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THE EFFECT OF WORD LENGTH, ORAL-MOTOR MOVEMENT, ARTICULATION, AND LEXICALITY ON GAIT AND BALANCE

Krista Davie

THE EFFECT OF WORD LENGTH, ORAL-MOTOR MOVEMENT, ARTICULATION, AND LEXICALITY ON GAIT AND BALANCE

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Krista Davie

Graduate Program in Health and Rehabilitation Sciences

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

THE UNIVERSITY OF WESTERN ONTARIO
School of Graduate and Postdoctoral Studies

CERTIFICATE OF EXAMINATION

Joint-Supervisor

____

Dr. Andrew Johnson

Joint-Supervisor

____

Dr. Janis Oram Cardy

Supervisory Committee

____

Dr. Marilyn Kertoy

____

Dr. Jeffrey Holmes

Examiners

____

Dr. Marilyn Kertoy

____

Dr. J.B. Orange

____

Dr. Riley Hinson

The thesis by

Krista Davie

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Date: ______________________

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Chair of the Thesis Examination Board

ABSTRACT

Performing two tasks in dual-task situations is a requirement in activities of daily living. An inability to dual-task is demonstrated generally by diminished performance on one or both of the tasks. Performing a verbal task can produce a reduced ability to perform a gait task and to maintain balance. Impairment on either of these postural tasks can increase the likelihood of falling, particularly among older adults. Dual-task interference has been demonstrated to be significantly impacted by a number of characteristics of secondary verbal tasks (including dimensions of both motoric and cognitive complexity). Previous studies have not, however, exerted sufficient control over articulation or cognitive-linguistic processing, within the secondary task. The studies presented in this thesis used a dual-task paradigm that manipulated word length, oral-motor movement, articulation, and lexicality, within a verbal task, while assessing the affects of dual-task interference on both gait and balance. A sample of healthy young adults (pilot study: 15 women; gait and balance studies: 20 women and 20 men) were asked to repeat a series of verbal stimuli while walking approximately 6m, and while maintaining an independent upright posture for 10 seconds at a time. Participants also were asked to complete a test of perceptual speed, as an indicator of information processing speed, separate from the dual-task protocol. Results suggest that oral-motor movement, articulation, and lexicality had unique effects on dual-task performance, with women demonstrating significantly more dual-task interference than men. Furthermore, results suggested that the ability to dual-task is directly related to an individual's information processing capacity. Results supported the capacity-sharing model of dual-task interference.

Keywords: dual-task interference, articulation, oral-motor movement, lexicality, gait, balance, information processing speed

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This work is dedicated to my brother Jeff, whose life and spirit will always inspire me to accomplish my goals and to continue to dream.

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CHAPTER 1

Introduction

Introduction to Dual-Task Interference

Performing two tasks at one time, or *dual-tasking*, is a common requirement within activities of daily living. There are numerous benefits to being able to perform simultaneously a variety of different tasks, regardless of whether they are motor, verbal, or cognitive. For example, the ability to dual-task successfully enables individuals to communicate with others while walking, transport objects from one place to another (i.e., carry an object and walk), and monitor the surrounding environment while walking, standing, or performing other complex behaviors (O'Shea, Morris, & Iansek, 2002).

Dual-tasking often is completed unconsciously due to the ubiquity of its involvement in our daily lives. As a result, an individual who is dual-tasking is likely to be unaware of the potential impact that *dual-task interference* may have on his or her ability to successfully complete one (or both) of the tasks. Dual-task interference is defined as the decline, in performance or accuracy, of one (or both) of two tasks being performed simultaneously (Woollacott & Shumway-Cook, 2002). Dual-task interference occurs when cognitive capacity (be it attention, or information processing speed) is constrained by competing tasks. Although it is possible that any division of an individual's cognitive resources may result in interference, this interference is especially likely to occur when the capacity limits of that individual's cognitive system are exceeded or overwhelmed (Pashler, 1994).

To study dual-task interference, researchers require participants to perform two or more tasks concurrently. Dual-task paradigms are most commonly used to examine the attentional demands of gait (Allali, et al., 2007; Armieri, Holmes, Spaulding, Jenkins, & Johnson, 2009; O'Shea, et al., 2002), but also have been used in studies of posture (Dault, Yardley, & Frank, 2003; Holmes, Jenkins, Johnson, Adams, & Spaulding, 2010; Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997; Yardley, Gardner, Leadbetter, & Lavie, 1999). Regardless of the exact cognitive mechanisms that are proposed to explain interference effects, dual-task paradigms are based on the theory that the more challenging (and therefore demanding) the primary task, the fewer the resources available for allocation to performance of the secondary task.

Measurement of Dual-Task Interference

Within dual-task experimental paradigms, one of the tasks is designated the *primary task*, and the other is designated the *secondary task*. Although the distinction between primary and secondary tasks is largely arbitrary, in most studies of the effect of dual-task interference on gait and posture, it is the gait or posture task that is considered to be the primary task, owing to the fact that the primary task is generally the task that is considered to be more automatic in nature. Movements that are learned and automatic are thought to be controlled by the basal ganglia, which allow attention to be directed to controlling more novel or attention-demanding tasks (the secondary tasks, within a dual-tasking study) by the frontal cortical regions. Dual-task interference becomes increasingly problematic as the automaticity of either or both of the primary or secondary tasks is reduced, with the largest effect being seen from varying the automaticity of the secondary task (O'Shea, et al., 2002).

It is particularly important to examine dual-task scenarios that involve gait and/or posture because these scenarios have a great potential for risk of harm, due to the increased probability of falls and injury. Often, the first way that people with balance or motor issues compensate for perceived dual-task interference is to stop performing one task until they complete the other task. This can be either an adaptive or a maladaptive strategy, depending upon whether or not the individual chooses to prioritize the task that involves physical risk. For example, it is adaptive for an individual experiencing an unacceptable level of dual-task interference to discontinue a primarily verbal task (e.g., talking) while performing a primarily motor task (e.g., walking). Conversely, it is potentially maladaptive (i.e., dangerous) if that individual continues to perform the verbal task at a deficit to multiple spatial-temporal parameters of their motor task, especially if that deficit creates a loss of control.

When individuals adapt in order to maintain the components of a motor task over a verbal task, these individuals are adopting what is called a *posture-first* strategy. This strategy would result in a decrease in performance on a cognitive task, but the safety of the individual would be maintained. This strategy would therefore be considered adaptive (Shumway-Cook, et al., 1997). A *posture-second* strategy, in which the individual sacrifices performance on the postural task in favor of the cognitive (or other secondary) task, may place the individual at greater risk. This is due to valuable resources being allocated to the cognitive task, which could possibly leave the motor task to show greater deficits, and therefore place the individual at a greater risk for falling (for a review, see Johnson, et al., 2009).

Various research studies have been conducted on simultaneous performance of either motor or cognitive tasks while performing a posture task (Holmes, et al., 2010; Kerr, Condon, & McDonald, 1985; Pellecchia, 2003). Some of this previous research focused on testing populations with a movement disorder. These protocols frequently tested balance by examining postural instability on the basis of changes in stance position or time before demonstrated need for external support (e.g., Morris, Iansek, Smithson, & Huxham, 2000; Smithson, Morris, & Iansek, 1998), while more recent research incorporated biomechanical measurements of postural sway (Holmes, et al., 2010), and limb support (Marchese, Bove, & Abbruzzese, 2003). Dual-task interference of a concurrent task performed with a balance task has been examined using a number of different cognitive and motor secondary tasks (Kerr, et al., 1985; Morris, et al., 2000). Previous research has demonstrated that successive increases of the complexity of a concurrent cognitive task has shown a direct impact on postural instability (Pellecchia, 2003). This research demonstrates a direct relationship between the performance and regulation of a motor task, while using the same mechanisms to regulate a simultaneous cognitive task (Pellecchia, 2003; Teasdale, Bard, LaRue, & Fleury, 1993).

Models of Dual-Task Interference

The cognitive mechanisms surrounding dual-task interference remain somewhat equivocal, with competing models having been developed to account for previous research findings (Klingberg, 1998). The three models of dual-task interference that are most widely supported in the literature are (in no particular order): (a) *the bottleneck model* (Pashler, 1994; Welford, 1967) (b) *the cross-talk model* (Kinsbourne, 1981; O'Shea, et al., 2002; Pashler, 1994); and (c) *the capacity-sharing model* (Broadbent, 1958; Kahneman, 1973; Navon & Grophe, 1979; Norman & Brobow, 1975; Pashler, 1994).

