in a power of 1.0 for surface (partial eta squared = 0.47) and task (partial eta squared = 0.45) individually, and a power of 0.08 for surface and task interaction (partial eta squared =.13).

Table 1. Study Demographics and Subject Characteristics

Variable	**N (%)**	**Mean (STD)**
Gender		
Male	13 (46)	
Female	15 (54)	
Age		
Male	13	69 (±3.3)
Female	15	67 (±2.8)
Dynamic Gait Index (DGI)		21 (±1.2)
Male		21 (±1)
Female		21 (±1.4)
Mini Mental State Examination (MMSE)		27 (±1.3)
Male		27 (±1.3)
Female		27 (±1.1)

Hypothesis 1

It was hypothesized that there would be observable changes in spatio-temporal gait characteristics among functional, independent-community older adults as they walked on an even surface compared to an uneven surface, regardless of the tasks. To evaluate this hypothesis, a repeated measures analysis of variance was performed with the participants to compare the differences between their spatio-temporal gait characteristics on even and on uneven surfaces. The overall test for differences in means in the repeated-measures ANOVA was significant for velocity $F(1,27)= 24.3$, $p \leq 0.05$; cadence $F(1,27)= 22.2$, $p \leq 0.05$; stride time $F(1,27)= 23.49$, $p \leq 0.05$; and double-support time $F(1,27)= 7.4$, $p = 0.011$ on surfaces. There is a decrease in velocity on uneven surfaces compared to even surfaces, *M diff* = -6.89, 95% CI [-9.73, -4.01], $p < .001$ (Figure 1) and a decrease in the number of steps on uneven surfaces when compared to even surfaces, *M diff* = -4.15, 95% CI [-5.96, -2.34], $p< .001$ (Figure 2). Alternately, an increase was noted in stride time on uneven surfaces when compared to even surfaces, *M diff* = .05, 95% CI [.03, .07], $p < .001$ (Figure 3) and an increase in double-support time on uneven surfaces when compared to even surfaces, *M diff* = .01, 95% CI [.003, .025], $p < .001$ (Figure 4). This finding supported hypothesis one.

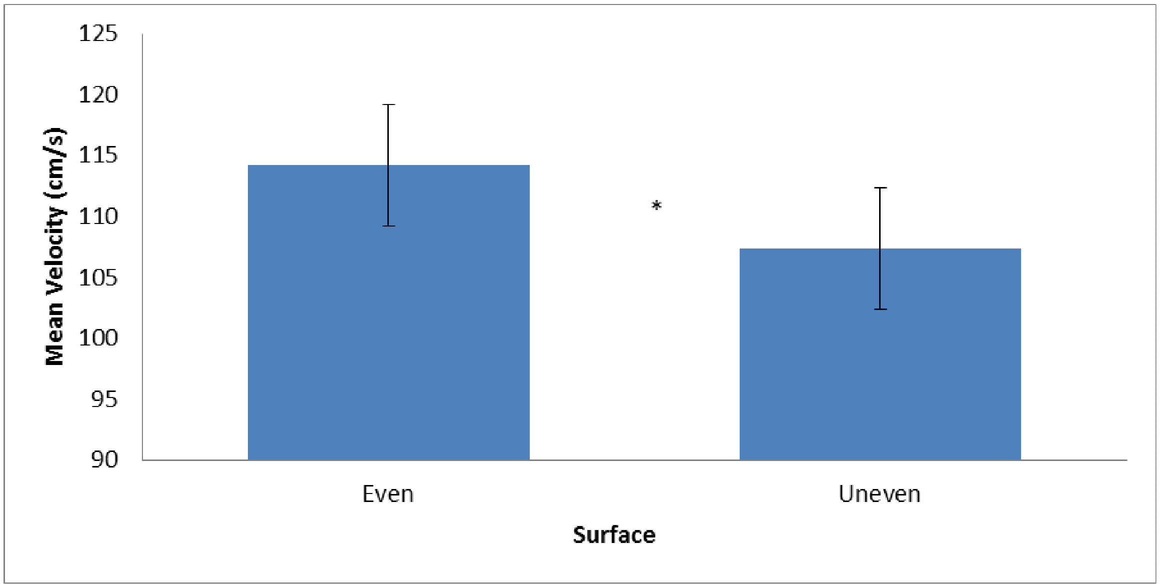


Figure 1. Mean Velocity in Cm/s While Walking on Even and Uneven Surfaces Regardless of the Tasks. There is a significant decrease in velocity on the uneven surface (*= *P*< .05).

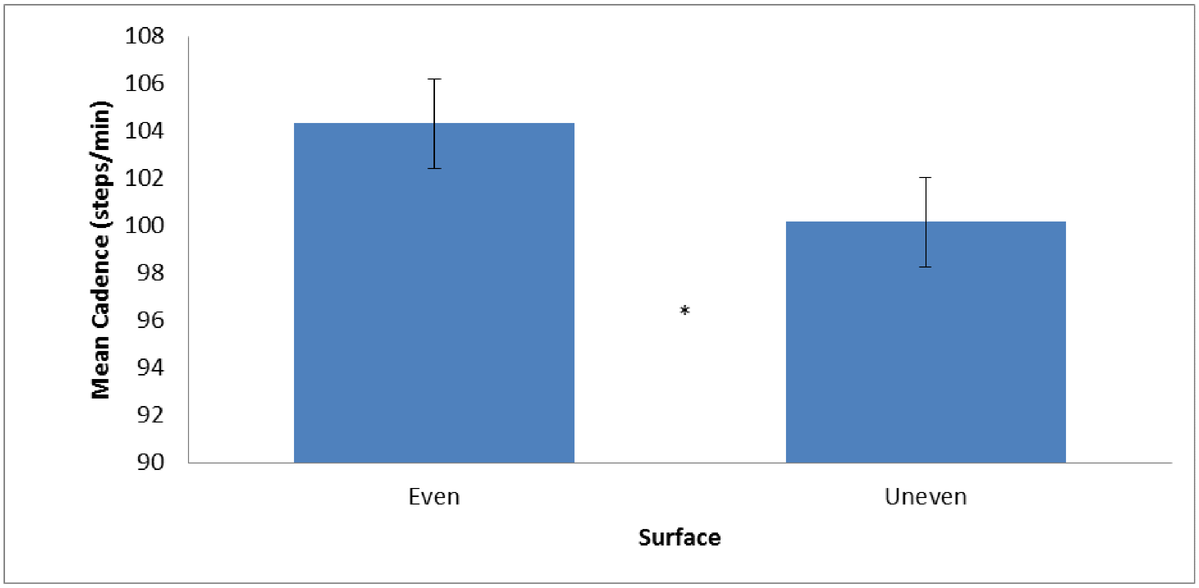


Figure 2. Mean Cadence in Steps/min. While Walking on Even and Uneven Surfaces Regardless of the Tasks. There is a significant decrease in cadence on the uneven surface (* = $P<.05$).

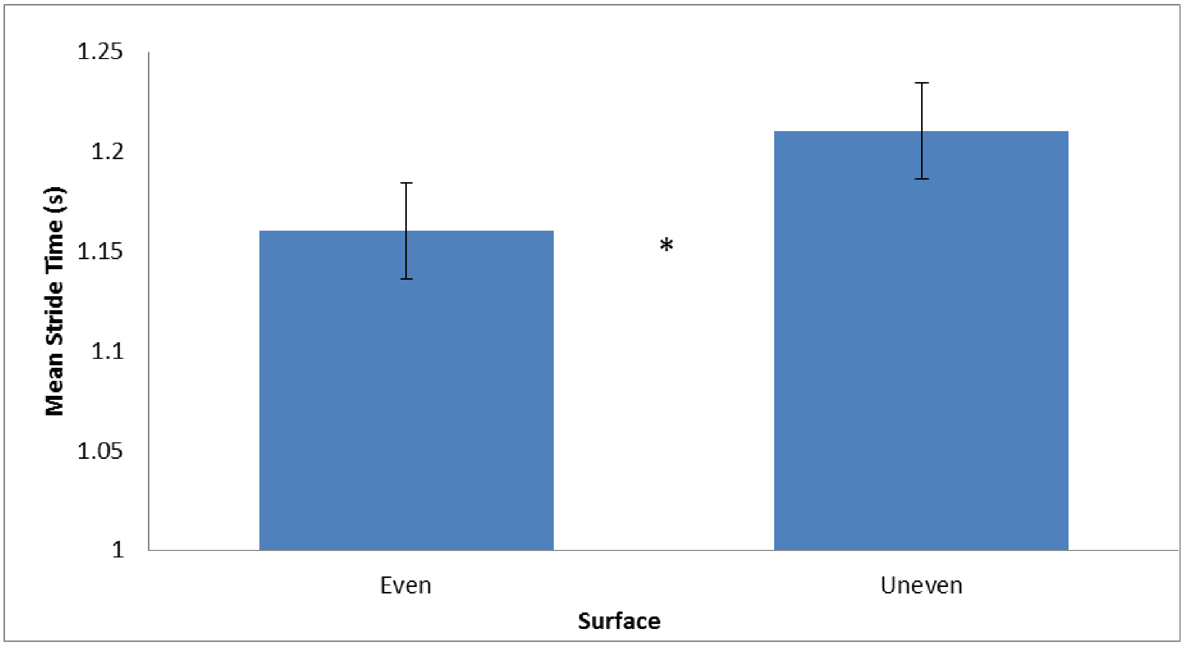


Figure 3. Mean Stride Time in Seconds While Walking on Even and Uneven Surfaces Regardless of the Tasks. (*= *P* < .05). There is a significant increase in stride time on the uneven surface.

