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The effect of articulation and word-meaning on gait and balance in people with Parkinson's disease

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

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THE EFFECT OF ARTICULATION AND WORD-MEANING ON GAIT
AND BALANCE IN PEOPLE WITH PARKINSON'S DISEASE

(Thesis format: Monograph)

by

Kevin Wood

Graduate Program in Health and Rehabilitation Sciences

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

The School of Graduate and Postdoctoral Studies
The University of Western Ontario
London, Ontario, Canada

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ABSTRACT

Performing two tasks simultaneously is ubiquitous in everyday life, and the resulting interference may degrade performance on one or both of the tasks. This is important because diminished performance of a postural task places an individual at a greater risk for falling, especially in a movement impaired population such as individuals with Parkinson's disease (PD). Many secondary tasks have been shown to reduce the performance of gait and balance, but to date only one study has investigated the effects of a verbal secondary task that systematically controls articulatory, speech, and cognitive-linguistic demands. Previous research suggested that these components have independent effects on gait and balance within a sample of healthy young adults. The purpose of the present study was to replicate this research protocol within a sample of healthy older adults (n=20) and a sample of individuals with PD (n=20) and to evaluate the effects of individual differences in information processing speed on dual-task interference. Results suggested that oral-motor movement significantly affected parameters of gait and balance, with men displaying significantly more dual-task interference than women. The addition of speech and lexicality to the secondary task did not significantly increase interference during the gait or balance protocol. Results also indicated that dual-task interference is directly related to individual differences in information processing speed, a finding that supports the capacity-sharing model of dual task interference.

Keywords: dual-task interference, Parkinson's disease, older adults, oral-motor movement, articulation, lexical complexity, gait, balance, information processing speed

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Chapter 1: Introduction and Literature Review

1.1 What is Parkinson's disease?

Parkinson's disease (PD) is a progressive neurodegenerative disorder that is characterized by tremor, rigidity, akinesia/bradykinesia, and gait and postural instability (Abbruzzese, Pelosin, & Marchese, 2008; Forno, 1996; Jankovic, 2008; Meissner et al., 2011). PD occurs worldwide, affecting both men and women, although a slightly higher incidence has been recorded among men (Zhang & Roman, 1993). The typical age of onset of PD is approximately 60 years (Fahn, 2003), but the disease has been identified in much younger individuals, and "early onset PD" may be diagnosed as early as 30 years of age (Cooperman, Forwell, & Hugos, 2002). The pathophysiology of PD relates to the substantia nigra, a structure of the brain involved in movement, wherein dopaminergic nerve cell degeneration in the pars compacta subnuclei occurs (Braak et al., 2003; Forno, 1996). Why the nerve tissue in the substantia nigra deteriorates prematurely, and how this can be delayed, is unclear (Forno, 1996). The etiology of PD has, however, been addressed by a number of theories.

Environmental factors such as pesticides and herbicides used in the agricultural industry have been identified as increased risk factors for PD (Zayed et al., 1990). In addition to environmental risk factors, there is some evidence to suggest a genetic basis of the disease. Although the exact mechanism for intergenerational transmission of PD is unclear, an increased risk of contracting the disease has been identified in first and second degree relatives of individuals with PD (Marder et al., 1996; Rybicki, Johnson, Peterson, Kortsha, & Gorell, 1999). Furthermore, mutation of the alpha-synuclein gene has been linked to the expression of a familial form of PD (Singleton et al., 2003).

According to the “double hit hypothesis,” the development of PD results from an interaction between environmental risk factors and genetic predisposition (Allam, Del Castillo, & Navajas, 2005; Gorell, Peterson, Rybicki, & Johnson, 2004).

The prevalence of PD varies depending on the method employed for data collection, the geographic location being studied, and the age of the population in question. Canadian estimates indicate 100 – 200 cases per 100, 000 (Harris, Koehoorn, & Teschke, 2011; Lai, Schulzer, Marion, Teschke, & Tsui, 2003), which are in line with national statistics worldwide (Dorsey et al., 2007). Among neurodegenerative disorders, the prevalence rate for PD is second only to that of Alzheimer’s disease. Therefore, it is not surprising that the cost of this disease (both socially and economically) is expected to substantially increase as the population ages (de Lau & Breteler, 2006).

1.2 Treatment of Parkinson’s disease

There is no known cure for PD, so treatment is limited to symptom management (Abbruzzese et al., 2008). Although this treatment is multifaceted and may involve a combination of surgery, pharmacotherapy, and physical rehabilitation (Rascol, Goetz, Koller, Poewe, & Sampaio, 2002; A. H. Schapira, 2007), dopamine replacement therapy via levodopa and dopamine agonists is the standard of care. The oldest treatment of PD is levodopa – a dopamine precursor that, unlike dopamine, is able to cross the blood brain barrier (Hardebo & Owman, 1980). Levodopa reverses the dopamine deficiency in the substantia nigra by directly increasing neural concentrations of dopamine, thereby markedly reducing parkinsonian symptoms (Forno, 1996; A. H. Schapira, 2007). Unfortunately, long-term treatment with levodopa tends to produce motor fluctuations,

most notably dyskinesia, that can be almost as debilitating as the symptoms of PD (Rascol et al., 2002; A. H. Schapira, 2007) . For this reason, dopamine agonists are most often used as an initial treatment option, as they tend to delay the onset of dyskinesia (A. H. Schapira, 2007). Unfortunately, dopamine agonists have been associated with negative neuropsychiatric side effects, most notably impulse control disorders (Johnson, Hyson, & Roland, 2011).

Although pharmaceutical treatment is generally effective in ameliorating rigidity and tremor (albeit to a lesser extent than rigidity), postural instability and gait impairment remain relatively unresponsive to dopaminergic stimulation (Hely, Morris, Reid, & Trafficante, 2005). Given that PD is progressive in nature, the severity of the disease increases with time, thereby increasing the demand for symptomatic medication.

Although pharmaceutical treatments are effective at mitigating some PD symptomology, their benefits gradually diminish, as the medications take increasingly shorter amounts of time to “wear off” (Abbruzzese et al., 2008; A. H. Schapira, 2007). To accommodate these motor fluctuations, physicians may either increase the individual doses and/or increase dosage frequencies, (Rascol et al., 2002), or prescribe other medications (i.e., COMT and MAO-B inhibitors) that work to increase the “on” time and reduce the “off” time within the levodopa cycle (Goetz, Poewe, Rascol, & Sampaio, 2005; Pahwa et al., 2006). Patients are also at an increased risk of experiencing increasingly more potent adverse effects as drug intake increases, especially dyskinesia (Abbruzzese et al., 2008; Archibald & Burn, 2008; Hely et al., 2005; Meissner et al., 2011). Other adverse effects include hallucinations, drowsiness, and possible behavioural changes (Archibald & Burn, 2008; Meissner et al., 2011; A. H. Schapira, 2007). These inherent limitations with drug

therapy have led some physicians to advocate treating symptoms only after activities of daily living have been significantly impacted; however, treatment early in the disease progression has gained more traction as this benefits motor control and quality of life early in the disease course, with the potential to be maintained in the long-term (A. H. Schapira, 2007; A.H. Schapira & Obeso, 2006). The ideal course of action remains unclear (Aminoff, 2006).

1.3 Gait and Balance Impairment in PD

Although not experienced by all individuals living with PD, postural instability is a cardinal symptom of the disease, and is increasingly compromised throughout the disease course (Meissner et al., 2011). Individuals with PD tend to take short, slow steps (Knutsson, 1972; Urquhart, Morris, & Iansek, 1999), have a stooped posture (Morris, Martin, & Schenkman, 2010), and experience difficulty initiating gait (Schaafsma et al., 2003). Factors believed to contribute to gait impairment in PD include: hypokinesia (Morris, Iansek, Matyas, & Summers, 1994), gait asymmetry (Baltadjieva, Giladi, Gruendlinger, Peretz, & Hausdorff, 2006), postural instability (Bloem, van Vugt, & Beckley, 2001), and decreased joint range of motion (Schenkman, Morey, & Kuchibhatla, 2000).

Freezing of gait is another common gait impairment exhibited by people with PD (Giladi et al., 2009). Characterized by a momentary inability to step, with the feeling that one's feet are stuck in place, freezing of gait most commonly occurs while individuals are attempting to turn, initiate gait, or traverse through narrow areas such as corridors, doorways, and elevators (Nutt et al., 2011). Freezing of gait has been linked to falls in

several studies (Grimbergen, Munneke, & Bloem, 2004; Schrag, Jahanshahi, & Quinn, 2000), and is reported to be more prevalent as the disease progresses (Grimbergen et al., 2004). Some studies have, however, indicated that approximately 26% of individuals with PD experience this freezing early in their disease course, even before they begin to manage their disease pharmacologically with levodopa (Giladi et al., 2001; Giladi et al., 1992; Lamberti et al., 1997).

Due to the reduced gait performance associated with PD, individuals with PD are at a greater risk for falls than individuals who are not afflicted with PD (Grimbergen et al., 2004; Schrag et al., 2000; Shulman, 2010; Shulman et al., 2008). A meta-analysis by Pickering et al. (2007) aggregated PD falls data across six separate prospective studies. Pickering et al. (2007) determined a fall rate of 46% (95% CI: 38-54%) among all participants in a three-month timespan. Among individuals who had reported no previous falls within the last year, the fall rate was 21% (95% CI: 12 -35%), while among those who had fallen once or more in the past year the rate was 57% (95% CI: 53– 61%). These findings highlight the risk of falls among the PD population regardless of fall history, a risk important not only to the individual in terms of potential injury, but also costly to the healthcare system for treatment and rehabilitation. For instance, in the meta-analysis performed by Pickering et al. (2007), similar rates were provided by the two studies that did report the proportion of patients with falls causing injury, with 24-27% of patients experiencing injurious falls.

When individuals experience imbalance, an important strategy to avoid falls is taking compensatory steps to regain postural stability (Jobges et al., 2004). Studies have indicated that PD patients struggle to initiate a compensatory step and are more likely to

fall as a result (Jacobs & Horak, 2006; King & Horak, 2008). Added to this, Bloem, Grimbergen, Cramer, Willemsen, and Zwinderman (2001) suggest many falls among individuals with PD may be “intrinsic” to the individual and not due to obvious environmental conditions, for example stepping on slippery surfaces or colliding with an object. Rather, most falls are believed to be caused by abrupt changes in posture or while an individual is walking or balancing and simultaneously performing one or more attention demanding tasks, such as carrying on a conversation (Grimbergen et al., 2004).