The *bottleneck model* takes a structural perspective in explaining the effects of dual-task interference, in that it is based on the availability of the neural pathways for allocation of available cognitive resources (Pashler, 1994; Wickens, 1980). In the bottleneck model, it is the type of tasks that are being performed simultaneously that affects performance, not the resources available to perform the tasks (Pashler, 1994). Proponents of this model suggest that interference occurs when two concurrent tasks require resources from similar categories of information (Broadbent, 1958; Huang & Mercer, 2001). When the system is attempting to access information in order to complete the required tasks, the same pathway is required in order to retrieve the same type of information for both tasks, thus resulting in a slowdown (or impairment) in task performance (Pashler, 1994). Conversely, the theory predicts that there would be reduced interference when the two tasks are accessing different types of cognitive resources.

The *cross-talk model* also is a structural model of dual-task interference. It is similar to the bottleneck model in that it explains dual-task interference based on the neural pathways that are used to allocate the cognitive resources necessary for completing a task. Unlike the bottleneck model, however, the cross-talk model suggests that interference is reduced, and performance accordingly enhanced, when two similar tasks are performed (Kinsbourne, 1981; Pashler, 1994). Under this theory, it is suggested that when the cognitive system uses the same neural pathways, the system works more efficiently, by using fewer of the available resources (Allali, et al., 2007; O'Shea, et al., 2002; Pashler, 1994).

Unlike the bottleneck and cross-talk models, the *capacity-sharing* model of dual-task interference suggests that dual-task interference is exacerbated by a reduction in overall system capacity (i.e., when fewer cognitive resources are available to the task at hand; O'Shea, et al., 2002). Introduction of a secondary task is thought to overwhelm processing resources, and the magnitude of the deterioration is thought to be proportional to increasing complexity, or decreasing automaticity, of the secondary task (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998). Proponents of this model suggest that interference is a direct result of central overload of a limited system, when two tasks are competing simultaneously for the same set of resources (Huang & Mercer, 2001). Accordingly, with the capacity of the central processing system exceeded, performance on one (or both) of the tasks is correspondingly impaired (Navon, 1977; Pashler, 1994). Under this theory, performance on a secondary task may be considered to be a direct quantification of residual cognitive capacity (Posner & Boies, 1971).

Previous research that has been conducted to examine the capacity-sharing model has focused mainly on the *psychological refractory period* seen in tests of reaction time (Fitts & Peterson, 1964; McLeod, 1977; Navon & Miller, 2002; Tolkmitt, 1972). The psychological refractory period is the delay that is typically observed when an individual is forced to react to two stimuli (thereby making two responses) that are presented close together. Generally speaking, the psychological refractory period increases as time between tasks decreases. The capacity-sharing model can also be evaluated by assessing information processing speed directly, through the use of a *probe reaction time task* (Johnson, Forester, Calderwood, & Weisgerber, 1983; Ogden, Martin, & Paap, 1980; Posner & Boies, 1971). In this task, an individual must determine whether two successively presented stimuli, such as letters, are identical by making a rapid button push response shortly after the second letter appears. The speed at which this decision can be made is representative of the individual's information processing speed. Given that both of these measurements of information processing speed can be conducted outside the dual-task paradigm itself, it is possible to assess directly the extent to which the interference of the secondary task is related to an individual's system capacity, by including information processing speed as a covariate in an analysis of dual-task interference. Ideally, this measurement should be done using a method that is not confounded by motoric speed – either through the separation of response selection and response execution (Johnson, Vernon, Almeida, Grantier, & Jog, 2003), or through the use of entirely non-motoric chronometric measurements, such as *inspection time*. Inspection time is a measure of the minimum length of time that a stimulus can be presented before participants can no longer reliably identify it's characteristics (Johnson, et al., 2004). After covarying out the effects of information processing speed in this fashion, any remaining variance left in the model would represent the variability in dual-task interference that is not related to an individual's information processing capacity. To the best of my knowledge, this has not been described within the published literature.

Dual-Task Interference and Articulation

No cognitive task is more basic to activities of daily living than having the ability to communicate with others (O'Keefe, 1996). The ubiquity of spoken language is clearly evident when assessing cognitive performance using virtually any verbal task. Verbal tasks present a number of demands, including the fact that spoken language is comprised of many unique cognitive and motoric determinants. Most of the previous dual-task research that has used a verbal secondary task has not carefully considered the *articulatory demands* of the verbal task. For example, this limitation was evident in Pellechia's (2003, 2005) manipulations of digits and digit recall and when Holmes et al. (2010) asked participants to recite digits and to engage in a monologue task. When the articulatory demands of a verbal task are not well controlled, verbal cognitive function (language) is confounded with the motor demands of speech production (articulation). A few investigators have begun to examine the role of articulation in dual-task paradigms in which participants perform motor and verbal tasks simultaneously. To date, these studies have suggested that when a verbal task is introduced as the secondary task, articulatory demands become important predictors of the impact of dual-task interference on spatial-temporal parameters of gait.

Yardley and colleagues (1999) investigated the impact of verbal secondary task demands in a sample of 36 healthy volunteers aged 18 to 47. They employed a force platform to examine *postural sway*, which was operationalized as the movement of one's centre of pressure in both the anterior/posterior and medial/lateral planes. These researchers also examined the movement of the participants centre of mass using a 3D tracking system. Participants were evaluated under four different conditions: (a) repeating a random number aloud, (b) counting backwards silently by multiples of sevens, (c) counting backwards aloud by multiples of seven, and (d) performing no concurrent mental task. The silent condition involved no subvocalization, so there were no oral movements performed during the completion of the task. Results revealed that repeating a random number and counting aloud had the same effect, while counting silently showed no effect on postural sway. These findings suggested that balance is affected by articulation and not just (verbal) mental activity.

Dault and colleagues (2003) extended the work of Yardley et al. (1999) by increasing the number of dimensions used in the assessment of postural sway. Healthy young individuals were tested while seated, while standing on a stable force plate, and while standing on an unstable force plate. Secondary tasks were then performed either orally or silently, with the latter condition intended to eliminate the influence of articulation. The *silent* task required the participant to listen to prerecorded "letter sounds" that spelled out a nonsense phrase. Participants were not required to repeat the phrase that they had memorized until after the trial. The silent condition was therefore intended to maximize cognitive load while eliminating any effect of articulation (Dault, et al., 2003). The *articulation* task required the participant to repeat each individual letter immediately after it was presented, thereby reducing cognitive load by avoiding memory demands. The *combination* task combined both the silent and the articulation tasks, requiring individuals to repeat the letters as they were presented and to hold the letters in working memory in order to repeat them at the end of the task. Both tasks that involved articulation (the articulation and the combination tasks) led to an increase in frequency of sway, suggesting that there is some aspect of the act of articulation that increases postural sway, beyond simple cognitive complexity of the task.

Both of the above studies examined articulation as the motor speech movement component of a secondary verbal task. Armieri and colleagues (2009) further examined the effects of cognitive load on gait, while focusing on the additional cognitive demands that are inherent to performing a verbal task. To this end, they manipulated complexity and articulation within a single working memory task (a digit span task). Participants were required to memorize a non-repeating sequence of digits of varying length (i.e., complexity), and to rehearse this sequence either aloud or silently, during the performance of the gait task. The results showed a significant interaction between complexity and articulation, with articulation having more of an effect at higher levels of complexity. This suggests that it is important to manipulate carefully stimulus properties, in order to deconstruct correctly the effects of cognitive complexity and articulatory complexity inherent to verbal tasks.

All three of these studies demonstrate the importance of controlling the articulatory demands of a verbal task within a dual-task paradigm. However, all three studies demonstrate a similar limitation, namely, a lack of control over the motoric complexity of the phonemes involved in the digits (or letters) that were spoken aloud. When these phonemes were combined in varying orders, the mouth movements that participants were required to complete were never consistent in place or manner of articulation.