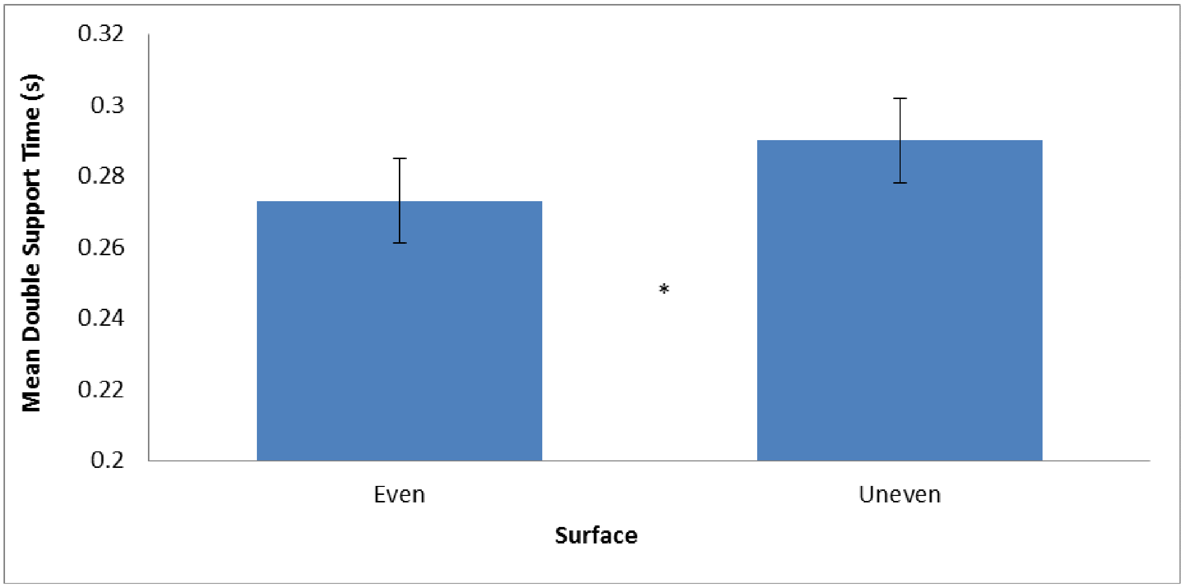


Figure 4. Mean Double-Support Time in Seconds While Walking on Even and Uneven Surfaces Regardless of the Tasks. (*= *P*< .05). There is an increase in stride time on the uneven surface.

Hypothesis 2

Hypothesis 2 inferred that changes in spatio-temporal gait characteristics in functional, independent-community older adults exist based upon the characteristics of the task being performed regardless of the walking surface. The assumption of sphericity using Mauchly's was violated, therefore Greenhouse-Geisser was used to report the result. The ANOVA was the significant main effect for velocity $F(1.86,50)= 21.93$; $p \leq 0.05$; cadence $F(1.85,50)=33.824$, $p \leq 0.05$; stride time $F(1.94,52.34)= 33.41$, $p \leq 0.05$; and double support $F(1.99,53.62)= 7.4$; $p \leq 0.05$.

The Pairwise comparison (Figure 5) shows that the velocity decreased between occasions of no tasks and cognitive tasks *M diff* = 5.82, 95% CI [2.78, 8.85], $p < .001$. There was a significantly lower velocity between no tasks and motor tasks *M diff* = 4.34, 95% CI [.24, 8.45], $p < .001$ and a significantly lower velocity between no tasks and cognitive/motor tasks *M diff* = 11.60, 95% CI [5.69, 17.50], $p < .001$. There was a significant decrease in velocity between motor tasks and cognitive/motor tasks *M diff* = 7.25, 95% CI [2.95, 11.55], $p < .001$ and between cognitive tasks and cognitive/motor tasks *M diff* = 5.76, 95% CI [1.96, 9.60], $p = .001$. However, there was no significant effect in velocity between cognitive tasks and motor tasks *M diff* = -1.47, 95% CI [-4.26, 1.31], $p = .86$.

Pairwise comparison (Figure 6) shows that there was a significant decrease in the cadence mean when comparing no tasks to cognitive tasks *M diff* = 3.38, 95% CI [1.76, 4.99], $p < .001$ and no tasks to motor tasks, *M diff* = 1.57, 95% CI [.35, 2.79], $p = .006$. There was also a significant decrease in the cadence mean between no tasks and the cognitive/motor tasks, *M diff* = 6.11, 95% CI [3.56, 8.67], *p* < .001; cognitive tasks and the cognitive/motor tasks, *M diff* = 2.74, 95% CI [.99, 4.48], *p* = .001; and the motor tasks and cognitive/motor tasks, *M diff* = 4.55, 95% CI [2.53, 6.56], *p* < .001. However, there was also a significant increase in cadence comparing cognitive tasks to motor task s*M diff* = -1.81, 95% CI [-3.27, -3.5], *p* = .009.

Pairwise comparison (Figure 7) shows that there was a significant increase in the stride time mean comparing no tasks to cognitive task,s *M diff* = -.04, 95% CI [-.06, -.02], *p* < .001; no tasks to motor tasks, *M diff* = -.02, 95% CI [-.04, -.001], *p* = .041; and no tasks to cognitive/motor tasks, *M diff* = -.07, 95% CI [-.09, -.04], *p* < .001. In addition, there was a significant increase in stride time when comparing motor and cognitive/motor tasks, *M diff* = -.05, 95% CI [-.07, -.03], *p* < .001; cognitive and cognitive/motor tasks, *M diff* = -.03, 95% CI [-.05, -.01], *p* = .015. However, there was a significant decrease in stride time between cognitive and motor tasks, *M diff* = .02, 95% CI [.003, .034], *p* = .006.

Pairwise comparison (Figure 8) shows that there was a significant increase in double-support time when comparing no tasks to cognitive tasks, *M diff* = -.024, 95% CI [-.04, -.02], *p* < .001 and no tasks to motor tasks, *M diff* = .02, 95% CI [-.03, -.01], *p* = .002. There was also an increase in double-support time when comparing no tasks to cognitive/motor tasks, *M diff* =-.05, 95% CI [-.07, -.03], *p* < .001; cognitive tasks to cognitive/motor tasks, *M diff* = -.02, 95% CI [-.04, -.01], *p* = .001; and motor tasks and cognitive/motor tasks , *M diff* = -.03, 95% CI [-.05, -.01], *p* < .002. However, there was no significant difference between cognitive tasks and motor tasks, *M diff* = .01, 95% CI [-.01, .02], *p* = 1.

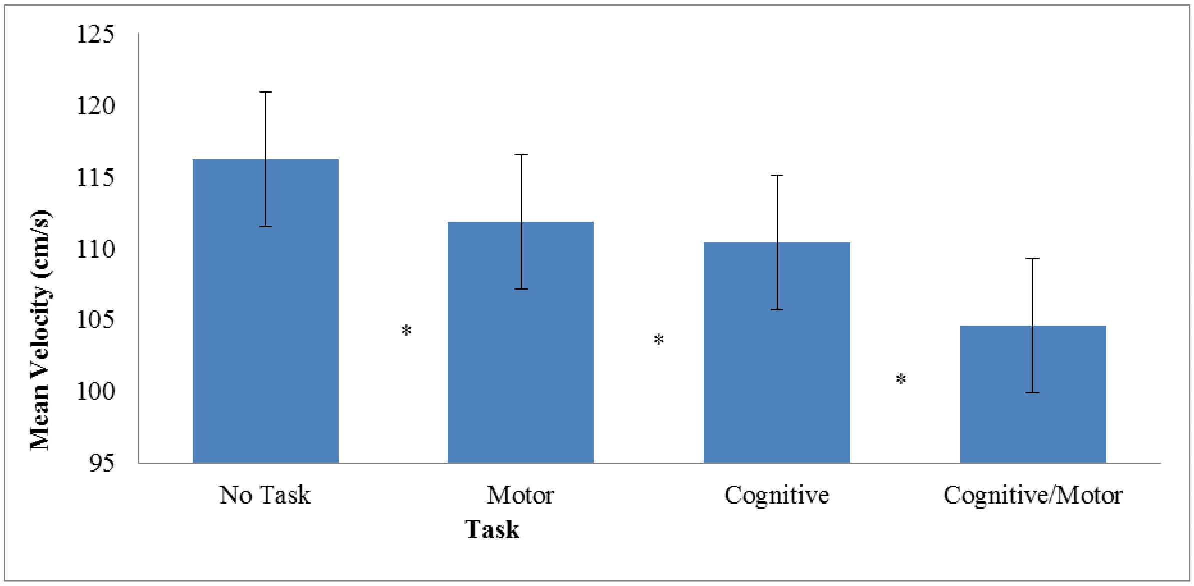


Figure 5. Mean Velocity in Cm/s While Performing Secondary Task Regardless of the Surfaces. There is a significant decrease in velocity when no tasks are compared to cognitive, motor and cognitive-motor tasks (□ $p<.05$).