The role of attention, in the form of information processing capacity, in maintaining static and dynamic postural stability has been investigated in several studies (Allali et al., 2007; Dault, Yardley, & Frank, 2003; Holmes, Jenkins, Johnson, Adams, & Spaulding, 2010; O'Shea, Morris, & Ianssek, 2002; Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). Although balance and gait have traditionally been thought to be relatively automatic processes (i.e., require minimal attentional resources; Seitz & Roland, 1992), a number of studies have indicated otherwise. For example, several studies have demonstrated a reduction in one's performance of a secondary (distractor) task (e.g., a spatial memory task, a simple auditory reaction time task, or a fine motor task), when performed concurrently with a balance (Brauer, Woollacott, & Shumway-Cook, 2002; Kerr, Condon, & McDonald, 1985; Teasdale, Bard, LaRue, & Fleury, 1993), or gait task (Lajoie, Teasdale, Bard, & Fleury, 1993, 1996). In both studies by Lajoie et al. (1993, 1996), a significantly slowed reaction time was reported when subjects walked, in comparison to when they were seated. These findings suggest that gait requires more attentional resources than being in a sitting position, thereby producing the slowed reaction time when walking.

Results of the aforementioned studies suggest that both static and dynamic postural stability require attentional resources. Moreover, research has suggested that the demand for attentional resources grows with increasing postural requirements. In a sample of older adults, Lajoie et al. (1996) had subjects perform an auditory reaction time task concurrently with the following five incrementally difficult postural tasks: seated, comfortable stance, standing with a narrow base of support, dual-limb support phase of gait, and single-limb support phase of gait. Results demonstrated that reaction time was significantly faster when sitting compared to standing or walking, and was faster during standing with a normal base of support than with a narrow base of support. The implication of these findings, in addition to similar findings reported by Brown, Shumway-Cook, and Woollacott (1999), suggest that individuals need to allocate additional attentional resources in order to maintain postural stability, as the complexity of the postural task increases. Accordingly, most researchers now consider gait and balance to be a complex attention demanding process, rather than automatic form of motor movement (Yogev-Seligmann, Hausdorff, & Giladi, 2008).

1.4 Dual-Task Interference

Performing multiple tasks at once, or multi-tasking, is a very common activity in daily life. Texting while walking, or maintaining a conversation while chopping vegetables for a meal, are just a few examples of how frequently multi-tasking occurs in an individual's life. In research, dual-task paradigms are used to examine the mechanism through which an individual accommodates his or her performance of two tasks. Dual-task performance is defined as the execution of two tasks simultaneously. From carrying an object while rising to one's feet from a sitting position, to walking and talking, the

ability to dual-task is integral to the performance of functional activities. The pervasiveness of dual-tasking in activities of daily living can lead individuals to become comfortable, in the sense of feeling safe, with the performance of two simultaneous tasks, causing them to develop a lack of awareness of (or to discount) the consequences of divided attention. Consequently, many people are unfamiliar with the interference that may exist between two tasks that can result in a decrease in performance of one, or both, of the tasks. This interaction between tasks is known as dual-task interference, defined as the reduction in performance of one or both concurrent tasks (Woollacott & Shumway-Cook, 2002).

The importance of understanding dual-task interference is evident in relation to monitoring the surrounding environment while walking or when performing a concurrent task during gait or stance. Any dual-task situation that may place an individual at a greater risk for falling should be limited. Therefore, many studies examine dual-task related changes in gait (Armieri, Holmes, Spaulding, Jenkins, & Johnson, 2009; Lundin-Olsson, Nyberg, & Gustafson, 1997; O'Shea et al., 2002) and in posture (Berger & Bernard-Demanze, 2011; Dault et al., 2003; Holmes et al., 2010; Shumway-Cook et al., 1997).

The effects of dual-task interference become more pronounced when one or both of the tasks in the dual-task paradigm decrease in their automaticity, possibly due to an increase in the requirement for attentional resources (O'Shea et al., 2002). O'Shea et al. (2002) noted that the impact of dual-task interference is most visible when the complexity of the secondary task is increased.

Dual-task studies involving gait and posture are of particular importance because of the potential for a fall to occur if the system becomes overwhelmed. A common strategy used to accommodate interference caused by dual-tasking is halting the performance of one task in order to complete the other (Lundin-Olsson et al., 1997). During a dual-task situation involving gait or posture, one strategy to accommodate higher levels of interference would be to prioritize gait or posture, and cease the performance of the secondary task. In contrast, it is potentially hazardous for the individual to prioritize the secondary task over gait or posture – dual-task interference may degrade performance of the primary task by impairing the movement quality. The former (prioritizing gait or posture) is an adaptive strategy, while the latter (maintaining the secondary task at the expense of movement quality) may be considerably more hazardous (Bloem, Grimbergen, van Dijk, & Munneke, 2006; Johnson et al., 2012; Lundin-Olsson et al., 1997).

When an individual accommodates dual-task interference by prioritizing postural stability over a secondary cognitive task, they are said to be employing a “posture-first strategy” (Bloem et al., 2006). Reduction in performance of the secondary task is accepted by the individual as a cost associated with maintaining the individual’s stability. A “posture-second strategy”, therefore, is a maladaptive strategy in which an individual focuses attention on the secondary task, leaving fewer attentional resources available for allocation to postural control, thereby placing him or her at a greater risk for falls (Bloem et al., 2006). For example, if an individual were to prioritize speech intelligibility over maintaining a consistent gait pattern, he or she would be employing a posture-second strategy. For reasons that are not fully understood, individuals with PD have been

suggested to be more likely to employ a “posture-second strategy” (Bloem et al., 2006; Bloem, Valkenburg, Slabbekoorn, & Willemsen, 2001; Canning, 2005; Marchese, Bove, & Abbruzzese, 2003; O'Shea et al., 2002). Coupled with the postural abnormalities and movement impairments with which this population tends to present with, this maladaptive strategy for coping with challenges to the allocation of attentional resources during gait or balance may exacerbate the risk of falling.

Previous research on dual-task interference has involved a multitude of motor or cognitive secondary tasks of varying complexity during the performance of a concurrent postural task (e.g., Armieri et al., 2009; Beauchet, Dubost, Aminian, Gonthier, & Kressig, 2005; Davie et al., 2012; Holmes et al., 2010; O'Shea et al., 2002; Yardley, Gardner, Leadbetter, & Lavie, 1999). For example, O'Shea et al. (2002) compared the effects of dual-task interference between two different secondary tasks, a motor task (transferring a coin from one pocket to another) and a cognitive task (digit subtraction), among PD patients while walking. They reported that both secondary tasks significantly reduced gait performance but that there was no difference in the extent of dual-task interference when comparing the two types of secondary tasks. Furthermore, research on dual-tasking has shown that postural instability escalates as the complexity of the concurrent task increases (Beauchet et al., 2005; Hall, Echt, Wolf, & Rogers, 2011; Pellecchia, 2003; Woollacott & Shumway-Cook, 2002). For instance, Beauchet et al. (2005) compared the effects of two cognitive tasks, a simple arithmetic task (counting backwards by one) and a verbal fluency task (speaking aloud as many animal names as possible), during gait in a sample of older adults. Their results suggested that the complexity of the cognitive task differentially impacted dual-task interference, indicating that the extent of interference

between two tasks increases as the difficulty of the secondary task increases. Finally, research has also suggested that task characteristics, such as articulation (Armieri et al., 2009; Dault et al., 2003; Yardley et al., 1999) and lexicality (Davie et al., 2012), can impact the extent of dual-task interference experienced. For example, Yardley et al. (1999) compared a spoken and silent backwards-counting task and found that postural sway during the counting backwards aloud task was greater than during the silent task. The authors suggested that the increased sway was primarily the consequence of the articulatory demands of the speech task.

1.5 Dual-task interference models

Multiple theoretical models of cognitive mechanisms have been proposed to explain how interference occurs when an individual performs two concurrent tasks. The three models most commonly cited in the literature are the bottleneck model (Pashler, 1994; Welford, 1967), the cross-talk model (Kinsbourne, 1981; O'Shea et al., 2002; Pashler, 1994), and the capacity-sharing model (Broadbent, 1958; Kahneman, 1973; Navon & Grophe, 1979; Norman & Bobrow, 1975; Pashler, 1994). The bottleneck and cross-talk model of dual-task interference follow a 'structural' approach in that interference is dependent upon the degree of sharing of neural pathways between the two tasks (Huang & Mercer, 2001; O'Shea et al., 2002). The bottleneck model posits that the primary and secondary task contend for the same neural pathway (O'Shea et al., 2002). According to the bottleneck model, interference is the result of two concurrent tasks in competition for similar 'types' or 'categories' of information (Broadbent, 1958; Huang & Mercer, 2001; O'Shea et al., 2002). Interference is abated when the two concurrent tasks access different categories of information. In contrast, the cross-talk model theorizes that

attentional resources are used more efficiently when both tasks make use of the same neural pathway, thereby decreasing the amount of interference (Huang & Mercer, 2001). Researchers have reasoned that interference is reduced because both tasks are efficiently using the same neural pathways, ultimately leaving more cognitive resources available (Allali et al., 2007; O'Shea et al., 2002; Pashler, 1994).

The capacity-sharing model differs from the bottleneck and cross-talk models insofar as the hypothesis defining capacity-sharing does not rely on theories of brain structure. Instead, this model is based on the hypothesis that the primary and secondary task compete for limited attentional resources, and that performance is diminished when processing capacity is overwhelmed (Huang & Mercer, 2001). Dual-task interference results from both tasks utilizing an individual's processing capacity, and interference is increasingly apparent as an individual's finite amount of processing capacity is exceeded by the demand for attentional resources by the two tasks (Huang & Mercer, 2001; O'Shea et al., 2002). It is generally regarded that performance of the secondary task causes an individual to surpass his or her processing capacity, and the magnitude of interference is proportionate to the increasing complexity of the secondary task, or conversely, the decreasing automaticity of the secondary task (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998).