Controlling the Motor Components of the Verbal Task

Producing speech involves both a language component and a motor-speech component, namely, *phonology* (i.e., access to the phonemes or units of sound of the language) and *articulation* (i.e., the complex and dynamic neuromuscular process of producing speech sounds). Although these are separate components that contribute very differently to verbal output, the motor component (articulation) cannot be completely separated from the cognitive/linguistic (phonological) component. Saarinen et al. (2006) examined the localized areas of the brain that are involved in deconstructed components of a verbal task. Using magnetoencaphalography (MEG), they compared kinetically similar speech and non-speech oral movements that were either one item or four items in length. Non-speech movements were chosen to be natural and easily visualized gestures such as touching the teeth with the tongue or making a kissing movement. Substituting phonemes from speech sequences with these mouth movements formed the non-speech sequences. Results revealed involvement of the primary motor cortex, not only in the activation of the facial muscles involved in motor-speech movements, but also with the functional cognitive processes involved in control of these visually triggered mouth movements (Salmelin & Sams, 2002). This study also demonstrated that it is possible to teach individuals to perform individual mouth movements in isolation (i.e., out of the context of a meaningful word or syllable). This will prove important within the present research, as individuals will be required to perform (non-speech) oral-motor movements throughout the performance of gait and balance tasks.

Armieri et al. (2009) were able to demonstrate that the act of speaking aloud contributes significantly to dual-task interference, even when balancing the cognitive demands of the task between conditions. It is possible, however, that the increase in interference found by the authors could have been produced by the oral-motor demands of the articulation component of the task (rather than speech per se), and so it is of interest to further deconstruct the oral-motor demands of the task. Their longer digit spans required more oral-motor involvement than their shorter spans. More importantly, there are potential differences in the motor demands of articulating particular numbers within the digit spans (e.g., the number "one" involves different motor demands as compared with the number "five"). Therefore, it is important to balance carefully the motor-speech demands, and the phonological influences, of the spoken syllables within the stimuli. Furthermore, it is important that the cognitive complexity of the spoken targets within the verbal task be carefully controlled and balanced.

In order to control better the verbal task, a number of controls can be introduced among the presented stimulus words. Firstly, the stimuli can be balanced at the phonemic level, to allow for a careful control of the motoric complexity of the stimuli. Secondly, stimuli can be balanced in terms of length (i.e., number of syllables). This not only manipulates the motoric complexity of the stimulus, but (potentially) the cognitive complexity of the verbal task (e.g., bisyllabic words may be considered to be one increment more complex than monosyllabic words from a memory perspective, based on longer word length and more combinations of phonemes). Thirdly, stimuli can be balanced in terms of cognitive-linguistic complexity, by arranging the elemental phonemes into words and non-words. Although words and non-words should both create similar phonological demands, words may be expected to trigger additional semantic processing relative to non-words, thereby making them more cognitively complex. To allow for a balance in motoric and memory demands between the words and the non-words, the non-words can be a rearrangement of the same phonemes and syllable structure used for the cognate word stimuli. Taken together, these manipulations provide the experimenter with good control over both oral-motor and cognitive complexity.

Developing the Stimuli for the Present Research

A key contribution of the present research is the methodology used to create well-balanced (motorically and cognitively) speech stimuli that may be used in a dual-task paradigm with a secondary speech task. The secondary speech task within this study was broken down into two word lengths (bisyllabic versus monosyllabic) across four conditions: baseline (gait only); silent oral-motor movement; spoken non-word; and spoken word. Sixteen stimuli were created in total (four monosyllabic non-words, four bisyllabic non-words, four monosyllabic words, and four bisyllabic words). These stimuli were pilot-tested in a sample of 15 young women (and the results of this pilot study are presented as Study 1 in Chapter 2). Although the stimuli generated statistically significant and interpretable results, the verbal stimuli were re-examined and revised, in order to control better for both articulatory and phonemic components of the verbal task, specifically the syllable structure. These revised stimuli were used in a study of gait (presented as Study 2 in Chapter 2) and a study of balance (presented in Chapter 3).

The initial stimulus words lacked balance in the syllable structure, insofar as the consonant (C) and vowel (V) combinations were not evenly balanced in their position within the word/non-word. The placement of vowels and consonants is important because it changes the articulatory gestures that are performed in the production of the specific word. In order to better control for syllable structure, all monosyllabic words were re-worked in the revised stimulus list, so that they were composed of an open-ended syllable structure (i.e. CV), while bisyllabic stimuli were recast to be CVCV. The phoneme set that was used in the initial stimulus set was carried over to the set of phonemes that was used in the revised stimuli. Specifically, the phoneme set was restricted to those phonemes that are easy to visualize (e.g., bilabial, labiodental, and alveolar consonants; vowels with lip rounding or retraction) in order to facilitate correct imitation in the non-speech movement condition. Consonant use was restricted to phonemes that, when combined with the chosen vowel set, would provide both non-word and real word combinations in monosyllabic forms. For example, when combining the consonant /n/ with the available vowel set, it resulted in the following set of candidate stimuli: /ni/, /ne/, /nu/, /nɔ/ and /no/, that is, *knee, neigh, new, gnaw* and *no*. Since the consonant /n/ provided no options for non-words, it was eliminated from the set of consonants that would be used to develop the stimuli. This also occurred with the consonants /p/, /m/, /v/, and /l/. The remaining consonants that were available for use were therefore /b/, /f/, /t/, and /d/.

In attempting to balance the stimuli, an attempt was made to have each of the four stimuli, in each level, begin with one of the four consonants. Due to the lack of available monosyllabic real word combinations, this proved quite challenging when trying to develop the bisyllabic real words. For example, I was unable to create a real bisyllabic word that began with the phoneme /d/. Due to this limitation, I decided to begin two of the bisyllabic real words with the phoneme /t/, since /t/ and /d/ are voiced and voiceless cognates. Other than this one exception, the resultant stimuli were all balanced across word length (i.e., number of syllables) and lexicality (i.e., word versus non-word). Our main goal in creating the new stimuli was to exert complete control over the stimuli at the phonemic level. This resulted in the stimuli at the bisyllabic level being composed of the same phonemes used at the monosyllabic level. When creating the bisyllabic stimuli at the non-word level, I further balanced the stimuli by using the four monosyllabic non-word stimuli once as both the initial syllable and the final syllable. This resulted in each of the four monosyllabic non-word stimuli being used an equal number of times in each position.

The Present Research

The present research evaluated the extent to which gait (assessed using an instrumented carpet) and balance (assessed using a biomechanical force platform) are impacted by a verbal task that involved repeating the previously described verbal stimuli. These stimuli are, by virtue of both their length (either one or two syllables) and their continuous rehearsal, easily remembered, and so any dual-task interference that occurs as a result of the performance of the secondary task is likely to be due to the motoric or cognitive-linguistic demands of the words.

The present research also involved a direct assessment of the capacity-sharing model, through the use of an information processing speed task that was administered separately from the dual-tasks. The task that was chosen was an inspection time (IT) task. IT is a simple information-processing paradigm that is described as a measure of perceptual speed. It is intended to reflect the ability of an individual to identify physical properties of stimuli when they are presented at a limited time interval (Nettelbeck, 1982). IT has been shown to estimate levels of information processing speed in individuals, and which has further been linked to certain aspects of intellectual ability (Brody, 2001; Deary & Stough, 1996). In this way, IT measures can be considered as direct indicators of information processing speed that are distinct from reaction time tasks, in that they do not measure the time required to select and execute a motor response (Johnson, et al., 2004). This independence of IT and speed of motor output is critical when considering the information-processing speed of populations in which it would be beneficial to remove (as much as possible) any motoric demands of the task. This may include individuals with Parkinson's disease (Johnson, et al., 2004) and older adults who experience difficulties with upper limb movement that may be unrelated to their information processing speed deficits (Deary, Hunter, Langan, & Goodwin, 1991). Because the current research has the potential for future applications with these groups of individuals, it was important to make this consideration of motoric demands when selecting our measure of cognitive speed.

This research builds upon that of Armieri et al. (2009), by further deconstructing the language, speech, and motor components of verbalization in dual-task interference. In Chapter Two, I examine the effects of these aspects of verbalization on parameters of gait, while in Chapter Three, I examine their effects on balance. The goal of this research is to evaluate the extent to which selected parameters (i.e., word length, motoric involvement, vocalization, and lexical complexity) contribute to the dual-task interference demonstrated by the participants. To this end, two different word lengths were used (monosyllabic words versus bisyllabic words), and four conditions were presented: (a) baseline (no secondary speech task); (b) non-speech movement (wherein movement of the articulatory structures such as lips, tongue, and jaw is required of the participant, in the absence of speech); (c) spoken non-word (in which a speech component was added to the motoric demands by asking the participant to repeat a nonsense word); and (d) spoken word (in which lexical demands were added to the speech and motor demands of the task by asking the participant to repeat a meaningful word).