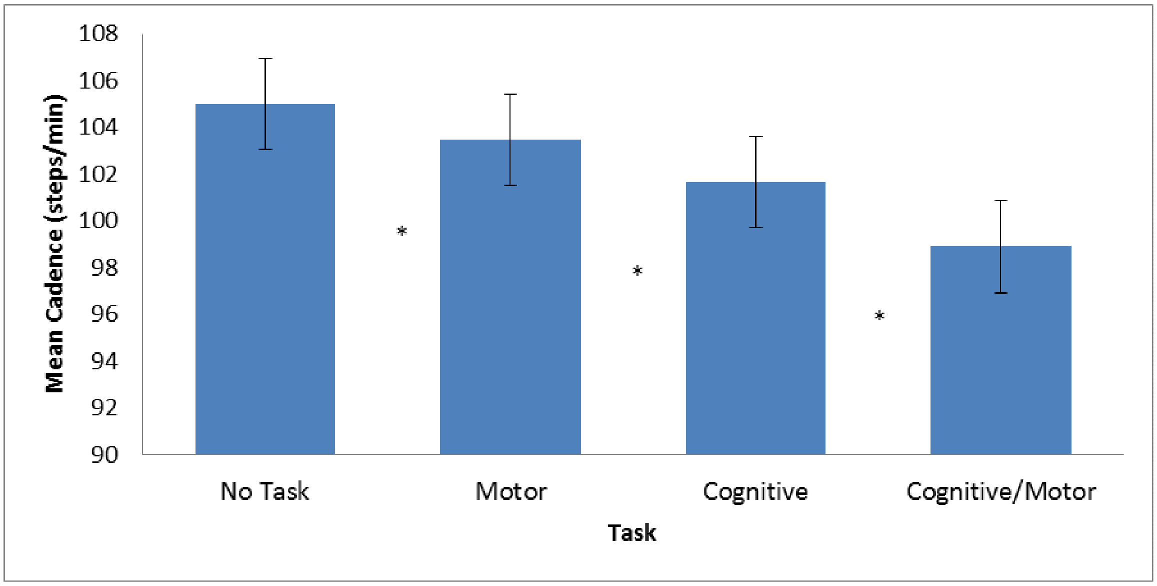


Figure 6. Mean Cadence in Steps/Min. While Performing Secondary task Regardless of the Surfaces. There is a significant decrease in cadence with the addition of cognitive, motor, and cognitive-motor tasks (* *p*< .05).

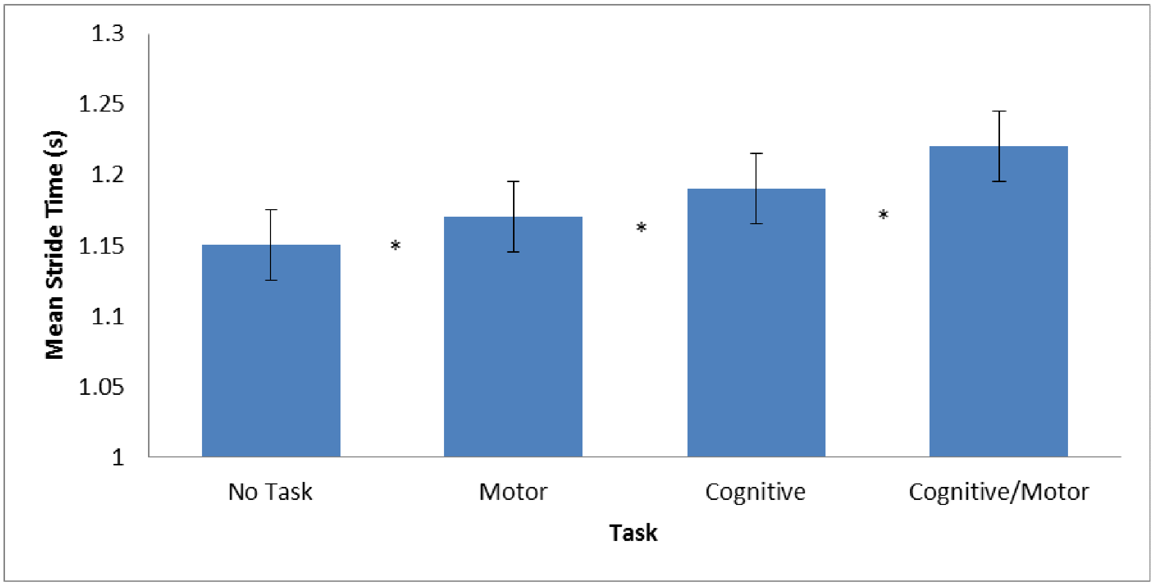


Figure 7. Mean Stride Time in Seconds While Performing Secondary Task Regardless of the Surfaces. There is a significant increase in stride time with the addition of cognitive, motor and cognitive-motor tasks (*$p < .05$).

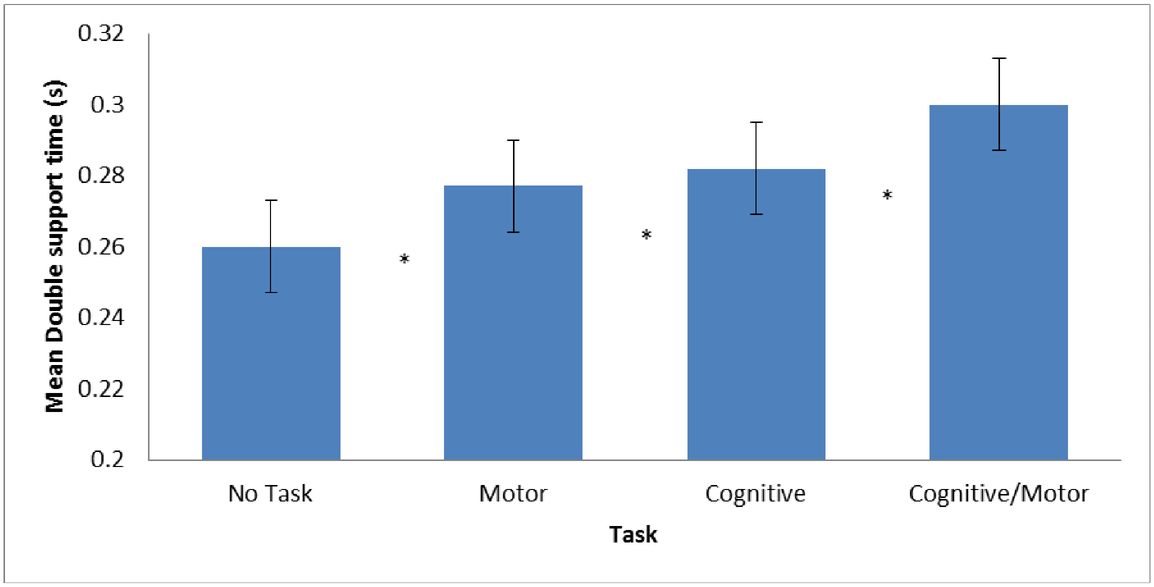


Figure 8. Mean Double-Support Time in Seconds While Performing Secondary Task Regardless of the Surfaces. There is a significant increase in double-support time with the addition of cognitive, motor and cognitive motor tasks $p< .05$. However, there is no significant difference in double-support time between cognitive and motor tasks $p<.05$.