The processing capacity of the system within the capacity-sharing model has been evaluated by assessing the *psychological refractory period* (Fitts & Peterson, 1964; McLeod, 1977; Navon & Miller, 2002; Tolkmitt, 1973) and through *probe reaction time tasks* (Ogden, Martin, & Paap, 1980; Posner & Boies, 1971). The psychological refractory period (PRP) is the delay in an individual's response to a second stimulus

while still processing a response to the first stimulus, presented shortly before. The PRP typically increases as time between the tasks decreases. Probe reaction time tasks, on the other hand, measure the time it takes an individual to determine whether two stimuli, presented one after the other, are identical. Individuals must push a button as fast as possible following the second stimulus indicating if the two were identical. Information processing speed is represented by the speed at which an individual can make the decision that the stimuli are identical and push the button. Information processing speed has been suggested to be an estimate of an individual's cognitive capacity (P. J. Johnson, Forester, Calderwood, & Weisgerber, 1983; Ogden et al., 1980).

Measurement of speed-of-information processing can be performed independently from the dual-task paradigm, allowing researchers to assess the extent to which dual-task interference is related to an individual's cognitive capacity by adding information processing speed as a covariate in the analysis. Unfortunately, most chronometric (i.e., "reaction-time") measures are heavily dependent upon motor systems for the output. This may be particularly problematic within a sample of individuals with motoric impairments (e.g., individuals with PD). This confound can, however, be minimized if the measure can separate time for response selection and response execution (A. M. Johnson, Vernon, Almeida, Grantier, & Jog, 2003), or if the measure does not rely on motor outputs, such as inspection time. Inspection time (IT) is an estimate of information processing speed (Brody, 2001; Deary & Stough, 1996) that differs from reaction time tasks in that it estimates information processing speed from the speed at which a stimulus can be presented without obscuring key characteristics of the stimulus. The most commonly cited IT task is "visual inspection time", and this task typically involves

asking individuals to examine physical characteristics of a visual stimulus (e.g., two vertical lines) presented in a restricted time interval, and asking them to make a decision about the properties of the stimulus (e.g., identify which line is shorter). Individuals who are capable of making these distinctions on stimuli that are presented for a shorter period of time are judged to have a faster speed of information processing (Stough, Bates, Mangan, & Colrain, 2001). IT is, therefore, an appropriate test of information processing speed among individuals with PD, as it is not dependent upon the time needed to plan and execute a motor response (A. M. Johnson et al., 2004). IT as an estimate of information processing speed is important to this study because it can be used to assess the relationship between interference of the secondary task and an individual's cognitive capacity.

1.6 The Role of Articulation in Dual-Task Interference

Emerging in the dual-task interference research is the role of articulation (Armieri et al., 2009; Dault et al., 2003; Davie et al., 2012; Plummer-D'Amato et al., 2008; Yardley et al., 1999). The ability to communicate with one another is one of the most basic tasks involved in activities of daily living, and is critical within the daily routine of most individuals. Accordingly, dual-task studies examining a secondary cognitive task often employ a speech component during the assessment. Requiring participants to speak while performing a cognitive task may lead to the possibility of spoken language confounding the dual-task interference analysis due to the cognitive and motoric impact speech entails. Thus, research has begun to investigate the effect of articulation on motor task performance in a dual-task paradigm.

Yardley et al. (1999) examined the effect of verbal secondary tasks on postural sway in healthy adults. Postural sway was tested under four conditions: (1) repeating a random number aloud; (2) counting backwards by seven aloud; (3) counting backwards by seven silently; and (4) performing no concurrent mental task. Postural instability was assessed using a biomechanical force platform that measured centre of pressure in the anterior/posterior and medial/lateral directions. Results indicated postural instability was increased by articulation rather than mental activity, as backwards counting aloud (attention-demanding and articulation) and number repetition (articulation) both significantly increased postural sway, while the silent cognitive task, which required no oral movements, was found to have no effect. The results of this study identified that articulation is an important factor that needs to be considered when employing a dual task paradigm.

Building on the study by Yardley et al. (1999), Dault et al. (2003) measured additional dimensions of postural sway, including sway path, sway amplitude, and sway frequency. The purpose of this study was to examine the extent to which oral motor movements cause postural control changes, and to test to see if the type of measure used to assess postural sway had an impact on the results. To examine this, participants performed a series of four separate secondary tasks (with and without articulation) while sitting and standing. The *silent task* entailed participants listening to pre-recorded letters forming words in a nonsense phrase, memorizing the phrase, and then reciting it upon completion of the trial. This task was engineered to maximize attentional load without including an articulation component. The *combination task* was similar to the silent task but participants were required to repeat each letter aloud after hearing it and recite the

phrase at the end of the trial. This trial was designed to simultaneously manipulate both attentional load and articulation. The *articulation task* entailed repeating random letters aloud after hearing the pre-recorded version. The letters were presented in blocks that did not form words. This trial evoked articulation while requiring minimal attentional load. Lastly, the *motor task* necessitated participants to repeatedly bite a plastic tube, designed to investigate the effects on postural sway by oral motor coordination involving low attentional load without articulation. Results of this study revealed that an increased sway path was observed only during the two tasks involving articulation, the combination task and articulation task. These findings confirm the findings of Yardley et al. (1999) in that they suggest that postural sway is affected by articulation and not merely the cognitive complexity of the task.

While the studies by Yardley et al. (1999) and Dault et al. (2003) examined articulation as a component of a secondary speech task during stance, Armieri et al. (2009) investigated both complexity and articulation within a single working memory task (a digit span task) during gait. Armieri et al. were interested in determining whether increasing levels of complexity of articulation produced increased gait disturbance. Participants memorized varying lengths (i.e. complexity) of non-repeating sequences of digits and were required to repeat the digits during the gait task aloud or silently. Results identified a significant interaction between articulation and complexity, indicating that articulation has a greater impact on parameters of gait at higher levels of complexity. These results suggest that a secondary verbal task entails both a cognitive and speech component, resulting in the need for thoughtful consideration of stimulus properties as a

means to control for cognitive complexity and articulatory demands intrinsic to a verbal task.

The three aforementioned studies collectively underscore the importance of a secondary verbal task as a predictor of dual-task interference on gait and posture. Similarly, these studies have shown that controlling the articulatory requirements of a secondary verbal task is important as articulatory complexity may confound the results within a dual-task paradigm. Although these studies have contributed to our understanding of the role articulation plays within a dual-task paradigm, these studies are limited by the absence of control over the motoric complexity of the speech sounds associated with the verbal stimuli employed. More specifically, these studies did not control the articulatory complexity of the phonemes used in the letters (Dault et al., 2003; Yardley et al., 1999) or digits (Armieri et al., 2009) that were spoken aloud.

Recently, Davie et al. (2012) addressed the aforementioned limitations by deconstructing the spoken language demands of a secondary speech task by systematically manipulating the word length, oral-motor movement, articulation, and lexicality of the task. To accomplish this, Davie et al. (2012) re-worked the stimuli of the secondary verbal task used by Armieri et al. (2009) through careful control over the phonology and articulation of the stimuli. Phonology refers to how individual speech sounds are arranged into a predictable system, wherein a speaker can recognize forms that are allowable and forms that are not, to produce a language. Articulation, on the other hand, refers to the production of speech sounds by modifying airflow using a complex variety of parts in the human respiratory system (Davenport & Hannahs, 2010). The motor-component (articulation) and the cognitive-linguistic component (phonology)

combine to form speech. Although the two are separate entities, the motor-component of speech is not fully independent from the cognitive-linguistic component.

In particular, the oral-motor movements in the longer digit span tasks used by Armieri et al. were greater in duration relative to the shorter span tasks, which could have led to their significant findings. In addition, the numbers within each span varied in oral-motor movement complexity, which also could have confounded the results. Davie et al. (2012) controlled oral-motor complexity within their stimulus list by balancing stimuli at the phonemic level. Specifically, Davie et al. (2012) accounted for differences in the cognitive-linguistic complexity of the stimuli by rearranging the same set of phonemes into words and non-words, effectively balancing the phonological demands of words and non-words while maintaining the added semantic processing related to the meaningful word stimuli. In addition, the stimuli used in the silent oral-motor movement condition were taken from the two spoken conditions such that the stimuli were balanced across all three conditions.

Collectively, the methodological innovations by Davie et al. (2012) allowed for a set of verbal stimuli that were well balanced in oral-motor, speech, and cognitive-linguistic complexity. In doing so, Davie et al. (2012) were in a better position to examine the effects of introducing secondary verbal tasks on gait in healthy young adults. To accomplish this, participants were asked to complete the following tasks: a non-speech movement task, a spoken non-word task, and a spoken word task. The *non-speech movement* task required participants to imitate the movement of stimuli, but without any speech production. The *spoken non-word* task involved participants speaking aloud a nonsense word that consisted of a sequence of phonemes plausible in English but that

carry no meaning. This task was designed to isolate articulation from cognitive complexity, referring to the semantic processing involved in meaningful words, that is absent in non-words. The *spoken-word* task consisted of participants speaking aloud a meaningful word made of different arrangements of the same phonemes used to make non-words. This allowed for the manipulation of cognitive complexity while balancing the oral-motor complexity between the *spoken non-word* and *spoken-word* task. Results demonstrated that the introduction of an oral-motor component to a secondary task generates significant dual-task interference with gait, evidenced by the finding that the non-speech movement condition affected gait to a greater extent than the no-dual-tasking condition. Results also suggested that dual-task interference affects gait parameters to a significantly greater extent during the spoken-word condition as compared to the non-speech movement condition, but that there may be no significant difference in gait performance between the spoken non-word and non-speech movement conditions. These findings suggest that the addition of a speech component to a non-speech oral-movement task generates significantly greater dual-task effects on gait only if the speech component entails lexical complexity. Additionally, these findings lend support to the capacity-sharing model of dual-task interference, as the results demonstrate that primary task performance diminishes as the cognitive load of the secondary task increases. Interestingly, stimulus length was found not to impact gait parameters, with the authors suggesting the difference in length between the one and two syllable stimuli may not have been potent enough to produce a measurable effect.

1.7 Oral-Motor Movements involved in the Verbal Task

Although the stimuli utilized by Davie et al., 2012 were developed to control for articulatory complexity, phonemic components, and lexicality, it was identified that syllable structure was not balanced in the initial stimuli. To address this limitation, the stimuli were further refined and pilot tested in a sample of healthy young adults. Specifically the revised stimuli were developed with open-ended syllable structure for both the monosyllabic and bisyllabic conditions (i.e. a pattern of consonant and then vowel for each syllable). The set of phonemes used to create the list of stimuli was restricted only to phonemes that were easily visualized so as to facilitate proper imitation during the non-speech movement condition. To accomplish this level of control, Davie (2011) controlled the stimuli at a phonemic level, composing the bisyllabic stimuli from the same phonemes used in the monosyllabic stimuli. The non-word stimuli were further balanced by incorporating the four monosyllabic non-word stimuli an equal number of times in the bisyllabic non-word stimuli, once as the initial syllable and once as the final syllable. Finally, the stimuli used in the silent oral-motor movement condition were taken from the two spoken conditions such that the stimuli in the oral-motor movement condition were balanced equally with real-word and non-word stimuli. Therefore, the final set of stimuli were balanced across word length (i.e. number of syllables), lexicality (i.e. word versus non-word), and articulatory complexity.