These eight blocks of stimuli (i.e., 2 levels of word length crossed with 4 conditions) were presented randomly to participants for use in both gait and balance trials.
The oral-motor complexity of the stimuli was balanced by constructing both the words and the non-words with the same phonemes (and combinations of phonemes), and constructing silent oral-motor movements based on the articulatory gestures associated with these same phonemes. Through this control of the motor-speech component and manipulation of linguistic (semantic, phonological), speech, and cognitive demands, I was able to determine which component(s) of the verbal task had the greatest effect on the gait and balance tasks.

Hypotheses and Predictions

I hypothesize that increasing levels of complexity (both motoric and cognitive-linguistic) across the three levels will have successively greater interference effects on both gait and balance. In particular, I hypothesize that words will have a greater effect on gait and balance than non-words, due to the fact that individuals will engage in more cognitive-linguistic processing while implicitly parsing the meanings of, and connections with, the stimulus words. I predict that words and non-words spoken aloud will have a greater effect on gait and balance than silent movement of the articulators, due to added motor (speech) and linguistic (phonological) demands of verbalization. I also predict that longer words/gestures will have a greater effect on gait and balance than shorter items due to the increased cognitive load of the longer span. Finally, I predict that the removal of the effects of information-processing speed (i.e., by covarying inspection time within the model) will produce substantive effects on dual-task interference, thereby providing direct evidence for the capacity-sharing model of dual-task interference.

References

Allali, G., Kressig, R.W., Assal, F., Herrmann, F.R., Dubost, V., & Beauchet, O. (2007). Changes in gait while backward counting in demented older adults with frontal lobe dysfunction. *Gait and Posture, 26(4)*, 572-576.

Armieri, A., Holmes, J.D., Spaulding, S.J., Jenkins, M.E., & Johnson, A.M. (2009). Dual task performance in a healthy young adult population: Results from a symmetric manipulation of task complexity and articulation. *Gait and Posture, 29*, 346-348.

Broadbent, D. (1958). *Perception and Communication*. London: Pergamon Press.

Brody, N. (2001). Inspection time: Past, present, and future. *Intelligence, 29*, 537-541.

Camicioli, R., Oken, B.S., Sexton, G., Kaye, J.A., & Nutt, J.G. (1998). Verbal fluency task affects gait in Parkinson's disease with motor freezing. *Journal of Geriatric Psychiatry and Neurology, 11(4)*, 181-185.

Dault, M.C., Yardley, L., & Frank, J.S. (2003). Does articulation contribute to modifications of postural control during dual-task paradigms? *Brain Research. Cognitive Brain Research, 16(3)*, 434-440.

Deary, I.J., Hunter, R., Langan, S.J., & Goodwin, G.M. (1991). Inspection time, psychometric intelligence and clinical estimates of cognitive ability in pre-senile Alzheimer's disease and Korsakoff's psychosis. *Brain, 114 (Pt 6)*, 2543-2554.

Deary, I.J., & Stough, C. (1996). Intelligence and inspection time: Achievements, prospects, and problems. *American Psychologist, 51(6)*, 599-608.

Fitts, P.M., & Peterson, J.R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67*, 103-112.

Holmes, J.D., Jenkins, M.E., Johnson, A.M., Adams, S.G., & Spaulding, S.J. (2010). Dual-task interference: The effects of verbal cognitive tasks on upright postural stability in Parkinson's disease. *Parkinson's Disease, 10.4061/2010/696492.*

Huang, H.J., & Mercer, V.S. (2001). Dual-task methodology: applications in studies of cognitive and motor performance in adults and children. *Pediatric Physical Therapy, 13(3)*, 133-140.

Johnson, A.M., Almeida, Q.J., Stough, C., Thompson, J.C., Singarayer, R., & Jog, M.S. (2004). Visual inspection time in Parkinson's disease: Deficits in early stages of cognitive processing. *Neuropsychologia, 42(5)*, 577-583.

Johnson, A.M., Armieri, A., Holmes, J.D., Grau, A.L., Jenkins, M.E., & Spaulding, S.J. (2009). Metacognition and metamovement: Links between cognition and motor function in Parkinson's disease. In C. B. Larson (Ed.), *Metacognition: New research and developments* (pp. 43-58). Hauppauge, NY: Nova Science Publishers.

Johnson, A.M., Vernon, P.A., Almeida, Q.J., Grantier, L., & Jog, M.S. (2003). A role of the basal ganglia in movement: The effect of directional precues on discrete bi-directional movements in Parkinson's disease. *Motor Control, 7*, 71-81.

Johnson, P.J., Forester, J.A., Calderwood, R., & Weisgerber, S.A. (1983). Resource allocation and the attentional demands of letter encoding. *Journal of Experimental Psychology, 112(4)*, 616-638.

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

Kerr, B., Condon, S.M., & McDonald, L.A. (1985). Cognitive spatial processing and the regulation of posture. *Journal of Experimental Psychology: Human Perception and Performance, 11(5)*, 617-622.

Kinsbourne, M. (1981). Single-channel theory. In D. Holding (Ed.), *Human Skills* (pp. 65-89). New York: Wiley.

Klingberg, T. (1998). Concurrent performance of two working memory tasks: potential mechanisms of interference. *Cerebral Cortex, 8(7)*, 593-601.

Marchese, R., Bove, M., & Abbruzzese, G. (2003). Effect of cognitive and motor tasks on postural stability in Parkinson's disease: a posturographic study. *Movement Disorders, 18(6)*, 652-658.

McLeod, P. (1977). Parallel processing and the psychological refractory period. *Acta Psychologica, 41*, 381-391.

Morris, M., Iansek, R., Smithson, F., & Huxham, F. (2000). Postural instability in Parkinson's disease: a comparison with and without a concurrent task. *Gait and Posture, 12(3)*, 205-216.

Navon, D. (1977). Forest before the trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*, 353-383.

Navon, D., & Grophe, D. (1979). On the economy of the human processing system. *Psychological Review, 86*, 254-284.

Navon, D., & Miller, J. (2002). Queuing or sharing? A critical evaluation of the single-bottleneck notion. *Cognitive Psychology, 44*, 193-251.

Nettelbeck, T. (1982). Inspection time: an index for intelligence? *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 34(2)*, 299-312.

Norman, D., & Brobow, D. (1975). On data-limited and resource-limited processing. *Cognitive Psychology, 7*, 44-60.

O'Keefe, B.M. (1996). Communication disorders: Just minor inconveniences? In R. Renwick (Ed.), *Quality of Life in Health Promotion and Rehabilitation: Conceptual Approaches, Issues, and Applications* (pp. 219-236). Thousand Oaks, CA: Sage Publications.

O'Shea, S., Morris, M.E., & Iansek, R. (2002). Dual task interference during gait in people with Parkinson's disease: Effects of motor versus cognitive secondary tasks. *Physical Therapy, 82(9)*, 888-897.

Ogden, W.C., Martin, D.W., & Paap, K.R. (1980). Processing demands of encoding: What does secondary task performance reflect? *Journal of Experimental Psychology: Human Perception and Performance, 6(2)*, 355-367.

Pashler, H. (1994). Dual-task interference in simple tasks: data and theory. *Psychological Bulletin, 116(2)*, 220-244.

Pellecchia, G.L. (2003). Postural sway increases with attentional demands of concurrent cognitive task. *Gait and Posture, 18(1)*, 29-34.

Pellecchia, G.L. (2005). Dual-task training reduces impact of cognitive task on postural sway. *Journal of Motor Behavior, 37(3)*, 239-246.

Posner, M.I., & Boies, S.J. (1971). Components of attention. *Psychological Review, 78(5)*, 391-408.

Saarinen, T., Laaksonen, H., Parviainen, T., & Salmelin, R. (2006). Motor cortex dynamics in visuomotor production of speech and non-speech mouth movements. *Cerebral Cortex.*

Salmelin, R., & Sams, M. (2002). Motor cortex involvement during verbal versus non-verbal lip and tongue movements. *Human Brain Mapping, 16(2)*, 81-91.

Shumway-Cook, A., Woollacott, M., Kerns, K.A., & Baldwin, M. (1997). The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 52(4)*, M232-240.

Smithson, F., Morris, M.E., & Iansek, R. (1998). Performance on clinical tests of balance in Parkinson's disease. *Physical Therapy, 78(6)*, 577-592.