Table 2. Cognitive, Motor and Cognitive/Motor Task Performance on Even and Uneven Surfaces

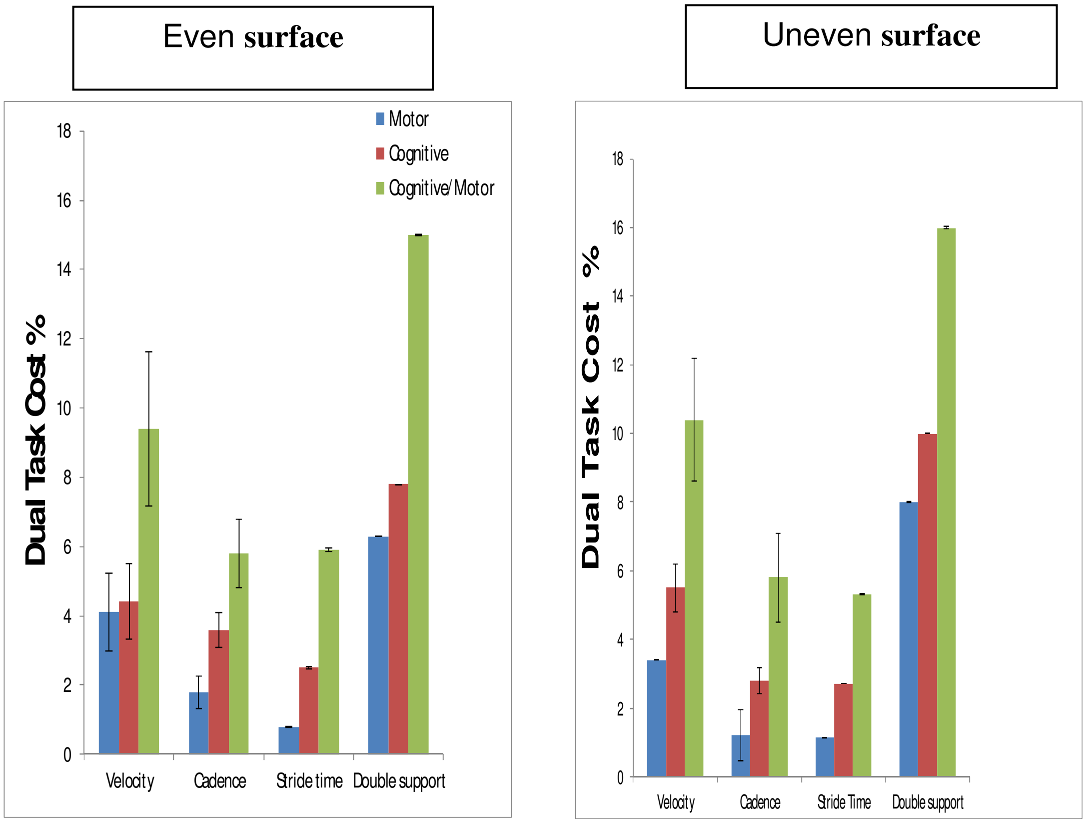
	Mean Raw Data	Mean Rank	Mann-Whitney U	Z	*P*
Cognitive Task					
Even surface	5.64	34.21	232	-2.64	.008
Uneven surface	4.86	22.79			
Motor Task					
Even surface	19.95	38.52	111.5	-4.6	.0001
Uneven surface	16.92	18.48			
Cognitive-Motor Task					
Cognitive:			95.5	-4.88	.0001
Even surface	5.0	39.1			
Uneven surface	3.7	17.9			
Motor:					
Even surface	15.52	37.9	129.5	-4.3	.0001
Uneven surface	12.83	19.1			

Hypothesis 3

Hypothesis 3 inferred that gait velocity, cadence, stride time and double-support time would change while performing different tasks depending upon the walking surface (even, uneven) among functional, independent-community older adults. The assumption of sphericity using Mauchly's was violated for velocity, therefore; Greenhouse-Geisser was used in the result. There was no significant interaction between surfaces and tasks for velocity $F(2.1, 56.2) = 1.13$, $p = .331$; cadence $F(3,81) = .39$, $p = .12$; stride time $F(3, 81) = .26$, $p = .86$; or double support $F(3, 81) = .97$, $p = .41$. The results did not support hypothesis three.

Dual Task Costs

Dual-task cost is a measure of performance decrement when two tasks performed concurrently. Thus, to quantify the participants' performance ability to execute dual-tasks, we calculated dual-task costs using the formula previously mentioned. As seen in Figure 9, dual-task costs increased in a linear manner as the complexity of the task increased similarly on both surfaces. It was observed that the cognitive-motor task had the greatest dual-task cost compared to the cognitive and motor tasks. This outcome supports the basis for Gentile's Taxonomy of Tasks, which purports that the environmental context and the functional role it plays classify a skill. Thus, as the results show shown, the more complicated the task was functionally more was the dual-task cost on spatio-temporal parameters while walking.



Even surface

Uneven surface

Figure 9. Dual-Task Cost on Uneven and Even Surfaces

Discussion

The result of this study demonstrate that surface type and task attentional complexity affect the velocity, cadence, stride time and double support time in older community dwelling adults however, no significant interactions between the task type and surface condition were observed. Similar to previous studies that have reported deficits during walking on even surfaces while performing a dual task in older adults (Beauchet et al. 2009, Duost et al. 2006), our findings extend these observations to uneven walking surfaces. Importantly, the adoption of different gait strategies by participants while concurrently performing a dual task on an uneven surface supports the need to ensure that when rehabilitating older adults they experience and train on uneven walking surfaces while performing a dual-task.

Additionally, the observation that the type of concurrent dual-task performed regardless of the walking surface characteristics, resulted in older adults changing their gait strategy thus offering insight regarding differing secondary task demands influences on gait. In our study, it was noted that dependent upon the type of secondary task performed gait strategies changed. Not surprising, the task (Table 3) requiring the most attentional demand showed the greatest change which further supported the findings of Ebersbach, Dimitrijevic, and Poewe (1995) who reported an increase in double support time and stride time while walking on even surface when the secondary task was a cognitive task.

Taken together, we believe our findings can be discussed within the context of two ‘attention’ theories (capacity sharing and cross talk theory). In the capacity sharing theory when two or more tasks are performed simultaneously, more attention might be needed to perform the tasks than the total available capacity regardless of task similarities. Therefore, one or both of the task performances might deteriorate in the dual task trials (Woollacott & Shumway-Cook, 2002). As in our study findings, changes were observed in several gait parameters when walking over uneven surfaces and performing a dual task especially the cognitive-motor task thus leading us to infer that uneven surface walking while performing cognitive-motor task shared the same available attentional resources (Lajoie, Teasdale, Bard, & Fleury, 1993).

As we consider the tenets associated with the crosstalk theory, when two tasks are similar in nature, the two tasks use similar codes and thus conflict with each other producing “crosstalk”. Crosstalk can impair performance on one or both tasks. Clearly, in our study the tasks used varied not only their level of difficulty but similarity. As the tasks were more similar in nature we saw greater variability in gait strategies used. In terms of the motor task being the least disruptive, supports that this task is different from walking therefore, there is a less interference and crosstalk. Alternately, performances of cognitive and motor tasks are more similar and performing them together causes more interference and crosstalk.

Significant changes in spatio-temporal variables were observed when the older adults concurrently performed a cognitive-motor task versus a cognitive or a motor task. The observed progressive decrease in velocity and cadence was evident as the task complexity increased both on even and uneven surface. Interestingly though, there was a progressive increased in stride time and double support time which lead to enhanced balance. This finding compliments the findings of Huffman, Horslen, Carpenter and

Adkin (2009) who reported a decrease in the ability to track more than one moving target while walking as a strategy to stabilize ones balance.

In addition, to the difference amongst the dual tasks performed with the cognitive-motor task being the most challenging as evident by the greatest changes in walking pattern there was a observed higher DTC with increase in task complexity across surfaces. The cognitive-motor task had the highest DTC as compared to cognitive or motor task. Our finding that older adults showed larger dual-task costs when performing dual task (cognitive-motor) is consistent with the finding of Lindenberger, Mariske, and Baltes, (2000), and with others showing that dual-task costs in older adults becomes larger as the demands on attentional control processes increases (Bock, 2009; Salthouse et al., 1996; Hall et al., 2011). In addition, Neider et al (2011) concluded that older adults were more vulnerable to dual-task impairments than younger adults when cross task was present as dual-task costs effects were largely absent in younger adult groups.

Our findings are consistent with Hsieh and Cho (2012) who assessed gait performance on two different floor surfaces (hard and soft), and found an increased stance time and decreased swing time when walking on a soft floor. The authors explained the differences noted based upon floor type as a strategic plan used by the participants to enhance balance control on an unstable floor. This finding complements our findings in that when encountering the uneven surface, subjects used a longer double support time and stride time as compared to the even surface. Increasing stride time provided a plan to maximize safe first in order to enhance balance control while walking on an uneven surface.