1.8 The Present Investigation

Building on the work of Davie et al. (2012), this thesis used the refined stimuli developed by Davie (2011) to examine how healthy older adults and people with PD perform under dual-task conditions that involve a systematically manipulated secondary

verbal task. Through the use of an instrumented carpet and a biomechanical force plate, parameters of gait and balance were investigated during the simultaneous performance of a verbal task consisting of repeating the verbal stimuli described above. Due to the continuous rehearsal of the stimuli, and because their short length facilitates easy memorization, any observed dual-task interference derived from the performance of the secondary verbal task was attributed to the motoric or cognitive-linguistic demands of the words. Finally, visual inspection time was used to assess information processing speed. This measurement of information processing speed was important in demonstrating the extent to which interference of the secondary task is related to an individual's cognitive capacity.

1.9 Hypotheses

It was hypothesized that the PD participants would display more impaired gait and balance than the HOC participants under dual-task conditions. In particular, it was expected that the grouping factor would significantly interact with the secondary task condition factor within the analysis. Furthermore, in both groups it was expected that interference between the gait/balance task and verbal task would increase as motoric and cognitive-linguistic complexity was introduced, causing poorer performance on the gait and balance measures. Specifically, it was predicted that the silent oral-motor movement task would reduce gait performance compared to baseline. The non-word task was expected to further impair gait in comparison to the silent oral-motor task, due to the added verbalization entailed in speech (evoking articulatory and phonological processes). We also predicted that words would have a greater impact on gait and balance than non-words owing to the increased demand for attentional resources involved in cognitive-

linguistic processing during the meaningful word task. Finally, it was predicted that effects of dual-task interference would be highly correlated with information processing capacity of participants, and that this would be demonstrated through a substantive reduction in the effects of dual-task interference after the variability due to individual differences in information processing speed were removed from the model as a covariate.

Chapter 2: Methods

2.1 Participants

A total of 40 participants (20 individuals with idiopathic PD, and 20 age and sex-matched healthy controls) participated in this study. Healthy older adult participants without PD were recruited through the Retirement Research Association, a branch of The Canadian Centre for Activity and Aging at the University of Western Ontario. Individuals with PD were recruited to participate from the practice of a neurologist specializing in movement disorders. All diagnoses of PD were confirmed by this physician.

2.2 Inclusion / Exclusion Criteria

To be eligible for the study, participants were required to be over the age of 55, able to walk unassisted for a distance of 20 feet, not have any physical impairments that significantly affected their gait, and not have any speech or language disorders. Prior to participation, PD participants were evaluated by the neurologist using the Unified Parkinson's Disease Rating Scale (UPDRS), a standardized assessment that evaluates rigidity, tremor, slowness of movement, gait, and balance. Furthermore, the Hoehn and Yahr Staging Scale (HY) was used in conjunction with the UPDRS to measure stage of disease. The UPDRS is the most widely used measure to evaluate PD and has been shown to have high internal consistency and inter-rater reliability, with moderate construct validity (Ramaker, Marinus, Stiggelbout, & Van Hilten, 2002). The UPDRS has considerable clinical utility, and has been demonstrated to be a correlate of disease severity (Shulman et al., 2008). The HY was developed by Hoehn and Yahr (1967) and is widely used to evaluate the degree of disability from parkinsonism by rating patients on a 5-stage scale, mainly assessing the progression of postural instability. The HY has been

well-accepted by clinicians as the standard impairment rating scale and has demonstrated reliability and validity (Goetz et al., 2004).

PD participants were excluded (for safety reasons) if they displayed severe PD symptomology. The testing area was not equipped with a harness to prevent falls, and so only participants with mild to moderate PD severity were included in the study.

Specifically, individuals were excluded from the study if they were at a disease stage of 3 or higher on the Hoehn and Yahr staging scale. Furthermore, individuals were excluded if they presented any cognitive impairment, or neurological (other than PD) or orthopaedic conditions that impaired their gait or balance. Participants were provided with a letter of information detailing the study and written informed consent was obtained before the individual participated in the study. This study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario (protocol #16113E).

A total of ten females with PD, aged 56 to 72 ($M = 63.60$, $SD = 6.80$), ten males with PD, aged 62 to 85 ($M = 69.36$, $SD = 6.44$), ten healthy female controls without PD, aged 65 to 86 ($M = 73.80$, $SD = 6.29$), and ten healthy male controls without PD, aged 68 to 87 ($M = 76.30$, $SD = 5.64$) participated in the study. Table 2.1 provides descriptive statistics for all participants. All PD participants were on an optimal medication regimen (as determined by their neurologist), and were in the "on" phase of their medication cycle.

Table 2.1. Means (and Standard Deviations) for Participant Characteristics

Descriptives	Group		Mean (SD)
Age (years)	PD	Male	69.36 (6.44)
		Female	63.60 (6.80)
	HOC	Male	76.30 (5.64)
		Female	73.80 (6.29)
IT Score (ms)	PD	Male	126.61 (69.10)
		Female	114.00 (34.56)
	HOC	Male	116.55 (24.37)
		Female	102.36 (21.13)
UPDRS	PD	Male	23.00 (6.74)
		Female	20.90 (10.25)
HY	PD	Male	2.00 (0.00)
		Female	1.85 (0.47)

2.3 Procedure

All testing took place in the Interdisciplinary Movement Disorders Laboratory in Elborn College at the University of Western Ontario. Participants completed the study in a single testing session lasting for approximately 90 minutes. The testing procedure required participants to complete balance and gait testing under both single task (baseline, no secondary speech task), and dual task conditions (concurrent speech task), in addition to completing a computerized IT task.

The ordering of gait and balance testing was randomized, with half of the participants completing the gait testing first, and the other half completing balance testing

first. Completion of the IT exercise was also randomized, with half of the participants completing the IT exercise at the beginning of the testing procedure, and the remaining half completing the exercise at the end of the testing procedure. This counterbalancing was intended to account for the effects of fatigue and practice.

Although the labeling of the primary and secondary task in the dual-task paradigm is relatively arbitrary, the postural task will, for this study, be labeled as the primary task, given that the performance of this task (gait or balance) is most important to maintain due to the negative consequences entailed with the absence of postural stability. Accordingly, the verbal task is considered the secondary task.

Gait and balance testing each consisted of eight blocks of four trials each. Four blocks (baseline, the oral-motor movement condition, the non-word condition, and the word condition) were crossed with two syllable lengths (monosyllabic and bisyllabic) to create the eight separate blocks.

2.4 Gait Assessment

Spatial-temporal parameters of gait were measured using a 23-foot GAITRite® instrumented carpet. The GAITRite system has been found to be a reliable quantitative measurement of gait parameters in this population (Chien et al., 2006). For each trial, participants were instructed to continuously repeat the stimuli (either aloud or silently) while they walked along the GAITRite at a comfortable self-selected pace. The dependent variables included: velocity, step time, swing time, stance time, step length, single-limb support, double-limb support, and step-to step-variability (i.e. standard deviations) associated with each of these measures.

2.5 Balance Assessment

Quantitative assessment of postural stability during balance trials was done using a model OR6-5 biomechanics force platform (Advanced Mechanical Technology Inc., Watertown, USA). The force platform encompassed an aluminum plate embedded with electronic force sensors collecting data in the x-, y-, and z-axis. The data outputs were analyzed using the BioAnalysis software package (version 2.2). For each trial, participants were instructed to stand on the force platform in a comfortable stance (e.g., feet shoulder width apart), looking straight ahead with their arms hanging by their sides. For each trial, data was acquired at 100 Hz for 10 seconds, and during this time participants were instructed to remain standing as still as possible. For trials that involved dual tasking, participants were instructed to continuously repeat the stimuli (either aloud or silently) at a self-selected pace until instructed by the investigator that the trial was over. The dependent variable was the length of the centre of pressure pathway.

2.6 Secondary Cognitive Speech Task

The secondary cognitive speech task consisted of spoken and silent production of speech sounds, and represented the independent variable within this study. The speech stimuli used were developed and tested by Davie (2011). As outlined in Davie (2011), a restricted set of phonemes were selected to create the set of stimuli – only phonemes that were easily visualized were selected to facilitate proper imitation of the stimuli during the non-speech movement condition (Saarinen et al., 2006). The phonemes were arranged to create eight meaningful words and eight non-words (phoneme sequences that are plausible in English but do not actually form real words), and all stimuli are presented in Table 2.2. The set of phonemes were combined to form monosyllabic and bisyllabic

stimuli. Specifically, four monosyllabic words, four bisyllabic words, four monosyllabic non-words, and four bisyllabic non-words were used. The oral-motor movement condition contained a balanced mix of words and non-words in both the monosyllabic and bisyllabic conditions. To control phonemic complexity between the two different word lengths, the same speech sounds used to develop the monosyllabic stimuli were used to compose the bisyllabic stimuli.

To facilitate correct speech production, and articulation, the stimuli were presented to participants via an instructional video. At the beginning of each trial, participants viewed the instructional video that demonstrated the correct oral movements necessary to produce the specified stimulus (i.e., participants were not presented with the spelling of the stimuli). The video also served to inform the participants as to whether they were to recite the stimuli aloud or silently. The following is an example of the instructions that were read to participants at the beginning of each trial.

For this block of trials, we would like you to walk while mouthing the words we are about to show you, without speaking aloud.

Before each trial, we will show you a clip of a woman saying a word or non-word. This is the mouth movement that you should make (repeatedly) as you walk along the length of the carpet.

Upon listening to the instructions and viewing the video, participants were asked to repeat the stimulus aloud, thus affording investigators an opportunity to ensure the stimuli were being produced correctly. Similarly, throughout the course of each trial

investigators' continuously monitored participant production of stimuli to ensure correct imitation.

Table 2.2. Verbal Stimuli Used as Secondary Tasks

Condition	Monosyllabic	Bisyllabic
Non-Speech Motor	toe	today
	tay	taydee
	bay	photo
	foo	footay
Non-Word	tay	taydee
	foo	footay
	dee	deebaw
	baw	bawfoo
Word	toe	today
	bay	photo
	do	tofu
	fee	body

Note: These spellings provided are for illustrative purposes only – all words were pronounced aloud for participants without presenting any written information.