Teasdale, N., Bard, C., LaRue, J., & Fleury, M. (1993). On the cognitive penetrability of posture control. *Experimental Aging Research, 19(1)*, 1-13.

Tolkmitt, F.L. (1972). A revision of the psychological refractory period. *Acta Psychologica, 37*, 139-154.

Welford, A.T. (1967). Single-channel operation in the brain. *Acta Psychologica, 27*, 5-22.

Wickens, C.D. (1980). The structure of attentional resources. In R. Nickerson (Ed.), *Attention and Performance* (Vol. 8, pp. 239-257). Hillsdale, NJ: Erlbaum.

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

Yardley, L., Gardner, M., Leadbetter, A., & Lavie, N. (1999). Effect of articulatory and mental tasks on postural control. *Neuroreport, 10(2)*, 215-219.

CHAPTER 2

The Effects of Word Length, Articulation, Oral-Motor Movement, and Lexicality on Gait[1]

Dual-task interference results in a decline in performance or accuracy, on one (or both) of two tasks that are performed simultaneously (Woollacott & Shumway-Cook, 2002). Introduction of a secondary task may overwhelm processing resources, and the magnitude of the deterioration is likely to be proportional to the complexity of the secondary motor task (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998). Previous research has suggested that when a verbal task is introduced as the secondary task, articulatory demands become important predictors of the impact of dual-task interference on spatial-temporal parameters of gait (Armieri, Holmes, Spaulding, Jenkins, & Johnson, 2009). Armieri and colleagues (2009) examined this by crossing complexity with articulation within a verbal memory-scanning task (digit memorization). Their results suggested that the effects of complexity are most pronounced under conditions of articulation (as opposed to silent rehearsal). Although these researchers demonstrated that the act of speaking aloud contributes significantly to the dual-task interference, they did not provide information as to whether the increase in interference was produced by motor-speech (as opposed to linguistic) demands of the task, and did not manipulate the cognitive-linguistic complexity of the verbalizations themselves.

The capacity-sharing model of dual-task interference suggests that individuals are likely to experience dual-task interference under conditions in which there is an overall reduction in the cognitive capacity of the system (i.e., performance is impacted when there

[1] A version of this chapter is being prepared for resubmission to *Gait and Posture*, as a full-length research article.

are fewer resources available to allocate to either task; O'Shea, Morris, & Iansek, 2002). Previous research that has been conducted to examine the capacity-sharing model has focused mainly on the *psychological refractory period* seen in tests of reaction time (Fitts & Peterson, 1964; McLeod, 1977; Navon & Miller, 2002; Tolkmitt, 1972). The psychological refractory period is the delay that is typically observed when an individual is forced to react to two stimuli (thereby making two responses) that are presented close together. Generally speaking, the psychological refractory period increases as time between tasks decreases. The capacity-sharing model also can be evaluated using a *probe reaction time task* (Johnson, Forester, Calderwood, & Weisgerber, 1983; Ogden, Martin, & Paap, 1980; Posner & Boies, 1971). In this task, an individual must determine whether two successively presented stimuli, such as letters, are identical by making a rapid button push response shortly after the second letter appears. Both of these approaches are based on a measurement of information processing speed (via the length of the refractory period, or the speed of reaction time). If we consider that performance on a secondary task may be considered to be a direct quantification of residual cognitive capacity (Posner & Boies, 1971), it is feasible to evaluate the impact of system capacity on dual-task interference, by statistically controlling information processing speed within a dual-task protocol, as might be done by including information processing speed as a covariate in an analysis of dual-task interference. To the best of my knowledge, this analysis has not been described within the published literature.

Ideally, information processing speed should be measured using a task that is not confounded by motoric speed – either through the separation of reaction time (response selection) and movement time (response execution), or through the use of inspection time measures that are entirely non-motoric (Johnson, et al., 2004; Johnson, Vernon, Almeida, Grantier, & Jog, 2003). After covarying out the effects of information processing speed in this fashion, any remaining variance left in the model would represent the variability in dual-task interference that is not related to an individual's information processing capacity.

In this chapter, I present two studies, both of which examine the effects of oral-motor, articulatory, and lexical demands of a verbal task, on temporal and spatial parameters of gait. Both studies build upon the research of Armieri et al. (2009), by further deconstructing the language, speech, and motor components of verbalization. The goal of this research was to evaluate the extent to which word length, motoric involvement, vocalization, and lexical complexity contribute to the dual-task interference demonstrated by the participants. To this end, two different word lengths were used (monosyllabic words versus bisyllabic words), and four conditions are presented: (1) baseline (no secondary speech task); (2) non-speech movement (wherein movement of articulatory structures is required of the participant, in the absence of speech); (3) spoken non-word (in which the spoken pronunciation of a non-word is added to the motoric demands of the non-speech movement condition); and (4) spoken word (in which lexical demands were added to the task by asking the participant to pronounce a meaningful word).

Additionally, in study #2, I measured the information processing speed of participants, and evaluated the extent to which this variable is related to the dual-task interference demonstrated by participants. The capacity-sharing model of dual-task interference will predict that removal of the variability due to information-processing speed will significantly reduce the effects of dual-task interference.

I hypothesize that increasing levels of complexity (both motoric and cognitive) across the three levels will have successively greater effects on the examined components of gait. In particular, I hypothesize that words will produce greater interference than non-words, due to the fact that individuals were likely to engage in more cognitive processing while implicitly parsing the meanings of, and connections with, the stimulus words. I expect that words and non-words spoken aloud will produce greater interference than silent movement of the articulators, due to the added motor (speech) and linguistic (phonological) demands inherent in verbalization. Finally, I predict that longer words/gestures will produce greater interference than shorter items due to the increased cognitive load of the longer span.

Study #1

Method

Fifteen healthy young women, aged 21 to 26 (*M* = 23.40, *SD* = 1.50) were recruited for participation in this study. All participants: (a) were fluent in English (written and spoken); (b) were able to walk 20 feet without assistance; and (c), reported no history of any speech or language disorders. Gait was assessed using a 23' instrumented GAITRite carpet. This device collects spatial-temporal information during continuous gait, through the use of 13,824 sensors located along its length. This information is then digitally processed, and used to create a quantitative summary of gait. Of interest within this study are: velocity, step length, step time, swing time, stance time.

The independent variable involved spoken or silent production of a restricted number of speech sounds (phonemes) that were arranged to create eight words, and eight non-words (which are not real words but are comprised of phoneme sequences that are possible in English). The phoneme set was restricted to those that are easy to visualize (e.g., bilabial, labiodental, and alveolar consonants; vowels with lip rounding or retraction) to facilitate correct imitation in the non-speech movement condition. These words (and non-words) are shown in Table 2.1. As is apparent from Table 2.1, half of the phoneme combinations are monosyllabic, and half of the phoneme combinations are bisyllabic. The 16 stimuli were arranged in eight experimental blocks (four trials per block) that cross word length (monosyllabic and bisyllabic) with condition (baseline, non-speech movement, spoken non-word, and spoken word). Words and non-words were balanced within the non-speech movement experimental block.

At the outset of each block, participants were instructed as to the nature of the task requirement (i.e., whether or not they were to speak aloud while repeating the mouth movements). Before each trial, participants were shown a video demonstration of the required movements, and were asked to demonstrate the correct mouth movements. They were observed throughout the task to ensure that they made the correct oral movements continuously throughout the trial.

Results

Data were analyzed within a 2 x 4 within-subjects factorial multivariate analysis of variance, with word length (monosyllabic versus bisyllabic) and condition (baseline, non-speech movement, spoken non-word, and spoken word) as independent variables. Significant multivariate effects were parsed with univariate tests of significance, and post-hoc analysis of all significant univariate effects was conducted using repeated contrasts. The experiment-wise alpha was set at 0.05 for all analyses, and multiple comparison bias

Table 2.1

Verbal Stimuli for Study #1

Condition	Monosyllabic	Bisyllabic
Non-speech Movement	ought	oven
	vah	veemu
	of	movie
	tah	enov
Non-Word	eeb	beebay
	vee	tobble
	taw	veemu
	vah	enuv
Word	bee	baby
	eve	bottle
	ought	movie
	of	oven

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

was controlled by employing a modified Bonferroni correction (Jaccard & Wan, 1996) for all effects that did not demonstrate a statistically significant multivariate effect (Hummel & Sligo, 1971). All data were analyzed using SPSS version 19. Descriptive statistics for all variables are presented in Table 2.2.