Although, this current study did not demonstrate a significant interaction between surface type and task characteristics, a few possible explanations are offered. One possible explanation may be due to our small sample size (Table 1). Another possibility may be a resultant of the age of the participants. In this study, the age range was 65-75 years with mean age of 68.39 ± 3.04. In addition, the attentional requirements of the tasks may not have been enough to require an alteration in the motor control strategy used during dual tasking. It was observed that walking on an uneven surface caused greater decrements in task performance than even surface (Figure 9). The cognitive-motor task performance showed the largest decrement in performance among all the tasks.

As with all studies, limitations must be acknowledged. The small sample sizedecreased the study power, the use of a sample of convenience limits generalizability of findings, the fact that only one type of uneven surface was used does not allow us to infer what would occur on all types of uneven surfaces. Finally, given that the task variability and complexity was limited to only three types of tasks further limits one's generalizability from this work. However, this work does add to the literature and offers insight and direction for future work exploring these factors.

Conclusions

The findings from this study support that spatiotemporal gait changes do occur when performing a concurrent cognitive and / or motor dual task, or while walking on an uneven surface compared to an even surface in older community living adults. In the current study, older adults used a successful strategy which required them to slow down and decrease their cadence while walking on an uneven surface and when engaging in dual-tasks of increased complexity. Thus suggesting that when the task requires additional attentional resources older adults err on the side of safety by focusing their anticipatory motor control resources towards controlling balance by slowing down and increasing their forward base of support.

Based upon these findings, professionals such as physical therapists working to promote motor skill acquisition and prevention of secondary impairments in the elderly must ensure that they introducing uneven surfaces and multi-task conditions into their patient's management. The concurrent performance of two tasks may well create a situation that challenges participants to allocate attention to ensure their safety. In the clinical setting, instructing patients to explore gait stability strategies during dual task uneven surface walking to ensure safety should be included in the plan of care. Further study is warranted with increase in sample size, varying uneven surfaces, and differing types of tasks to increase generalizability.

As we seek to explain our findings globally, the capacity sharing theory which states that when more than one task is performed at any given moment there is less capacity for each individual task, and performance is impaired offers some insight on our findings.In this study we believe the tasks were different even though they may have fallen within the same or similar classification by Gentile’s taxonomy because they did require differing attentional demands. Therefore,   we believe that the capacity sharing theory is effective in explaining our findings as the more dissimilar the task the greater the disruption in performance. However, one might argue that the tasks were not so different based upon the function of the action (body and limb requirements) and thus the crosstalk theory might be more effective in explaining our findings as the tasks are more similar. While it was not the purpose of this study to lend support for one theory or another in explaining dual tasking effects the findings leave us with more questions that will help us to refine our methods and potentially address this issue in further work especially addressing the need for in-depth task classification.

This study provides some preliminary evidence that independent, community living elderly use a default strategy that rely on making adjustments in gait that result in greater motor control. In other words, the elderly err on the side of safety and focus their anticipatory resources towards controlling balance. It is important for clinicians to be aware of these strategies and incorporate them in the management of the elderly patient.

References

Abernethy, B., Hanna, A., & Plooy, A. (2002). The attentional demands of preferred and nonpreferred gait patterns. *Gait and Posture, 15*, 255–265.

Alexander, N. B., Ashton-Miller, J. A., Giordani, B., Guire, K., & Schultz, A. B., (2005). Age differences in timed accurate stepping with increased cognitive and visual demand: A walking trail making test. *Journal of Gerontology A: Biological Science Medical Sciences, 60A*, 1558-1562.

Beauchet, O., Annweiler, C., Allali, G., Berrut, G., Herrmann, F.R., & Dubost, V. (2008). Recurrent Falls and Dual Task-Related Decrease in Walking Speed: Is There a Relationship? *Journal of American Geriatric Society*, *56*,1265-1269.

Beauchet, O., Annweiler, C., Dubost, V., Allali. G., Kressig, R. W., Bridenbaugh, S., Berrut, G., Assal, F., & Herrmann, F. R. (2009) Stops walking when talking: a predictor of falls in older adults? *European Journal Neurology 16*,786–795.

Bilney, B., Morris, M., & Webster, K. (2003). Concurrent related validity of the GAITRite walkway system for quantification of the spatial and temporal parameters of gait. *Gait & Posture, 17,* 68-74.

Bock, O. (2009). Dual task costs while walking increase in old age for some, but not for other tasks: An experimental study of healthy young and elderly persons. *Journal of NeuroEngineering & Rehabilitation, 5*(27) [PubMed: 19014544].

Bootsma-van-der-Wiel, A., Gussekloo, J., de Craen, A. J. M., van Exel, E., Bloem, B. R., & Westendorp, R. G. J. (2003). Walking and talking as predictors of falls in the general population: The Leiden 85-Plus Study. *Journal of America Geriatric Society*, *51*, 1466–1471.

Butler, R. N. (2000). Fighting Frailty: prescription for healthier aging includes exercise, nutrition, safety and research. *Geriatrics,* 55:20-21.

Dubost, V., Kressig, R. W., Gonthier, R., Herrmann, F. R., Aminian, K., Najafi, B., & Beauchet, O. (2006) Relationships between dual-task related changes in stride velocity and stride time variability in healthy older adults. *Human Movement Science, 25*, 372–382.

Ebersbach, G., Dimitrijevic, M. R., & Poewe, W. (1995). Influence of concurrent tasks on gait: A dual-task approach. *Perceptual & Motor Skills, 81,* 107_113.

Ferraro, R., Pinto Zipp, G., Simpkins, S., & Clark, M., (2013) Effects of an incline walking surface and balance abilities on spatiotemporal gait parameters in older adults. *Journal of Geriatric Physical Therapy, 36,* 31-38.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-Mental State. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Frontera, W. R., Hughes, B. S., Fielding, R. A., Fiatarone, M. A., & Evans, W. J. (2000). Aging of skeletal muscle: a 12-year longitudinal study. *Journal of Applied Physiology. 88*, 1321- 1326.

Gentile, A.M. (1987) Skill acquisition: Action, movement, and neuromotor processes. In J.H. Carr, R.B. Shepherd, J. Gordon, A.M. Gentile, & J.M. Held, Movement Science. Foundations for Physical Therapy in Rehabilitation. MD: Aspen Publishers.

Gentile, A.M. (2000). Skill acquisition: Action, movement, and neuromotor processes. In J.H. Carr & R.B. Shepard (Eds.), Movement Science: Foundations for Physical Therapy (2nd ed., pp.111-187). Rockville, MD: Aspen.

Gerin-Lajoie, M., Richards, C.L., & McFadyen, B.J. (2005). The circumvention of obstacles during walking in different environmental contexts: A comparison between older and younger adults. *Gait & Posture, 24*, 364-369.

Grabiner, P. C., Biswas, S. T., & Grabiner, M. D. (2001). Age-related changes in spatial and temporal gait variables. *Archives of Physical Medicine and Rehabilitation*, 82, 31-35.

Hausdorff, J.M., Edelberg, H.K., Mitchell, S.L., Goldberger, A.L., Wei, J.Y. (1997). Increased gait unsteadiness in community-dwelling elderly fallers. *Archive of Physical Medicine & Rehabilitation, 78*, 278-283.

Himann, E., Cunningham, D. Rechnitzer, P., & Paterson, D. (1987). Age-related changes in speed of walking. *Medicine & Science in Sports & Exercise. 20*, 161-166.

Hofer, S., Berg, S., & Era, P. (2003). Evaluating the interdependence of aging-related changes in visual and auditory acuity, balance, and cognitive functioning. *Psychology &Aging*, *18***,** 285- 305.

Hollman, J.H., Kovash, F.M., Kubik, J.J., & Linbo, R.A. (2007). Age-related differences in spatiotemporal markers of gait stability during dual task walking. *Gait and Posture, 26,* 113-119.

Hsieh, Y-J., Cho, C-Y. (2012). Age-related changes of arm movements in dual task condition when walking on different surfaces. *Human Movement Science, 31* 190–201

Huffman, J. L., Horslen, B. C., Carpenter, M. G.,& Adkin, A. L. (2009). Does increased postural threat lead to more conscious control of posture? *Gait & Posture*,*30*, 528-532.

Johnson, M.E., Mille, M.L., Martinez, K.M., Crombie, G., & Rogers, M.W. (2004). Age-related changes in hip abductor and adductor joint torques. *Archives of Physical Medicine and Rehabilitation*, *85*, 593-597.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice-Hall.

Kavanagh, J.J., Barret, R.S., & Morris, S. (2004). Upper body accelerations during walking in healthy young and elderly men. *Gait & Posture, 20,* 291-298.