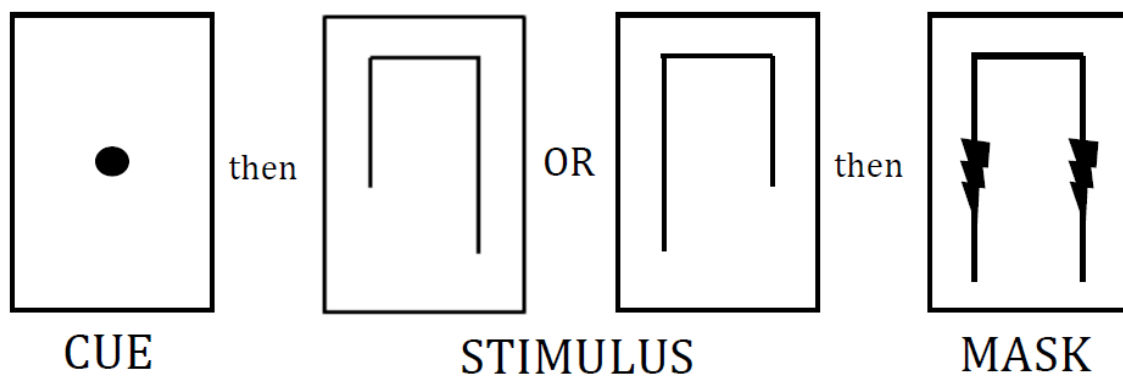
2.7 Inspection Time Exercise

IT is an estimate of information processing speed appropriate for a PD population

because, unlike most chronometric measures of information processing speed, it does not

rely on a motoric component. The motoric component of other chronometric indices of information processing speed, such as reaction time, would be a particularly serious confound in populations that have impaired movement. Administered on a 17-inch monitor (resolution 640 x 480 pixels), the task involved having participants examine the physical characteristics of a visual stimulus (two vertical lines connected at the top by a horizontal line) presented in a restricted time interval. Participants were instructed to inspect the stimulus and identify which of the lines was shorter (A. M. Johnson et al., 2004). The IT exercise is depicted in Figure 2.1. The cue, a small circle, was the first image displayed, for 500ms, in order to fix participants' attention to that particular area of the screen. Immediately following the cue, one of two stimuli was presented. The stimuli resemble the Greek letter *pi*; however, one of the vertical lines was shorter than the other, with the shorter leg being 21 mm in length and the longer leg 29 mm in length.

Figure 2.1 Inspection Time Exercise Stimuli, Adapted from Davie (2011)



The initial duration of stimulus presentation in the IT exercise was set at 120ms for all participants, and the duration of stimulus presentation was then varied according to an adaptive staircase algorithm based on the Parameter Estimation by Sequential Testing

method (PEST; Taylor & Creelman, 1967). The stimulus was immediately followed by a “lightning mask” (Stough et al., 2001) that remained on the screen for 360ms in each trial. This mask resembled the stimulus except the vertical lines were equal in length (set at 29 mm), and incorporated a symbol similar to that of a lightning bolt (see figure 2.1). The purpose of the mask was to ensure that the afterimage of the stimulus did not persist on the screen, and provide cues to the participant regarding the appropriate response. The duration of time between stimulus onset and mask onset represents the presentation time. IT is defined as the minimum length of exposure of the stimulus for an individual to reliably identify, at a threshold accuracy of 80%, which of the two lines is shorter. Participants were given instructions prior to the commencement of the exercise and were afforded time to practice, to ensure their familiarity with the IT task. Participants were allowed as many practice trials as needed to correctly identify ten consecutive stimuli at a presentation time set at 200ms. For participants who were still unable to reliably identify the stimulus by the third practice trial, presentation time was increased to 240ms. All participants were able to consecutively identify ten stimuli within 4 practice trials. In this study, IT was used to approximate participants’ information processing speed. The IT task was used to assess the extent to which interference of the secondary task is related to an individual’s cognitive capacity by including individuals’ differences in information processing speed as a covariate in the analysis of dual-task interference.

Lastly, participants wore an AKG C520 MicroMic Head-Worn microphone that rested upon their ears and was wired to a Zoom H4n Handy Recorder handset held in a hip pack. The pack did not interfere with comfortable gait. The audio recordings of the speech tasks will be analyzed in a subsequent study.

2.8 Statistical Analysis

Gait

All dependent variables were analyzed within a 4 x 2 x 2 split-plot multivariate analysis of variance (MANOVA), with condition (baseline, silent motor movement, non-word, and word) as a within-subjects factor, and group (HOC versus PD) and sex as between-subjects factors. Significant interactions were evaluated through the examination of simple main effects – for example, the significant condition-by-sex effect was evaluated using one-way MANOVAs on the condition factor, performed separately for men and women. Significant multivariate main effects were further investigated using univariate analyses, and were conducted without adjustment of the per-comparison alpha (Hummel & Sligo, 1971). Post hoc testing using repeated contrasts was conducted.

Step-to-step variability was evaluated within a similar 4 x 2 x 2 split-plot multivariate analysis of variance (MANOVA), with condition (baseline, silent motor movement, non-word, and word) as a within-subjects factor, and group (HOC versus PD) and sex as between-subjects factors. Univariate tests of significant multivariate main effects were conducted without adjustment of the per-comparison alpha (Hummel & Sligo, 1971).

Balance

Length of the centre-of-pressure pathway was analyzed within a 4 x 2 x 2 split plot ANOVA, with condition as the within-subjects factor and group and sex as the between subjects factors. Post hoc testing using repeated contrasts was performed.

Chapter 3: Results

3.1 Age Differences Between Groups

The difference in mean age between PD participants and HOC participants indicated that HOC participants were 8.43 years older than PD participants. This difference in age between the two groups was analyzed in an independent samples t-test, and this difference was found to be statistically significant [$t(38) = 4.178$, $p < 0.05$]. Given that dual-task interference is expected to increase with age (Lindenberger, Marsiske, & Baltes, 2000), and that information processing speed is similarly expected to decrease with age (Vernon, 1990), these group differences should serve to make group differences in dual-task interference more conservative. In other words, the increased age of the HOC participants should place them closer in performance to the PD participants. For this reason, we opted not to control for age differences within an analysis of covariance – this approach would only serve to reduce the variability within the sample, thereby artificially decreasing our ability to detect true differences within the analysis.

3.2 Analysis of Gait Variables

In the first set of analyses among the gait variables, five parameters of gait (velocity, step time, step length, single-limb support time, and double-limb support time) were analyzed within a 4 x 2 x 2 split-plot MANOVA, with condition as a within-subjects factor, and group and sex as between-subjects factors. Table 3.1 and 3.2 present descriptive statistics for these variables among individuals with PD and HOC, respectively.

Table 3.1. Means (and Standard Deviations) for Gait Variables by Condition, PD

Gait Parameter	Baseline	Non-Speech	Non-Word	Word
Velocity	116.3575	109.2750	109.9350	110.2525
(cm/s)	(17.10789)	(16.53090)	(16.92767)	(17.02549)
Step Time	0.5657	0.5878	0.5865	0.5871
(s)	(0.03653)	(0.04295)	(0.04377)	(0.04591)
Step Length	65.4336	63.7436	63.9904	64.1853
(cm)	(7.67906)	(7.41177)	(7.60384)	(7.38958)
Single Limb Support	0.4181	0.4316	0.4303	0.4307
(s)	(0.02593)	(0.02746)	(0.03087)	(0.02872)
Double-Limb Support	0.2969	0.3145	0.3154	0.3148
(s)	(0.04225)	(0.04810)	(0.04405)	(0.04877)

Table 3.2 Means (and Standard Deviations) for Gait Variables by Condition, HOC

Gait Parameter	Baseline	Non-Speech	Non-Word	Word
Velocity	132.6425	124.4625	126.4575	125.2525
(cm/s)	(12.41614)	(16.28721)	(15.87947)	(15.76540)
Step Time	0.5321	0.5541	0.5493	0.5520
(s)	(0.03937)	(0.05459)	(0.05286)	(0.05353)
Step Length	70.3590	68.2654	68.8499	68.5385
(cm)	(6.58164)	(6.42287)	(6.44179)	(6.45350)
Single Limb Support	0.4001	0.4120	0.4094	0.4115
(s)	(0.03240)	(0.03930)	(0.03747)	(0.03911)
Double-Limb Support	0.2667	0.2863	0.2832	0.2845
(s)	(0.02965)	(0.04419)	(0.04403)	(0.04419)

The multivariate effect of the three-way interaction of condition, group, and sex was not statistically significant [$F(15, 318) = 1.084$, $p > 0.05$, $\eta^2 = 0.049$], nor was the multivariate two-way interaction between group and condition [$F(15, 318) = 0.441$, $p > 0.05$, $\eta^2 = 0.020$]. However, the multivariate main effect of task was statistically

significant [$F(15, 318) = 4.140, p < 0.05, \eta^2 = 0.163$] as was the multivariate two-way interaction of sex by condition [$F(15, 318) = 1.876, p < 0.05, \eta^2 = 0.081$]. The significant condition by sex effect was further evaluated with one-way MANOVAs on the condition factor, performed for men and women separately.

The within-subjects repeated measures MANOVA among female participants showed that the multivariate main effect of condition remained statistically significant [$F(15, 165) = 2.135, p < 0.05, \eta^2 = 0.163$]. Table 3.3 presents the univariate effects on each dependent variable within the analysis.

Table 3.3

Univariate Effects for the Main Effect of Condition, Females Only

Gait Parameter	F(3,57)	p	Partial η^2
Velocity	7.512	0.001	0.283
Step Time	6.741	0.001	0.262
Step Length	5.156	0.003	0.213
Single Limb Support	3.621	0.018	0.160
Double-Limb Support	12.373	0.001	0.394

Univariate effects were statistically significant for each dependent variable within the analysis, suggesting that significant differences between conditions were identified for each variable. Post hoc testing using repeated contrasts are presented in Table 3.4 (for women only). Repeated contrasts indicated a significant difference ($p < 0.05$) between the baseline and oral-motor movement condition for each dependent variable. The

directionality of the change in each parameter is reported as mean gait decrement in the table. Non-statistically significant differences ($p > 0.05$) were found for both the non-speech and non-word condition comparison and the non-word and word condition comparison. The non-speech oral motor task compared to baseline was the only significant comparison between conditions, and all gait variables reported significant changes: gait velocity decreased, step time increased, step length decreased, single limb support increased, and double limb support increased.