Table 2.2.

Means (and standard deviations) for all gait parameters, by condition, for all participants

Word length	Monosyllabic				Bisyllabic			
Parameter	Baseline	Non-speech	Non-word	Word	Baseline	Non-speech	Non-word	Word
Velocity (cm/s)	149.37	142.60	142.65	140.97	149.02	143.57	141.95	141.64
	(13.13)	(17.52)	(12.65)	(15.21)	(13.71)	(14.05)	(16.13)	(14.33)
Step Time (s)	0.50	0.52	0.52	0.52	0.50	0.52	0.52	0.52
	(0.03)	(0.05)	(0.04)	(0.05)	(0.03)	(0.04)	(0.05)	(0.04)
Stance Time (s)	0.61	0.64	0.64	0.65	0.61	0.64	0.64	0.64
	(0.04)	(0.07)	(0.05)	(0.06)	(0.04)	(0.05)	(0.07)	(0.05)
Swing Time (s)	0.39	0.40	0.40	0.40	0.39	0.40	0.40	0.40
	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
Step Length (cm)	74.31	74.03	73.64	73.29	74.29	73.90	73.50	73.29
	(4.30)	(4.50)	(4.01)	(4.55)	(4.41)	(4.28)	(4.25)	(4.59)

The multivariate effect of word length was not statistically significant [$F(5,10) = 0.377$], nor was the interaction between word length and condition [$F(15,120) = 0.610$]. After applying a Bonferroni correction factor to analyses of the univariate effects within each of these factors (and factor combinations), no statistically significant univariate effects were evident. However, the multivariate effect of condition was statistically significant [$F(15,120) = 3.068, p < 0.05$], and this effect explained 71.1% of the variability in gait parameters. Univariate analyses within the condition factor are presented in Table 2.3. As apparent from these results, all temporal parameters of gait (velocity, step time, swing time, and stance time) demonstrated statistically significant dual-task interference, but step length (a spatial parameter) did not.

Table 2.3.

Univariate analyses of the condition factor, Study #1

Gait Parameter	F(3,42)	p	Partial η^2
Velocity	10.99	0.001	0.44
Step Time	12.63	0.001	0.47
Stance Time	14.00	0.001	0.50
Swing Time	9.08	0.002	0.39
Step Length	1.54	0.232	0.10

Post-hoc analyses suggested that dual-task interference produced significant changes in the parameters of gait, but that this interference was not significantly greater with non-words as compared to the non-speech movement condition, nor was it significantly greater with words as compared to non-words. These results are summarized in Table 2.4.

Table 2.4.

F-ratios (and partial eta-squares) for post hoc comparisons within the condition factor

Gait Parameter	Baseline vs. Non-Speech	Non-speech vs. Non-word	Non-word vs. Word
Velocity	* 16.724	0.590	0.758
	(0.544)	(0.040)	(0.051)
Step Time	* 18.238	0.052	0.356
	(0.566)	(0.004)	(0.025)
Swing Time	* 18.245	0.040	0.285
	(0.566)	(0.003)	(0.020)
Stance Time	* 14.472	0.014	0.093
	(0.508)	(0.001)	(0.007)
Step Length	0.671	0.830	0.596
	(0.046)	(0.0560	(0.041)

*Note: * denotes a contrast that is statistically significant, $p < 0.05$*

Study #2

Method

Although effective in their demonstration of a dual-task interference effect, the stimuli used in study #1 lacked balance in the types of syllables used – specifically, the consonant (C) and vowel (V) combinations were not evenly placed throughout the words that were being used. The placement of vowels and consonants is important because it changes the shape of mouth movements; the types of articulations that are performed in the production of that specific word. In order to control better for both the articulatory and the phonemic components of the verbal task, study #2 revisited the syllable structure of the stimuli, and utilized a new set of stimulus words. In this stimulus set, all syllables were composed of an open-ended syllable structure (i.e., CV), including both syllables composing the bisyllablic stimuli (i.e., CVCV). As was the case in study #1, the phoneme set for the stimulus list was restricted to those phonemes that are easy to visualize (e.g., bilabial, labiodental, and alveolar consonants; vowels with lip rounding or retraction) in order to facilitate correct imitation in the non-speech movement condition. To ensure that the phoneme complexity was similar for both word lengths, the bisyllabic stimuli were composed of the same phonemes used in the monosyllabic stimuli. When creating the bisyllabic stimuli at the non-word level, the stimuli were balanced even further by using the four monosyllabic non-word stimuli an equal number of times to compose the bisyllabic versions. The monosyllabic non-word stimuli were each used once in the initial syllable position, as well as once in the final syllable position. This resulted in each of the four monosyllabic non-word stimuli being used an equal number of times in each position. The revised stimuli used in this study are shown in Table 2.5.

Table 2.5.

Verbal Stimuli for Study #2

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: the above spellings are provided for illustrative purposes only – all words were pronounced for participants without presenting any written information

Individual differences in information processing capacity were estimated with a test of information processing speed. Although there are numerous methods available for the chronometric assessment of information processing speed (with the most common being reaction time), I chose to use *inspection time* as my measure of an individual's speed of information processing. Inspection time is a simple information-processing paradigm that can be described as a measure of perceptual speed, given that it is intended to examine the ability of an individual to identify physical properties of a stimulus when they are presented at a limited time interval (Nettelbeck, 1982). Within the present study, the primary advantage of inspection time was that it provided a method for assessing information processing speed that did not confound cognitive speed with motoric speed (i.e., the variable of interest was the speed at which a stimulus could be presented – not the speed at which an individual could respond to the stimulus). Inspection time is a good measure of information processing speed in individuals, and is further linked to certain aspects of intellectual ability (Brody, 2001; Deary & Stough, 1996). Inspection time, in comparison to reaction time, can account for the limited capacity of cognitive systems that are involved in dual-task paradigms.

The inspection time task was administered using a desktop computer with a 17 inch monitor (running at a resolution of 640 x 480 pixels). A small filled circle was presented initially, for 500ms, as a fixation point, and this was followed immediately by one of the two *pi* figures depicted in Figure 2.1. The pi figure was comprised of two vertical lines (21mm

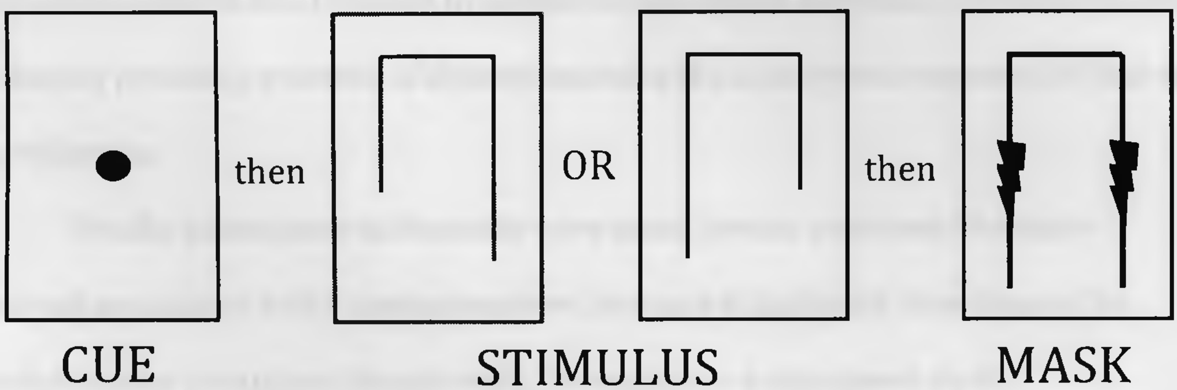

Figure 2.1. Inspection time stimuli.

in length for the short leg, and 29mm in length for the long leg) joined at the top by a horizontal line. This pi figure remained on the screen for a variable period of time, with presentation time (i.e. the length of time that the stimulus remained on the computer screen) set at 120ms initially, and then changed systematically throughout testing using a Parameter Estimation by Sequential Testing (PEST) adaptive staircase algorithm (Taylor, 1967), based on the accuracy of participant responses. Immediately following the presentation of the pi figure, a lightning mask (also depicted in Figure 2.1), with both legs set to be 29mm in length, was presented on the screen for a constant period of 360ms. To ensure that participants were comfortable with the inspection time testing procedure, all participants were given an opportunity to practice the task with presentation time fixed at 200ms. Participants were given as many practice trials as was necessary for them to identify correctly ten consecutive stimuli. None of the participants required more than 15 practice trials. The dependent variable on this task was the minimum presentation time at which a participant was able to achieve consistently 80% accuracy in their judgment of which line was shorter. As a proxy measure for information processing speed, this dependent variable was intended to provide insight into an individual's processing capacity – thereby providing a method of directly assessing the capacity-sharing model of dual-task interference.