Laessoe, U., Hoeck, H. C., Simonsen, O., & Voigt, M. (2008). Residual attentional capacity amongst young and elderly during dual and triple task walking, *Human Movement Science*, *27*, (3), 496-512.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M. (1993). Attentional demands for static and dynamic equilibrium. *Experimental Brain Research* 97, 139–144.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M., (1996). Upright standing and gait: Are there changes in attentional requirements related to normal aging? *Experimental Aging Research*, 22,185-198.Li, K. Z. H., Lindenberger, U., Freund, A. M., & Baltes, P. B. (2001). Walking while memorizing: Age-related differences in compensatory behavior. *Psychological Science, 12*, 230–237.

Lexell, J., Taylor, C. C., & Sjostrom, M. (1988). What is the cause of the ageing atrophy? Total number, size, and proportion of different fiber types studied in whole lateralis muscle from 15 to 83 year old men. *Journal of Neurological Science, 84*, 275-279.

Lindenberger, U., Marsiske, M., & Baltes, P. B. (2000). Memorizing while walking: Increase in dual-task costs from young adulthood to old age. *Psychology & Aging, 15,* 417-436.

Lundin-Olsson, L., Nyberg, L., & Gustafson, Y. (1997). 'Stops walking when talking' as a predictor of falls in elderly people. *Lancet,* 349, 617-617.

Magill, Richard A. (2007). *Motor Learning*. Boston: McGraw-Hill.

McConvey, J., Bennett, S. E. (2005). Reliability of the Dynamic Gait Index in individuals with multiple sclerosis. *Archives of Physical Medicine and Rehabilitation,* 86 (1), 130–133.

Marigold, D.S., & Patla, E.E. (2008). Age-related changes in gait for multi-surface terrain. *Gait & Posture, 27*, 689–696.

McDonough, A. L., Batavia, M., Chen, F. C., Kwon, S., & Ziai, J. (2001). The validity and reliability of the GAITERite system's measurements: A preliminary evaluation. *Archive of Physical Medicine & Rehabilitation*, *82*, 419-425.

Menz, H.B., Lord, S.R., & Fitzpatrick, R.C. (2003). Age-related differences in walking stability. *Age & Ageing, 32*, 137–142.

Mesure, S., Darmon, A., & Blin, O. (2001). Imbalance of attentional and sensory inputs on gait. *Advances in Neurology, 87*, 243-250.

Montero-Odasso, M., Schapira, M., Soriano, E.R., Varela, M., Kaplan, R., Camera, L. A., Mayorga, L.M. (2005). Gait speed as a single predictor of adverse events in healthy seniors aged 75 years and older. *Journal of Gerontology: Medical science, 60A,* 1304-1309.

Nashner, L. M. (1989). Sensory, neuromuscular and biomechanical contributions to human balance. *Proceedings of the Forum of the American Physical Therapy Association. Nashville*, 5-12.

National Safety Council. (2010). *Prevent Falls In and Outside of your Home* retrieved from http://www.nsc.org/safety_home/HomeandRecreationalSafety/Falls/Pages/OlderAdultFalls.aspx

Neider, M. B., Gaspar, J. G., McCarley, J. S., Crowell, J. A., Kaczmarski, H., & Kramer, A. F. (2011). Walking & talking: dual-task effects on street crossing behavior in older adults. *Psychology & Aging* 26 (2) 260–268.

Ostrosky, K.M., VanSwearingen, J.M., Burdett R.G.,& Gee, Z. (1994). A comparison of gait characteristics in young and old subjects. *Physical Therapy, 74,* 637-646.

Pashler, H., (1994). Dual-task interference in single tasks. Data and theory. *Psychological Bulletin, 116*, 220-244.

Patla, A. E. (1997). Slips, trips and falls: Implications for rehabilitation and ergonomics. In S. Kumar (Ed.), *Perspectives in rehabilitation ergonomics* (pp. 196–209). London: Taylor & Francis.

Peng, L., & Zhizhong L. (2012). Task complexity: A review and conceptualization framework. *International Journal of Industrial Ergonomics, 42,* 553-568.

Pinto Zipp, G., Mickeal, H., Mollina, P., Byrne, A., Mehta, S., Ferraro, R., & Maher, C. (2013). Effect of Dual Task Performance on Spatiotemporal Gait Parameters of Older Adults during Incline Walking: Preliminary Data. Oral presentation, CSM, San Diego, CA.

Portney, L. G.,& Watkins, M. P. (2009). Foundations of Clinical Research: Applications to Practice. Pearson Education, Inc.; Upper Saddle River, N.J.

Priest, A. W., Salamon, K. B., & Hollman, J. H. (2008). Age-related differences in dual task walking: a cross sectional study. *Journal of NeuroEngineering & Rehabilitation, 5*: 29-37).

Prince, F., Corriveau, H., Hebert, R., & Winter, D.A. (1997). Gait in the elderly. *Gait & Posture, 5,* 128-135.

Rakauskas, M. E., Gugerty, L. J., & Ward, N. J. (2004). Effects of naturalistic cell phone conversations on driving performance*. Journal of Safety Research*, *35*, 453– 464.

Rubino, F.A. (1993). Gait disorders in the elderly: Distinguishing between normal and dysfunctional gaits. *Postgraduate Medicine, 93*(6), 185-190.

Salthouse, T. A., Hambrick, D. Z., Lukas, K. E., & Dell, T. C. (1996). Determinants of adult age differences on synthetic work performance. *Journal of Experimental Psychology: Applied.* 2, 305–329.

Scott, G., Menz, H. B., & Newcombe, L. (2007). Age-related differences in foot structure and function. *Gait and Posture*. 26, 68-75.

Silsupadol, P., Siu, K., Shumway-Cook, A., & Woollacott, M. H., (2006). Training of Balance under Single and Dual Task Conditions in Older Adults with Balance Impairment: Three Case Reports. *Physical Therapy*, 86, 269-281.

Shkuratova, N., Morris, M.E., & Huxham, F. (2004). Effects of age on balance control during walking. *Achieve Physical Medicine Rehabilitation*, *85*, 582-588.

Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the Timed Up and Go Test. *Physical Therapy, 80*, 896–903.

Shumway-Cook, A., & Woollacott, M. H. (2001). Motor Control: Theory and Practical Applications**.** Philadelphia: Lippincott, Williams & Wilkins.

Sparrow, W.A., Bradshaw, E.J., Lamoureux, E., & Tirosh, O. (2002). Ageing effects on the attention demands of walking. *Human Movement Science, 21,* 961-972.

Springer, S., Giladi, N.,Peretz, C.,Yogev, G., Simon, E. S., & Hausdorff,J.M. (2006). Dual-tasking effects on gait variability:the role of aging,falls,and executive function. *Movement Disorder.* 7, 950–957.

Spirduso, W., Francis, K. & MacRae. P. (2005). *Physical Dimensions of Aging*, Human Kinetics, Champaign, IL.

Studenski, S., Duncan, P. W, & Chandler J. (1991). Postural responses and effector factors in persons with unexplained falls: results and methodology issues. *Journal of American Geriatrics Society*, 39, 229-234.

Thies, S.B., Richardson, J.K., & Ashton-Miller, J.A. (2005). Effects of surface irregularity and lighting on step variability during gait: A study in healthy young and older women. *Gait & Posture 22,* 26–31.

Tinetti, M. E. (2003). Clinical practice. preventing falls in elderly persons. *New England Journal of Medicine*, 348, 42-49

Tombu, M., & Jolicoeur, P. (2003). A capacity sharing model of dual task performance. *Journal of Experimental Psychology: Human perception and performance, 29*, 3-18.

U.S. Department of Health and Human Services. A Profile of Older Americans. (2010). Retrieved from http:// www.aoa.gov/aoaroot/aging_statistics/**Profile**/**2010**/docs/**2010profile**.pdf

US Censor Bureau (2010, October 13). Retrieved from http://www.census.gov/2010census/

Vandervoort, A. A. (2002). Aging of the human neuromuscular system. *Aging and Neuromuscular system*, *25*, 17-25.

Van Uden, C.J. T. & Besser, M. P. (2004). Test-retest reliability of temporal and spatial gait characteristics measured with an instrumented walkway system (GAITRite$^{®}$). *BMC Musculoskeletal Disorder, 5*, 13

Verghese, J., Buscke, H., Viola, L., Katz, M., Hall, C., Kuslansky, G., Lipton, R. (2002). Validity of divided attention tasks in predicting falls in older individuals: A preliminary study. *Journal of American Geriatric Society,* 50, 1572–1576.

Verghese, J., Holtzer, R., Lipton, R. B., & Wang, C. (2009). Quantitative Gait Markers and Incident Fall Risk in Older Adults. *Journals of Gerontology A Biological Science Medical Science, 64A,* 896-901

Verghese, J., Kuslansky, G., Holtzer, R., Katz, M., Xue, X., Buschke, H., & Pahor, M. (2007). Walking while talking: effect of task prioritization in the elderly. *Archive Physical Medicine Rehabilitation, 88*, 50-53.