Table 3.4

Post Hoc Comparisons Using Repeated Contrasts Within the Condition Factor.

F-Ratios (and Partial Eta-Squares), [Mean Gait Decrement], Women Only

Gait Parameter	1. Baseline vs. 2. Non-speech	1. Non-speech vs. 2. Non-word	1. Non-word vs. 2. Word
Velocity	*19.026 (0.500) [− 6.220]	0.228 (0.012) [0.680]	0.240 (0.012) [0.785]
Step Time	*13.707 (0.419) [0.0191]	0.397 (0.020) [− 0.0023]	0.275 (0.014) [− 0.0024]
Step Length	*13.493 (0.415) [− 1.270]	0.002 (0.000) [0.0190]	0.259 (0.013) [0.213]
Single Limb Support	*8.070 (0.298) [0.0098]	0.514 (0.026) [− 0.0016]	0.220 (0.011) [− 0.0015]
Double-Limb Support	*21.331 (0.529) [0.0187]	0.003 (0.000) [− 0.0002]	0.604 (0.031) [− 0.0025]

Gait decrement calculated using the formula: decrement = Condition 2 – Condition 1

The within-subjects repeated measures MANOVA among male participants parallels the results of the analysis of female participants. The multivariate main effect of condition was statistically significant [$F(15, 165) = 3.283$, $p < 0.05$, $\eta^2 = 0.230$] and the effect size was greater in men than in women. Similarly, all univariate tests were statistically significant (details are presented in Table 3.5).

Table 3.5

Univariate Effects for the Main Effect of Condition, Men Only

Gait Parameter	F(3,54)	p	Partial η^2
Velocity	19.656	0.001	0.508
Step Time	12.129	0.001	0.390
Step Length	12.095	0.001	0.389
Single Limb Support	9.071	0.001	0.323
Double-Limb Support	13.691	0.001	0.419

Post hoc comparisons using repeated contrasts are presented in Table 3.6 for men only. Results of the repeated contrasts parallel the results among women, with the baseline and non-speech comparison exhibiting statistically significant differences across all gait parameters. However, both men's gait velocity and step time were significantly different between the non-word and word condition. Comparing the non-speech

Table 3.6

Post Hoc Comparisons Using Repeated Contrasts Within the Condition Factor.

F-Ratios (and Partial Eta-Squares), [Mean Gait Decrement], Men Only

Gait Parameter	1. Baseline vs. 2. Non-speech	1. Non-speech vs. 2. Non-word	1. Non-word vs. 2. Word
Velocity	*25.200 (0.570) [− 9.043]	2.988 (0.136) [1.975]	*7.457 (0.282) [− 1.673]
Step Time	*17.528 (0.480) [0.0251]	1.186 (0.059) [−0.0038]	*4.481 (0.191) [0.0057]
Step Length	*22.341 (0.540) [− 2.513]	3.766 (0.165) [0.812]	2.368 (0.111) [− 0.329]
Single Limb Support	*16.332 (0.462) [0.0156]	0.985 (0.049) [− 0.0024]	2.775 (0.127) [0.004]
Double-Limb Support	*14.478 (0.432) [0.0185]	0.476 (0.024) [− 0.002]	4.151 (0.179) [0.0033]

Gait decrement calculated using the formula: decrement = Condition 2 – Condition 1

condition to baseline indicated that gait velocity decreased, step time increased, step length decreased, and both single limb support and double limb support increased. The significant gait decrements that occurred in the comparison between the word and non-word condition followed a similar pattern in which gait velocity decreased and step time increased during the word dual-task condition versus the non-word condition.

The impact of information processing speed on dual-tasking conditions was explored by including IT as a covariate in the one-way multivariate analysis of covariance on the condition factor done separately for each sex. Interestingly, in both sexes the previously noted multivariate main effect of condition was no longer present (i.e. not statistically significant, $p > 0.05$) when the variability accounted for by IT was removed. No other interaction effects were statistically significant.

In the second set of analyses among the gait variables, step-to-step variability was evaluated for the same parameters of gait discussed earlier (step time, step length, single limb support, and double-limb support). The standard deviations of these variables were analyzed within a $4 \times 2 \times 2$ split-plot MANOVA, in which condition (baseline, silent motor movement, non-word, and word) was a within-subjects factor, and both group (HOC or PD), and sex were between-subjects factors. Table 3.7 presents descriptive statistics for these variables among PD participants, and Table 3.8 presents descriptive statistics for these variables among the HOC participants.

Table 3.7
Means (and Standard Deviations) for Step-To-Step Gait Variability Variables by Condition, PD Only

Parameter	Baseline	Non-Speech	Non-Word	Word
Step Time SD	0.0197 (.00510)	0.0211 (.00586)	0.0207 (.00696)	0.0220 (.00730)
Step Length SD	2.2900 (.51698)	2.2570 (.57569)	2.2716 (.75282)	2.2396 (.63777)
Single Limb Support SD	0.0187 (.00394)	0.0208 (.00460)	0.0204 (.00579)	0.0217 (.00579)
Double-Limb Support SD	0.0224 (.00393)	0.0234 (.00510)	0.0233 (.00620)	0.0244 (.00629)

Table 3.8
Means (and Standard Deviations) for Step-To-Step Gait Variability Variables by Condition, HOC Only

Parameter	Baseline	Non-Speech	Non-Word	Word
Step Time SD	0.0143 (0.00150)	0.0174 (0.00629)	0.0169 (0.00447)	0.0177 (0.00435)
Step Length SD	2.1097 (0.83088)	2.1370 (0.66089)	2.2352 (1.06862)	2.1409 (0.68311)
Single Limb Support SD	0.0151 (0.00291)	0.0174 (0.00332)	0.0175 (0.00334)	0.0180 (0.00416)
Double-Limb Support SD	0.0204 (0.00370)	0.0207 (0.00404)	0.0209 (0.00441)	0.0216 (0.00322)

The multivariate effect of the three-way interaction of task, group, and sex was not statistically significant [$F(12, 321) = 1.187, p > 0.05, \eta^2 = 0.042$]. Neither the multivariate two-way interaction of task by group [$F(12, 321) = 0.344, p > 0.05, \eta^2 = 0.013$], nor the multivariate task by sex two-way interaction were statistically significant [$F(12, 321) = 0.883, p > 0.05, \eta^2 = 0.032$]. None of the univariate tests for these interactions were statistically significant, after controlling for multiple comparison bias using a Bonferroni correction.

The multivariate main effect of task was, however, statistically significant [$F(12, 321) = 2.335, p < 0.05, \eta^2 = 0.080$], and so the univariate tests of this main effect were conducted without adjustment of the per-comparison alpha (Hummel & Sligo, 1971). These univariate results are presented in Table 3.9. The univariate tests indicated that only step time variability and single limb support variability were significantly impacted under dual-task conditions.

Table 3.9

Univariate Effects for the Main Effect of Condition on Step-To-Step Variability

Parameters

Gait Parameter	F(3,108)	p	Partial η^2
Step Time SD	3.831	0.012	0.096
Step Length SD	0.188	0.905	0.005
Single Limb Support SD	9.689	0.001	0.212
Double-Limb Support SD	1.451	0.232	0.039

3.3 Analysis of Balance Variables

The effect of performing the secondary speech tasks while maintaining a steady stance was analysed in a 4 x 2 x 2 split plot ANOVA, with condition as the within-subjects factor and group and sex as the between subjects factors. Mean centre of pressure length (COPL) was recorded as the dependent variable. Table 3.10 provides descriptive statistics for COPL separated by group.

The main effect of condition was significant [$F(3, 108) = 8.286, p < 0.05, \eta^2 = 0.187$]. The multivariate interaction effect between condition, group, and sex was not statistically significant [$F(3, 108) = 0.809, p > 0.05, \eta^2 = 0.022$], and neither was the two-way interaction between sex and condition [$F(3, 108) = 2.375, p > 0.05, \eta^2 = 0.062$] nor the multivariate two-way interaction of group by condition [$F(3, 108) = 2.354, p > 0.05, \eta^2 = 0.061$] statistically significant.

Table 3.10

Means (and Standard Deviations) For Mean Centre of Pressure Length
Across Condition, in Centimeters.

Group	Baseline	Non-Speech	Non-Word	Word
PD	16.051	21.004	21.131	21.829
	(5.653)	(13.561)	(10.695)	(12.980)
HOC	16.051	16.549	18.071	18.359
	(3.683)	(4.857)	(5.414)	(6.444)

Post hoc testing using repeated contrasts was performed. Repeated contrasts indicated a statistically significant difference ($F = 5.766, p < 0.05, \eta^2 = 0.138$) between

the baseline condition and the non-speech condition. No significant differences ($p > 0.05$) between the non-speech and non-word condition or the non-word and word condition were identified.

Information processing speed as estimated by IT was included as a covariate in the 4x2x2 split-plot ANOVA to investigate the explanatory power of the capacity sharing model of dual-task interference. The main effect of condition remained statistically significant [$F(3, 105) = 4.594, p < 0.05, \eta^2 = 0.116$] and the interaction effect between condition and IT was also significant [$F(3, 105) = 7.624, p < 0.05, \eta^2 = 0.179$].

Chapter 4: Discussion

Most dual-task interference research has been conducted in older populations (Bootsma-van der Wiel et al., 2003) and among cognitively or neurologically impaired populations (e.g., Camicioli, Oken, Sexton, Kaye, & Nutt, 1998; O'Shea, Morris, & Iansek, 2002). A variety of secondary tasks have been investigated in these dual-task studies involving gait and balance, but only one previous study has deconstructed a speech-language secondary task in order to evaluate its elemental components (Davie et al., 2012). Meanwhile, few dual-task studies have examined the cognitive mechanisms underlying dual-task interference. Through the use of methodologies developed and tested by Davie (2011), this thesis utilizes a stimulus set deconstructing a secondary verbal task allowing for the consideration of speech and language contributions to dual-task interference among individuals with PD and healthy older controls without PD, while also evaluating the explanatory power of the capacity-sharing model of dual-task interference by controlling for individual cognitive differences.