Finally, participants in this study were asked to wear a wireless Bluetooth microphone, paired with a laptop computer, to create digital audio recordings of the verbalizations throughout the gait trials, for analysis in a subsequent study.

All other procedures within this study were identical to those described in study #1. Forty healthy young participants (20 women and 20 men) were recruited for participation in study #2, ranging in age from 21 to 29 (M = 23.90, SD = 2.02).

Results

Data were analyzed within a 2 x 4 x 2 multivariate split-plot analysis of variance, with word length (monosyllabic versus bisyllabic), condition (baseline, non-speech movement, spoken non-word, and spoken word), and sex as independent variables. Descriptive statistics for all variables are presented in Table 2.6 (with data presented on female participants only), and Table 2.7 (with data presented on the male participants only).

The multivariate effect of the two-way interaction of condition and sex was statistically significant [$F(15, 336) = 2.603$, $p < 0.05$, $\eta^2 = 0.293$]. Accordingly, this two-way interaction was parsed using two 2 x 4 (condition by word length) within-subject factorial MANOVAs, with women and men assessed in separate analyses.

In the first 2 x 4 MANOVA (conducted among the female participants), the multivariate word length by condition interaction was not statistically significant, nor was the multivariate main effect of word length. However, the multivariate main effect of condition was statistically significant [$F(15, 165) = 3.406$, $p < 0.05$, $\eta^2 = 0.622$]. This multivariate effect was interpreted through an inspection of the univariate effects on each dependent variable, and these univariate effects are presented in Table 2.8.

Table 2.6.

Means (and standard deviations) for all gait parameters, by condition, for women only

Word Length	Monosyllabic				Bisyllabic			
Parameter	Baseline	Non-speech	Non-word	Word	Baseline	Non-speech	Non-word	Word
Velocity	141.40	131.72	134.65	133.31	141.64	132.55	132.93	130.94
(cm/s)	(17.07)	(16.11)	(15.14)	(17.90)	(16.26)	(16.84)	(16.66)	(20.68)
Step Time	0.52	0.54	0.53	0.54	0.52	0.54	0.54	0.55
(s)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.06)
Swing Time	0.40	0.41	0.41	0.41	0.40	0.42	0.41	0.42
(s)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.06)	(0.03)	(0.04)
Stance Time	0.63	0.66	0.66	0.66	0.63	0.67	0.66	0.68
(s)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.08)	(0.05)	(0.08)
Step Length	72.84	70.58	71.46	71.18	73.09	70.75	70.93	71.15
(cm)	(6.37)	(6.51)	(5.78)	(6.66)	(6.45)	(7.06)	(6.14)	(7.09)

Table 2.7.

Means (and standard deviations) for all gait parameters, by condition, for men only

Word Length	Monosyllabic				Bisyllabic			
Parameter	Baseline	Non-speech	Non-word	Word	Baseline	Non-speech	Non-word	Word
Velocity	130.74	124.91	126.10	124.08	131.03	124.34	125.61	124.89
(cm/s)	(10.56)	(12.59)	(14.97)	(12.46)	(9.74)	(14.30)	(13.91)	(11.98)
Step Time	0.56	0.58	0.57	0.58	0.56	0.58	0.58	0.57
(s)	(0.04)	(0.05)	(0.05)	(0.05)	(0.03)	(0.05)	(0.05)	(0.04)
Swing Time	0.42	0.43	0.43	0.43	0.42	0.43	0.43	0.43
(s)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.03)
Stance Time	0.70	0.72	0.72	0.72	0.70	0.73	0.72	0.72
(s)	(0.05)	(0.07)	(0.07)	(0.07)	(0.05)	(0.07)	(0.07)	(0.06)
Step Length	73.35	71.50	71.76	71.28	73.46	71.53	71.87	71.41
(cm)	(3.69)	(4.35)	(4.48)	(4.09)	(3.85)	(4.48)	(4.72)	(4.26)

Table 2.8.

Univariate analyses of the condition factor, women only

Gait Parameter	F(3,57)	p	Partial η^2
Velocity	16.99	0.001	0.472
Step Time	13.92	0.001	0.423
Stance Time	5.54	0.012	0.226
Swing Time	11.87	0.001	0.385
Step Length	10.10	0.001	0.347

As apparent from Table 2.8, all of the univariate effects were significant among the female participants. Post hoc comparisons were conducted, using repeat contrasts within the general linear model (GLM) calculation, and these analyses are presented in Table 2.9. These results suggest that the largest effect was seen when comparing the baseline to the non-speech movement condition, and that this contrast was statistically significant for all five parameters of gait. Interestingly, none of the gait parameters demonstrated a statistically significant difference between the non-speech movement condition and the non-word condition, and only step time, swing time, and stance time demonstrated significant differences between the non-word condition and the word condition.

In the second 2x4 MANOVA, conducted on the data from the male participants, the main effect of word length [$F(5, 15) = 2.832$, $p < 0.05$, $\eta^2 = 0.486$], and the main effect of condition [$F(15, 165) = 2.404$, $p < 0.05$, $\eta^2 = 0.494$] were both statistically significant. There was no statistically significant multivariate interaction between word length and condition.

Table 2.9.

F-ratios (and partial eta-squares) for post hoc comparisons within the condition factor, women only

Gait Parameter	Baseline vs. Non-speech	Non-speech vs. Non-word	Non-word vs. Word
Velocity	* 45.782 (0.707)	1.369 (0.067)	1.216 (0.060)
Step Time	* 30.225 (0.614)	0.568 (0.029)	* 5.049 (0.210)
Swing Time	* 5.768 (0.233)	1.267 (0.062)	* 4.318 (0.185)
Stance Time	* 13.152 (0.409)	1.900 (0.091)	* 4.193 (0.181)
Step Length	* 27.464 (0.591)	1.322 (0.065)	0.004 (0.000)

*Note: * denotes a contrast that is statistically significant,* $p < 0.05$

Both of these multivariate main effects were evaluated at the univariate level, and these univariates are presented in Table 2.10.

Interestingly, the univariate analyses demonstrated that, despite the significant multivariate effect for the main effect of word length, none of the univariate analyses of the individual gait parameters were statistically significant. This suggests that the effect of word length was sufficiently subtle so as to be visible only as an overall effect on gait. The univariate analyses of the condition factor suggested, however, that with the exception of stance time, all of the gait parameters demonstrated a statistically significant effect from the main effect of condition. Post hoc comparisons were conducted, using repeat contrasts within the GLM calculation, and these post hoc analyses are presented in Table 2.11.

Table 2.10.

Univariate effects for the main effects of word length and condition, men only

Univariate Effects for the Main Effect of Word Length			
Gait Parameter	F(1,19)	p	Partial η^2
Velocity	0.000	0.988	0.000
Step Time	0.024	0.877	0.001
Stance Time	0.852	0.368	0.043
Swing Time	0.302	0.589	0.016
Step Length	0.197	0.662	0.010
Univariate Effects for the Main Effect of Condition			
Gait Parameter	F(3,57)	p	Partial η^2
Velocity	13.097	0.000	0.408
Step Time	6.676	0.005	0.260
Stance Time	2.527	0.109	0.117
Swing Time	8.570	0.001	0.311
Step Length	12.981	0.000	0.406

To identify the extent to which the aforementioned effects were due to information processing speed, the data were re-analyzed using 2 x 4 multivariate analysis of covariance calculations within each sex, with inspection time included as a covariate. Interestingly, neither women nor men showed any statistically significant effects of dual-task interference, after removing the variability due to inspection time.

Table 2.11.