Webster, K. E., Wittwer, J. E., & Feller, J. A. (2005). Validity of the GAITRite1 walkway system for the measurement of averaged and individual step parameters of gait. *Gait & Posture 22,* 317–321.

Whitney, S., Wrisley, D., & Furman, J. (2003). Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. *Physiotherapy Research International, 8,* 178-186.

Williams, K., Hinton, V., Bories, T, & Kovacs, C**.** (2006) Age differences in dual task performance: Walking and talking. *Research Quarterly in Exercise & Sport*, 77 (1), 137-141.

Woollacott M, & Shumway-Cook, A. (2002). Attention and the control of posture and gait: A review of an emerging area of research. *Gait & Posture, 16*, 1–14.

Yogev-Seligmann, G., Rotem-Galili, Y., Mirelman, A., Dickstein, R., Giladi, N. & Hausdorff, J. M. (2010). How does explicit prioritization alter walking during dual-task. *Physical Therapy, 2*, 177-186.

Young, A., Stokes, M., & Crowe, M. (1985). The size and strength of the quadriceps muscles of old and young men. *Clinical Physiology*, 5, 145–154.

Appendix A

Howare you walking?

Looking for independent community dwelling adults 65 to 75 years old willing to participate in a study that will analyze walking patterns on even and uneven surfaces while dual tasking (doing two things). During this study valuable information will be gained about walking while doing two or more tasks on different surfaces.

- Research will be conducted at Kebe Cares Physical Therapy located at 1285 Oliver Street Fayetteville, NC.
- Participation in this study will require approximately 90 minutes of your time.
- Individual appointment times will be made for each participant to avoid waiting.
- Participation in this study is completely voluntary.
- A code will be assigned to each participant to assure anonymity.

Eligibility requirements:

- You must be 65-75 years of age.
- You must be able to walk independently without assistive device in the community for at least 50 feet.
- You must be free from any falls in the last six months.
- You must be free from any neurological problems such as stroke, Parkinson disease, multiple sclerosis etc.

FOR MORE INFORMATION ON PARTICIPATION IN THIS STUDY AND TO SCHEDULE A TIME FOR TESTING PLEASE CONTACT THE PRIMARY INVESTIGATOR:

Olajide Kolawole, PT
917 753 3158

Appendix B

Screening Protocol

Hello Mr./Mrs.____________

Thank you for responding to the flyer posted.

As you know my name is Olajide Kolawole and I am the physical therapist and student at Seton Hall University in NJ as part of my doctoral program I am conducting a research study on walking in the older adult when doing more than one thing at a time. I would like to take a few minutes of your time before you come to the research site to ask you a few questions to make sure that you are eligible for this study.

These questions pertain to your level of interaction in the community and the level of assistance you require to walk in and around the community. If at any time you don't understand anything please stop me and ask that explain further.

At this time I ask that you respond yes or no to the following questions

Are you 65 years old and older and able to walk at least 50 feet Yes ___ No ___

Are you able to walk without assistive device? Yes___ No___

Note to PI for Exclusion (yes to any of these questions below will exclude participant from the study)

Have you fallen down within the last six months? Yes__ No ___

Are you able to read? Yes___ No__

Do you ever get dizzy when you walk? Yes___ No___

Did you ever have any traumas such as a broken bone to ankle/foot that required medical attention? Yes___ No ___

Are you currently experiencing pain in either leg? Yes ___ No ___

Do you suffer from any medical conditions that may affect your movement or balance? Yes__ No__

Do you have any neurological diagnosis such as stroke, Parkinsonism, multiple sclerosis etc? Yes___ No_

Do you have any problems using your hands to hold or carry items such as a coffee cup, book, or dish? Yes___
No_____________________________________

Do you have any sensory impairment in your lower extremities? Yes__ No_

Based upon your responses to the previous questions Mrs.______________-you do indeed qualify for this study so I would like to set up an appointment that is convenient for you to come and participate in this study. Your date and time of testing is ________________

Please wear comfortable shoes without a heel that he/she is comfortable walking in.

Or

Based upon your response to the previous questions Mrs.______________-you are not eligible to participant in the study. I thank you for your willingness to determine your eligibility.

Appendix C1

Data Sheet – Dual Task

Subject Code:________

Walking Cognitive task

Subjects will be instructed to walk at a self -preferred pace on the walkway while counting backwards in 5s starting from 100 to 0.

Instructions: If the individual skips a number while counting backwards, mark an "X" in the second column. If the individual says a completely different number make an "X" in the third column. If the individual completes the task without any errors place an '"x" in the last column.

Numbers	Number Missed	Wrong number was given	Task Completed without errors
100			
95			
90			
85			
80			
75			
70			
65			
60			
55			
50			
45			
40			
35			
30			
25			
20			
15			
10			
5			
0			

Appendix C2

Subject Code:__________

Walking Motor task

Subject will be instructed to press repetitively tally counter clicker with the dominant hand while walking on the walkway at a self-preferred pace on the walkway.

Instructions: If the individual stopped clicking, the task will be repeated. The number of counts on the clicker will be recorded.

Motor Task	**Number of counts**
Clicking	

Appendix C3

Subject Code:_________
Walking Cognitive/Motor task
Subject will be instructed to walk at a self-preferred while walkway while counting backwards in 5s starting from 100 to 0 and press repetitively tally counter clicker with the dominant hand simultaneously

Instructions: If the individual skips a number while counting backwards, mark an "X" in the second column. If the individual says a completely different number make an "X" in the third column. If the individual completes the task without any errors place an '"x" in the last column. In addition, if the individual stopped clicking, the task will be repeated. The number of counts on the clicker will be recorded.

Motor Task	**Number of counts**
Clicking	

Numbers	Number Missed	Wrong number was given	Task Completed without errors
100			
95			
90			
85			
80			
75			
70			
65			
60			
55			
50			
45			
40			
35			
30			
25			
20			
15			
10			
5			
0			

Appendix D

INFORMED CONSENT

You are invited to be a participant in a research project entitled “Effects of Dual-tasking on walking over even and uneven surfaces in functionally independent community older adults”.

Investigator: I am Olajide Kolawole the primary investigator and a doctoral student at Seton Hall University in the School of Health Science and Medical science, Department of Graduate Programs in Health Sciences. This research is being conducted under the direction of Dr’s. Zipp, and Cahill who are Associate professors in the Department of Graduate Programs in Health Sciences, School of Health and Medical Science, Seton Hall University and Dr. Parasher.

Purpose of Research:

The purpose of this study is to assess how walking on even and uneven surfaces when a person is doing one or more activities at a time which demand different levels of attention. The results of this study will help to identify which type of tasks demands more attention.

Procedure:

When participant arrives at the testing site, the participant will be required to read and sign this consent form. If the participant has any questions they will be answered by the primary investigator before signing the consent form. The participant blood pressure and pulse will be checked.

Thereafter, the participant cognitive abilities will be tested using a simple test consisting of ability to tell time and place, immediate recall, short-term memory, calculation, and language ability.

Next, the participant walking will be assessed. As part of the walking assessment, the participant will be asked to complete tasks that include walking while turning head, walking around and over objects, turning and stopping quickly, and walking up and down stairs. During all of these tasks the participant will be provided close supervision by the primary investigator (Olajide Kolawole) as he will be in close proximity to the subject.

If the participant is eligible to participate in the study, the participant will be asked to walk on a mat placed on an even surface and then on an uneven surface. The uneven surface is made of twenty-four strips of wood measuring two inches high under a smooth surface of artificial grass. The total length of this mat is 4 meters (13 feet). While walking on these surfaces participant will be asked to count backwards from100 by 5, and press a button on the tally counter repeatedly and do combination of counting backwards and pressing tally counter simultaneously. Participants will perform a total of three (3) trials under each of the task conditions in a random order. The mat upon which the participant walk will automatically allow us to measure the speed at which the participant walks, the number of steps the participant takes and the amount of time simultaneously spend on both legs while walking.

The primary investigator (Olajide Kolawole, Physical Therapist) will walk along the participant side to ensure safety. The entire testing session will last for approximately 90 minutes during which adequate rest intervals will be provided as needed.

All assessment tools used in this study will not be placed on the body. These are standardized tools used frequently in clinical practice.

Refusal or withdrawal of participation: Participation in this study is voluntary. Refusal to participate or discontinue participation at any time will involve no penalty or loss of benefits to which the participant is otherwise entitled.

Anonymity: The subject data will be assigned a code that will ensure anonymity. Only the primary investigator will have access to the code. If information obtained from this study is reported in a journal or at a professional meeting only codes will be used.

Confidentiality: All data collected will be stored on a USB drive and locked in a file cabinet at the primary investigator's office (Olajide Kolawole).

Access to research records: Olajide Kolawole (primary investigator) will have the only access to this cabinet via lock and key.