Many dual-task studies have employed secondary tasks involving speech/language components such as word generation tasks (Bootsma-van der Wiel et al., 2003), digit subtraction tasks (O'Shea et al., 2002)), and engaging participants in spontaneous conversation (Lundin-Olsson et al., 1997). However, each of these studies lack consideration for the components of speech involved in the verbal-cognitive tasks. Verbal communication is so pervasive in our daily lives that it is often overlooked as an attention-demanding behaviour. Davie et al. (2012) was the first to evaluate the extent to which speech and language, inherent in a secondary verbal task, interfere with a primary static or dynamic balance task. This thesis builds upon the research by Davie (2011) by replicating the methodology within a neurologically impaired population and comparing

the results to an otherwise healthy older population. The verbal task was systematically manipulated to present successively complex speech and language combinations to tease out their corresponding effects on dual-task interference. The components isolated in the verbal task were: motoric involvement, articulation, and lexical complexity.

Previous research involving secondary verbal tasks (Armieri et al., 2009; Dault et al., 2003; Yardley et al., 1999) have highlighted the impact of secondary speech tasks on gait and balance, but have not sufficiently made the separation between non-speech motor movements of a verbal task and its articulatory component. Most recently, Armieri et al. (2009) performed a study in which participants memorized digit spans of varying length (i.e. manipulating complexity) and either rehearsed the span aloud or silently (i.e. manipulating articulation). The authors demonstrated that speaking aloud (as opposed to silently) contributes to dual-task interference. Although attempting to separate non-speech motor movement from the articulatory component of a verbal task, the digit span task does not actually take into account all of the oral-motor and articulatory processes involved in the performance of the speech task. The increase in interference reported by Armieri and colleagues may have resulted from the oral-motor demands inherent in the articulation component and *not* speech production, since motor demands for articulating a specific number differs for each number (e.g. the number “two” requires different oral movements in comparison to the number “four”).

Accordingly, Davie (2011) extended the research by Armieri et al. (2009) by developing stimuli in which the articulatory complexity was controlled for by utilizing a fixed set of phonemes, by maintaining a stable vowel/consonant structure, and by limiting the stimuli to one or two syllables. Finally, a separate factor was isolated in the stimuli by

incorporating a spoken non-word condition and a spoken word condition. In doing so, the researchers were able to evaluate the lexical demands of the secondary verbal task.

Another key contribution to the literature made by Davie (2011) involved controlling for individual differences in cognition as a means to test the capacity-sharing model of dual-task interference. Davie used a measure of information processing speed that did not involve a motor response and that was completely separate from the dual-task study. Measures of information processing speed that require a motor response may be confounded by movement speed, especially in a motorically impaired population such as PD patients. Davie was able to account for individual differences in cognitive capacity and therefore able to remove the associated variability from the analysis, leaving the oral motor, speech, and cognitive-linguistic effects intact. This method for evaluating and controlling individual differences in information processing speed was replicated in this thesis.

This study was conducted in order to observe how healthy older adults and people with PD perform under dual-task conditions involving a systematically manipulated secondary verbal task. Davie (2011) demonstrated that dual-task interference affects the gait and balance performance of young adults, but reasoned that the reduction in the performance of these two tasks were unlikely to elicit an increased risk for falls within that population. In a study of dual-task interference among older adults by Lundin-Olsson et al. (1997), the authors reported a phenomenon they called ‘stops walking while talking’. The authors found that older adults who tend to stop walking when spontaneously engaged in conversation are significantly more likely to be fallers (individuals that have fallen within the previous six months). These findings suggest that individuals with a reduced capacity to perform two concurrent tasks face an increased

risk of falling in their daily lives, since dual-tasking is so pervasive throughout activities of daily living. Therefore, this thesis examines the effect speech and language has on gait and balance in a movement impaired population in comparison to healthy older adults.

It was hypothesized that the PD participants' gait and balance would be more impaired than that of the HOC participants under dual-task conditions resulting from a greater interference experienced by the PD patients. It was also expected that increases in the difficulty of the verbal task would produce successively greater gait and balance impairments in both groups, and the resulting interference would place the PD participants, in particular, at a greater risk of falling due to their disordered movement.

Although a sample of age-matched controls without PD was sought, the demographics indicated that the HOC group was older than the PD participants. Given that dual-task interference has been shown to increase with age (Lindenberger et al., 2000), this group difference, although significant, was judged to not compromise the results as the difference should make the analysis more conservative when identifying true differences between groups on the gait and balance tasks. Moreover, information processing speed is expected to decrease with age, meaning that the HOC group was expected to have a reduced cognitive capacity, further contributing to a more conservative analysis of dual-task interference. Although the difference in age between the two groups was significant, the variability accounted for by age as a covariate indicated age did not interact with the secondary task conditions or with any other factor. Thus, to remove the variability associated with age would only serve to reduce the ability to detect true differences between groups. The decision was therefore made not to control for age in subsequent analyses.

The resulting analyses indicated that the grouping factor did not significantly interact with the condition factor during the gait or balance trials, contradicting our hypothesis. Although this lack of interaction between group and condition could be a result of the conservativeness of the analysis, it is perhaps more interesting to consider that both groups experience a similar amount of interference under dual-task conditions, thereby explaining this finding. The capacity-sharing model of dual-task interference suggests that interference is dependent upon the individual's finite amount of cognitive resources; the more attentional capacity an individual has to allocate to performing two tasks the less interference will result. This model also contends that interference is likely to be more profound when the individual's attentional capacity is overwhelmed. Perhaps the difficulty of the secondary verbal task in this study was not sufficiently attention-demanding as to overwhelm either group. With this understanding of dual-task interference, both groups experienced similar interference and a similar decrement in gait performance.

The five gait parameters measured in this thesis were velocity, step time, step length, single-limb support, and double-limb support. In the first analysis of gait performed, the multivariate main effect of task was significant as was the multivariate two-way interaction between sex and condition. This two-way interaction indicated that in both sexes the secondary cognitive speech task significantly interfered with gait as the complexity of the speech task varied. The completely within-subjects repeated measures MANOVA done separately for each sex was performed to further explore the significant multivariate two-way interaction between condition and sex to identify the directionality of the differences and if they followed the hypotheses.

Results of this analysis support the findings by Davie (2011) in that both sexes demonstrated significant dual-task interference. However, in contrast to findings by Davie (2011) who reported women experienced significantly greater gait impairment than men, the results of the current investigation indicate that male participants demonstrated greater gait impairment under dual-task conditions. Specifically, men's gait speed and step length decreased and their step time increased more so than their female counterparts. Davie proposed that women may be more likely to employ a posture-first strategy when faced with dual-task conditions (i.e. women demonstrate a greater propensity to reduce gait speed and shorten step length while performing a secondary verbal task). However, in this study among older adults, the women demonstrated less dual-task interference. This sex difference may be a result of a combination of factors.

Women may be more accustomed to performing two simultaneous tasks in their daily lives, thereby unconsciously learning to perform two concurrent tasks and diminishing the interference between the two tasks. In doing so, women would be reducing their susceptibility to dual-task interference, allowing them to better maintain their gait under dual-task conditions. Future research is warranted to investigate dual-task training differences between men and women. For example, women may be unintentionally engaged in dual task training during their activities of daily living, gaining experience with dual-tasking, thereby affording them a better ability to learn how to dual-task more safely.

Alternatively, men and women may prioritize tasks to a different degree. Although both men and women's gait parameters changed in the same direction, the effect was larger among men. This may indicate that while both sexes engaged in a posture-first strategy, the men may have employed this strategy to a greater extent. This

contradicts the findings by Davie (2011) in a sample of young adults in which women demonstrated a greater effect size. However, in a meta-analysis of 150 studies by Byrnes, Miller, and Schafer (1999), the authors determined that younger men tended to engage in more risk taking behaviour than women, but this gender gap decreased with increasing age. This suggests that the younger men participating in Davie's study may have engaged in a more risky performance of the two tasks, opting not to prioritize the postural task to the extent that the women did. However, in the current study, the older men may have adopted a more conservative behaviour than women by prioritizing the postural task to a greater degree to avoid instability. Future research should investigate the merit of this interpretation.

Post hoc testing done in each sex identified that the baseline (single task walking condition) was significantly different from the non-speech condition for all gait parameters for both men and women. This finding supports the conclusions made by Davie et al. (2012) in that the introduction of an oral-motor articulatory gesture as a secondary verbal task produces the largest amount of dual-task interference with gait. In addition, men's gait velocity and step time were significantly different between the non-word and word condition. However, the majority of gait parameters were not incrementally affected by any of the conditions beyond the non-speech movement condition. This suggests that, after introducing the non-speech movement condition as a secondary verbal task, the conditions that were hypothesized to be increasingly difficult (spoken non-word task and spoken word task) were not sufficiently complex to elicit significant changes in gait properties during any dual-task situations except for gait velocity and step time, during the spoken word task in men. In other words, the addition of spoken phonological gestures to oral-motor demands did not produce a significant

increase in dual-task interference, with the exception of gait velocity and step time in men – and even then, only with the added lexical complexity of the spoken real-word condition.

The aforementioned contradicts the results of Armieri et al. (2009) as they reported that speech contributes significantly to dual-task interference. However, the methodology employed by Armieri and colleagues did not account for actual oral-motor and articulatory processes inherent in verbally producing digits and so this difference may not be completely due to speech. Although it is possible that our non-significant findings may be related to issues of power in the analysis, our results suggests that speaking aloud has no additional impact on dual-task interference beyond the interference effects created by the motor demands of the secondary speech task. Davie (2011) suggests that researchers should take care when interpreting the effects of a secondary verbal task because these studies may essentially involve “triple-tasking”. Studies incorporating a verbal task should take into consideration that this task involves oral-motor activity to produce the words and cognitive activity due to the lexical processing (involved in producing real words), in addition to a separate task (presumably gait or balance). The fact that men experienced reduced gait speed and increased step time when speaking real words when compared to non-words, supports this finding.

The analysis of step-to-step variability parameters indicated there was significant dual-task interference, but that this interference was no different among individuals with PD than in the comparison group. Gait variability as a result of dual-task interference also did not present a sex effect; gait variability in both men and women was impacted similarly. These results are particularly interesting in the context of research that suggests that step-to-step variability is a significant predictor of falls. Because gait is impaired in

the PD population, an increase in their gait variability was expected when compared to the HOC group. This lack of group differences may be explained by the fact that the comparison group was sufficiently old that their gait performance was similar to that of the PD group. In addition, this study was limited to a sample of individuals with mild to moderate PD in which gait impairment may not be as substantial as within a group of moderate to severe PD patients. Future research should be conducted in a more severely impaired PD population to determine dual-task interference effects in this more vulnerable group.