Anticipated risks/discomforts: Walking on even and uneven surfaces is a mobility task typically required during community ambulation. The primary investigator will walk along the mat with the subject during all trials to ensure safety.

Benefits: There will be no direct benefits to you other than increasing knowledge about what happens when walking and performing a second task.

Payment/remuneration: There will be no payment or remuneration for participating in this study.

Alternative procedures: This study is not designed to examine treatment/intervention therefore no recommendations for alternative procedures will be made.

Contact information: If you are interested in the results of this study or have any questions please contact Olajide Kolawole, at 917-753-3158 or Dr. Genevieve Zipp (researcher's advisor) at 973 273 2076. Questions need not be limited to this study but may also include what the researchers will do with the knowledge gained and future research ideas.

In addition, any pertinent questions about the research and participant's rights can also be addressed to the Institutional Review Board (Mary F. Ruzicka, Ph.D.) office at Seton Hall University at 972-313-6314.

A copy of the consent form will be provided to you for your records. The signature of the participants identifies their willingness to participate in the study.

Name of participant:__________________________________Date:__________

Signature of participant:_______________________________Date:________

Signature of researcher:______________________________Date__________

Assigned code:__________

Appendix E

Mini Mental Status Examination
Retrieved from http://www4.parinc.com/Products/Product.aspx?ProductID=MMSE

Appendix F

Physician notification letter

Date:

Dear Dr.___________________________

I have evaluated ____________________ and have a score of___on the Mini Mental States Examination.

Sincerely,

Olajide Kolawole, PT, MS

Appendix G

Dynamic Gait Index

Description:
Developed to assess the likelihood of falling in older adults. Designed to test eight facets of gait. Retrieve from http://iospress.metapress.com/content/xeb5qp3mkuna3cqm/

Appendix H

GAITRite on uneven surface

The picture on the right shows the arrangement of the woods

(Picture taken by Olajide Kolawole).

Appendix I

Definitions

Gait Cycle: The interval of time between the occurrence of initial foot-contact with one foot and its occurrence again. It consists of two phases the stance and swing phase.
Stance phase: The period of time when the foot is in contact with the ground.

Swing phase: The period of time when the foot is not in contact with the ground.

Double support: The period of time when both feet are in contact with the ground. This occurs twice in the gait cycle, at the beginning and end of the stance phase.

Single support: The period of time when only one foot is in contact with the ground. In walking, this is equal to the swing phase of the other limb.

Step length: The distance from a point of contact with the ground of one foot to the following occurrence of the same point of contact with the other foot. The right step length is the distance from the left heel to the right heel when both feet are in contact with the ground.

Step period: Is the period of time taken for one-step and is measured from an event of one foot to the following occurrence of the same event with the other foot.

Stride length: The distance from initial contact of one foot to the following initial contact of the same foot. It is sometimes also referred to as cycle length.

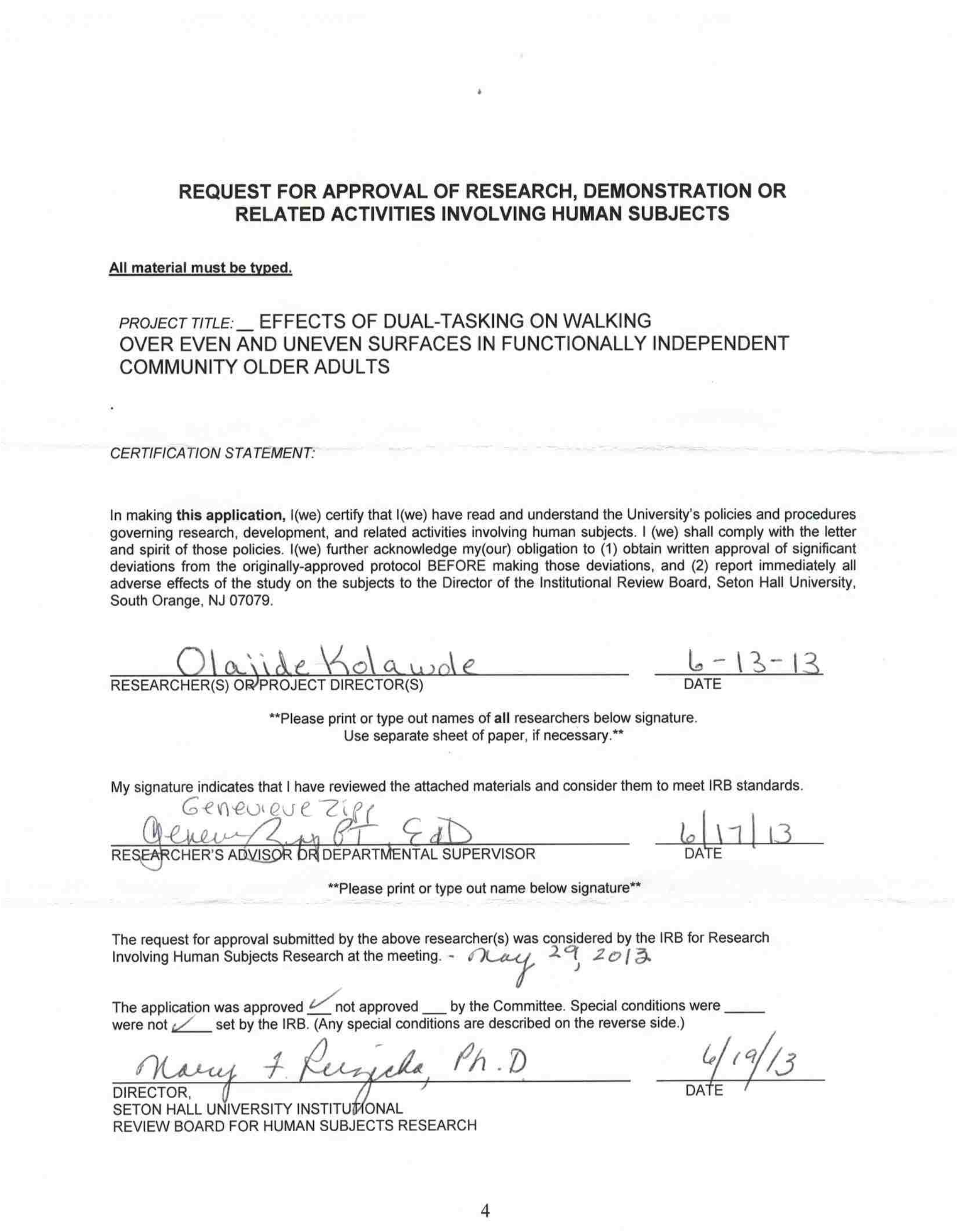
Velocity: The rate of change of linear displacement along the direction of progression measured over one or more strides.

Cadence: Rate at which a person walks, expressed in steps per minute.

Stride time: The period of time from initial contact of one foot to the following initial contact of the same foot, expressed in seconds.

Gait speed: Distance covered by the body in unit time.

Appendix J



REQUEST FOR APPROVAL OF RESEARCH, DEMONSTRATION OR RELATED ACTIVITIES INVOLVING HUMAN SUBJECTS

All material must be typed.

PROJECT TITLE: _ EFFECTS OF DUAL-TASKING ON WALKING OVER EVEN AND UNEVEN SURFACES IN FUNCTIONALLY INDEPENDENT COMMUNITY OLDER ADULTS

CERTIFICATION STATEMENT:

In making **this application,** I(we) certify that I(we) have read and understand the University's policies and procedures governing research, development, and related activities involving human subjects. I (we) shall comply with the letter and spirit of those policies. I(we) further acknowledge my(our) obligation to (1) obtain written approval of significant deviations from the originally-approved protocol BEFORE making those deviations, and (2) report immediately all adverse effects of the study on the subjects to the Director of the Institutional Review Board, Seton Hall University, South Orange, NJ 07079.

Olajide Kolawole 6-13-13
RESEARCHER(S) OR PROJECT DIRECTOR(S) DATE

Please print or type out names of **all researchers below signature.
Use separate sheet of paper, if necessary.**

My signature indicates that I have reviewed the attached materials and consider them to meet IRB standards.

Genevieve Zipp
Genevieve Zipp PT, EdD 6/17/13
RESEARCHER'S ADVISOR OR DEPARTMENTAL SUPERVISOR DATE

Please print or type out name below signature

The request for approval submitted by the above researcher(s) was considered by the IRB for Research Involving Human Subjects Research at the meeting. - May 29, 2013

The application was approved ✓ not approved ___ by the Committee. Special conditions were _____ were not ✓ set by the IRB. (Any special conditions are described on the reverse side.)

Mary F. Ruzicka, Ph.D 6/19/13
DIRECTOR, DATE
SETON HALL UNIVERSITY INSTITUTIONAL
REVIEW BOARD FOR HUMAN SUBJECTS RESEARCH