In the analysis of oral-motor movement, articulation, and cognitive-linguistic complexity on balance, the mean centre of pressure length significantly increased under dual-task conditions, indicating substantial interference between the balance task and the secondary verbal task. No group or sex differences were found. Similar to the findings by Davie (2011), this significant increase in dual-task interference was produced when oral-motor demands were introduced as a secondary verbal task. However, there was no increase in dual-task interference with balance that correlated with the introduction of phonological speech production or with increases in lexical complexity of the stimuli. It was expected that older adults, and especially PD participants that experience greater postural instability, would experience increased interference as compared to the young adult sample studied by Davie when the complexity of the verbal task increased. In particular, Davie (2011) reported a reduction in balance performance when lexical demand was introduced within the secondary verbal task. This was not supported by the results of the current study, even within a population with increased balance instability, and lower cognitive capacity relative to the healthy young adult sample Davie studied.

Relatively new to the literature, this study also incorporated a measure of cognitive capacity. In the gait study, the findings indicated that when individual differences in information processing speed were covaried out of the analysis, statistically significant effects of dual-task interference were completely removed. These findings support Davie's (2011) conclusion that information processing speed consistently accounts for a significant amount of dual-task interference in gait. Similar to Davie (2011), these results further support the notion that dual-task interference may be almost completely dependent upon an individual's information processing capacity, providing substantial support for the capacity-sharing model of dual-task interference; the findings in this thesis supports the merit of interpreting dual-task interference as a competition between two tasks for limited attentional resources.

The results of this thesis also support the findings by Davie (2011) in that it is possible to predict the level of dual-task interference experienced by an individual through an evaluation of his/her performance on a measure of information processing speed. The benefit of such a procedure is two-fold. First, the ease of performing a simple, non-motoric measure of cognitive speed can easily be conducted in a small environment with minimal equipment. Such testing would be particularly beneficial to the PD population for example, whose typical gait and balance performance is closer to the limit of safe gait/balance performance and therefore at an increased risk for falling. Every effort should be made to ensure their safety and well-being. By identifying PD patients most at risk for dual-task interference through a simple IT exercise, clinicians can effectively educate them and instruct them to avoid dual-task conditions that may place them at risk for falls. Before this can take place, however, accurate and reliable testing will need to be in place. Diagnostic threshold studies will need to be conducted in order

to determine the direct correlation between information processing speed and level of dual-tasking risk.

Secondly, this thesis supports the fact that commonly neglected tasks such as verbal communication can substantially impact gait and balance. Due to the frequency of dual-tasking in everyday life, individuals at elevated risk for falling should be educated on the potential risks of interference between two tasks. In doing so, these individuals can be equipped with the knowledge to consciously avoid such situations or to correctly prioritize competing tasks to ensure their safety. Clinicians and caregivers can use these findings to educate patients regardless of age or gait impairment on the dangers of dual-task interference since it affects people of all ages and gait patterns.

4.1 Study Limitations

There were various notable limitations to the present study. First is the matter of task prioritization. Although participants were asked to walk (or stand) while also repeating the stimuli (prioritizing the postural task first), the instructions provided before each block could also be argued to have prioritized the verbal task first since more time was spent detailing the verbal task. Because poor performance of a postural task may have immediate negative ramifications, namely increased risk of falling, we were more interested in participants' gait and balance. Future research in this discipline may benefit from clearly identifying the task priorities. Second, this study is limited by the significant difference in age between the PD group and the HOC group. A consequence of this age difference is the increased difficulty to identify true differences between groups. Finally, the inclusion of meaningful words in the silent oral-motor condition may have introduced greater cognitive processing than the non-words also included in this set of stimuli. This is particularly important because the stimuli were spoken aloud in the video played at the

beginning of each trial, which may have evoked phonological processing by the participants during the trials. Future research would benefit from using similar stimuli that are easily visualized but only play the video clip without audio to avoid this complication.

4.2 Conclusion

Building on the work of Davie et al., this thesis uses the refined stimuli to examine how healthy older adults and people with PD perform under dual-task conditions involving a systematically manipulated secondary verbal task. A systematically manipulated secondary verbal task significantly interfered with gait and balance among a sample of individuals with PD and among a sample of healthy older adults without PD. Oral-motor demands of speech produced the greatest amount dual-task interference with gait and balance, while speech did not significantly increase further interference. Lexical processing associated with producing real words did significantly impair some parameters of gait, but this was only reported in men. Finally, this study also demonstrates that dual-task interference may be almost completely dependent upon an individual's information processing speed.

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APPENDIX: ETHICS CERTIFICATES



Use of Human Participants - Ethics Approval Notice

Principal Investigator: Andrew Johnson
Review Number: 16113E
Review Level: Delegated
Approved Local Adult Participants: 135
Approved Local Minor Participants: 0
Protocol Title: The impact of non-speech mouth movements, speech pseudo-words, and speech on spatial-temporal parameters of gait and posture.
Department & Institution: Schulich School of Medicine & Dentistry, University of Western Ontario
Sponsor:
Ethics Approval Date: April 08, 2011 **Expiry Date:** June 30, 2014
Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Revised UWO Protocol	The researcher will now conduct audio recordings of the speech sounds produced during the gait and posture tasks.	
Revised Letter of Information & Consent	Version 3	2011/03/17

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research

Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Ethics Officer to Contact for Further Information

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Office of Research Ethics

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 Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
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Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. A.M. Johnson

Review Number: 16113E

Review Level: Expedited

Review Date: April 22, 2009

Protocol Title: The impact of non-speech mouth movements, speech pseudo-words, and speech on spatial-temporal parameters of gait

Department and Institution: Faculty of Health Sciences, University of Western Ontario

Sponsor:

Ethics Approval Date: June 17, 2009

Expiry Date: June 30, 2014

Documents Reviewed and Approved: UWO Protocol, Letter of Information and Consent, Advertisement

Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

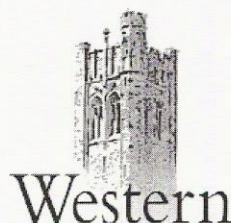
Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

Chair of HSREB: Dr. Joseph Gilbert

Ethics Officer to Contact for Further Information

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cc: ORE File
LHRI



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 Website: www.uwo.ca/research/ethics

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. A.M. Johnson **Review Level:** Expedited
Review Number: 16113E **Revision Number:** 1
Review Date: July 08, 2010 **Approved Local # of Participants:** 120
Protocol Title: The impact of non-speech mouth movements, speech pseudo-words, and speech on spatial-temporal parameters of gait and posture.
Department and Institution: Faculty of Health Sciences, University of Western Ontario
Sponsor:
Ethics Approval Date: August 16, 2010 **Expiry Date:** June 30, 2014
Documents Reviewed and Approved: Revised study instruments, number of study participants and letter of information and consent.
Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

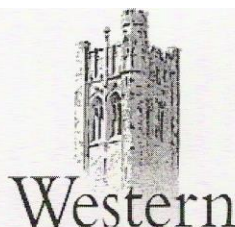
Chair of HSREB: Dr. Joseph Gilbert
 FDA Ref. #: IRB 00000940

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 Website: www.uwo.ca/research/ethics

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. A.M. Johnson

Review Level: Expedited

Review Number: 16113E

Revision Number: 2

Review Date: November 23, 2010

Approved Local # of Participants: 135

Protocol Title: The impact of non-speech mouth movements, speech pseudo-words, and speech on spatial-temporal parameters of gait and posture.

Department and Institution: Faculty of Health Sciences, University of Western Ontario

Sponsor:

Ethics Approval Date: November 23, 2010

Expiry Date: June 30, 2014

Documents Reviewed and Approved: Revised number of study participants.

Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

Chair of HSREB: Dr. Joseph Gilbert
 FDA Ref. #: IRB 00000940

Ethics Officer to Contact for Further Information

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This is an official document. Please retain the original in your files.

cc: ORE File
 LHRI

LAWSON HEALTH RESEARCH INSTITUTE**FINAL APPROVAL NOTICE**

RESEARCH OFFICE REVIEW NO.: R-10-505

PROJECT TITLE: The impact of non-speech mouth movements, speech pseudo-words, and speech on spatial-temporal parameters of gait

PRINCIPAL INVESTIGATOR: Dr. A Johnson

DATE OF REVIEW BY CRIC: October 5, 2010

Health Sciences REB#: 16113E

Please be advised that the above project was reviewed by the Clinical Research Impact Committee and the project:

Was Approved

PLEASE INFORM THE APPROPRIATE NURSING UNITS, LABORATORIES, ETC. BEFORE STARTING THIS PROTOCOL. THE RESEARCH OFFICE NUMBER MUST BE USED WHEN COMMUNICATING WITH THESE AREAS.

Dr. David Hill
V.P. Research
Lawson Health Research Institute

All future correspondence concerning this study should include the Research Office Review Number and should be directed to Sherry Paiva, CRIC Liaison, LHSC, Rm. C210, Nurses Residence, South Street Hospital.

cc: Administration

CURRICULUM VITAE

EDUCATION:

MSc, Measurement and Methods, University of Western Ontario, commenced September 2011 (ongoing)

BHSc (Hons Spec.), University of Western Ontario, 2011

EMPLOYMENT:

Date	Position
June 2012 – present	Research Project Coordinator – Dr. Heather Laschinger Arthur Labatt School of Nursing
Jan 2013 – April 2013	Teaching Assistant – Social Determinants of Health (First year undergraduate course)
Jan 2012 – Feb 2012	Research Assistant – Interdisciplinary Movement Disorders Laboratory
Sept 2011 – Dec 2011	Teaching Assistant – Research Methods and Analysis (Third year undergraduate course)

HONOURS AND AWARDS:

- 2011 **Graduation with distinction** (awarded to students who have achieved an overall average of 80%, with no grade lower than 70% on the entire program, and have not failed any courses), BHSc (Hons Spec.), The University of Western Ontario
- 2011 **Gold medal** (awarded to the student with the highest average, 80% or greater, in their Honors Specialization module), BHSc (Hons Spec.), The University of Western Ontario
- 2008-2011 Dean's Honor List, BHSc (Hons Spec.), The University of Western Ontario

PUBLICATIONS:

- Johnson, A.M., Holmes, J.D., **Wood, K.**, & Jenkins, M.E. (2012). The hidden cost of cognition: Examining the link between dual-task interference and falls. *Journal of Current Clinical Care*, 3, 33-43.