F-ratios (and partial eta-squares) for post hoc comparisons within the condition factor, men only

Gait Parameter	Baseline vs. Non-speech	Non-speech vs. Non-word	Non-word vs. Word
Velocity	* 24.580	1.959	1.456
	(0.564)	(0.093)	(0.071)
Step Time	* 7.432	0.804	0.462
	(0.281)	(0.041)	(0.024)
Swing Time	2.655	0.297	0.077
	(0.123)	(0.015)	(0.004)
Stance Time	* 10.383	0.851	0.699
	(0.353)	(0.043)	(0.035)
Step Length	* 40.377	1.403	1.309
	(0.680)	(0.069)	(0.064)

*Note: * denotes a contrast that is statistically significant, $p < 0.05$*

Discussion

The results of both studies supported the conclusions of Armieri et al. (2009) within a protocol that systematically manipulated oral-motor, articulatory, and lexical demands of speech stimuli. Although the length of the stimuli used in this study (i.e., monosyllabic versus bisyllabic) did not produce a statistically significant change in gait, the results of this research suggested that: (a) the introduction of an oral-motor component to a secondary task produces significant dual-task interference with gait; (b) the addition of spoken, phonological demands to oral-motor demands produced a significant increase in dual-task interference with some parameters of gait, but only with the addition of lexical complexity (spoken word condition). This increase in dual-task interference, corresponding with increases in articulatory and lexical demands, supports a capacity model of dual-task interference. In other words, as the load of the secondary task increases, the primary task is increasingly affected.

Furthermore, the results of study #2 provided interesting information that may be used in modeling sex differences in dual-task interference. The effect size of the dual-task interference was larger for women than it was for men, which would suggest that women show a significantly greater amount of dual-task interference. This may also indicate, however, that women show a significantly greater tendency to engage in a posture-first strategy for coping with dual-task interference (i.e., they are demonstrating a greater tendency to reduce speed and shorten step length, when faced with a competing cognitive task). Furthermore, women demonstrated a significant increase in change in dual-task interference when the lexical demands of the task increased.

Of potentially greatest interest, however, are the analyses that use inspection time as a covariate. Given that the inclusion of inspection time within the analysis of covariance produces (essentially) null results for all of the factors, and factor combinations, this suggests that dual-task interference may be almost entirely dependent upon an individual's information processing capacity. This provides the strongest support to date for the capacity-sharing model of dual-task interference.

The importance of testing this protocol on healthy young individuals is supported by the fact that this population is not significantly impaired in their gait or, presumably, their cognition. This differs significantly from examining the same protocol in an older or neurologically impaired population, which may demonstrate dual-task interference that is confounded by the effects of aging or disease. Consequently, the effects demonstrated here in a young, healthy population could be considered to be a more accurate representation of the most basic, underlying processes that are occurring in the cognitive system during dual-task interference.

Within the young population sampled for this study, the demands of the secondary task were not sufficient to produce pathological gait changes. In populations of individuals who have significantly impaired gait (e.g., individuals with Parkinson's disease, or older adults with a history of falls), however, it is likely that the demands associated with secondary verbal tasks will place the individual at an increased risk of falling. Accordingly, three important lines of research are suggested from these results: (a) an identification of the *safe limits* for secondary task complexity (i.e., the cognitive, motoric, and/or lexical complexity of a secondary task that may be completed safely while walking); (b) a systematic use of information processing speed measures, in the development of a diagnostic battery that may indicate which individuals are *most at risk* for unsafe gait under conditions of dual-task interference; and (c) the development of a *dual task training* protocol, which may be used to enhance the safety of individuals for whom the risk of falling is significantly exacerbated through dual-task performance. The latter may be accomplished by training individuals to prioritize effectively their primary task over their secondary task, by adopting a posture-first strategy. A posture-first strategy would result in individuals adapting in order to maintain the components of the motor task over the components of the verbal task, which may decrease their performance but would maintain the safety of the individual.

References

Armieri, A., Holmes, J.D., Spaulding, S.J., Jenkins, M.E., & Johnson, A.M. (2009). Dual task performance in a healthy young adult population: Results from a symmetric manipulation of task complexity and articulation. *Gait and Posture, 29*, 346-348.

Brody, N. (2001). Inspection time: Past, present, and future. *Intelligence, 29*, 537-541.

Camicioli, R., Oken, B.S., Sexton, G., Kaye, J.A., & Nutt, J.G. (1998). Verbal fluency task affects gait in Parkinson's disease with motor freezing. *Journal of Geriatric Psychiatry and Neurology, 11(4)*, 181-185.

Deary, I.J., & Stough, C. (1996). Intelligence and inspection time: Achievements, prospects, and problems. *American Psychologist, 51(6)*, 599-608.

Fitts, P.M., & Peterson, J.R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67*, 103-112.

Hummel, T.J., & Sligo, J.R. (1971). Empirical comparison of univariate and multivariate analysis of variance procedures. *Psychological Bulletin, 76(1)*, 49-57.

Jaccard, J., & Wan, C.K. (1996). *LISREL approaches to interaction effects in multiple regression*. Thousand Oaks, CA: Sage Publications.

Johnson, A.M., Almeida, Q.J., Stough, C., Thompson, J.C., Singarayer, R., & Jog, M.S. (2004). Visual inspection time in Parkinson's disease: Deficits in early stages of cognitive processing. *Neuropsychologia, 42(5)*, 577-583.

Johnson, A.M., Vernon, P.A., Almeida, Q.J., Grantier, L., & Jog, M.S. (2003). A role of the basal ganglia in movement: The effect of directional precues on discrete bi-directional movements in Parkinson's disease. *Motor Control, 7*, 71-81.

Johnson, P.J., Forester, J.A., Calderwood, R., & Weisgerber, S.A. (1983). Resource allocation and the attentional demands of letter encoding. *Journal of Experimental Psychology, 112(4)*, 616-638.

McLeod, P. (1977). Parallel processing and the psychological refractory period. *Acta Psychologica, 41*, 381-391.

Navon, D., & Miller, J. (2002). Queuing or sharing? A critical evaluation of the single-bottleneck notion. *Cognitive Psychology, 44*, 193-251.

Nettelbeck, T. (1982). Inspection time: an index for intelligence? *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 34(2)*, 299-312.

O'Shea, S., Morris, M.E., & Iansek, R. (2002). Dual task interference during gait in people with Parkinson's disease: Effects of motor versus cognitive secondary tasks. *Physical Therapy, 82(9)*, 888-897.

Ogden, W.C., Martin, D.W., & Paap, K.R. (1980). Processing demands of encoding: What does secondary task performance reflect? *Journal of Experimental Psychology: Human Perception and Performance, 6(2)*, 355-367.

Posner, M.I., & Boies, S.J. (1971). Components of attention. *Psychological Review, 78(5)*, 391-408.

Taylor, M.M. (1967). PEST: Efficient estimates on probability functions. *Journal of the Acoustical Society of America, 41(4)*, 782-787.

Tolkmitt, F.L. (1972). A revision of the psychological refractory period. *Acta Psychologica, 37*, 139-154.

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

CHAPTER 3

The Effect of Word Length, Oral-Motor Movement, Articulation, and Lexicality on Balance[1]

Dual-task interference results in a decline in performance or accuracy, on one (or both) of two tasks that are performed simultaneously (Woollacott & Shumway-Cook, 2002). Introduction of a secondary task may overwhelm processing resources, and the magnitude of the deterioration is likely to be proportional to the complexity of the secondary motor task (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998). Secondary tasks used in previous research have included manipulations of digits and digit recall (Pellecchia, 2003, 2005), conversational speech and rhythmic word rehearsal (Holmes, Jenkins, Johnson, Adams, & Spaulding, 2010), as well as secondary motor tasks (Kerr, Condon, & McDonald, 1985; Morris, Iansek, Smithson, & Huxham, 2000). What is lacking, however, is systematic control over the verbal stimuli used within the secondary task, with regards to both the oral-motor, and the cognitive-linguistic demands of the task. Although this has been done with some success in studies of dual-tasking in gait (Armieri, Holmes, Spaulding, Jenkins, & Johnson, 2009; Davie, et al., in preparation), it is equally important to consider the effects of interference on balance. Gait may be described as *dynamic balance,* comprising not only balance, but also timing (cadence), visual-spatial awareness, and speed regulation (Lajoie, Teasdale, Bard, & Fleury, 1993). Examining balance may, therefore, allow us to deconstruct gait, and isolate the extent to which the effects of dual-task interference on gait are explained by balance.

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[1] A version of this chapter will be submitted to *Gait and Posture* as a brief communication.

In addition to examining the oral-motor and cognitive-linguistic features of the verbal stimuli used in studies of dual-task interference, it is also of interest to consider the underlying cognitive mechanisms that may be responsible for individual differences in dual-task interference. There is significant support within the literature for the *capacity-sharing* model of dual-task interference, a model of dual-task interference that is built upon the notion that primary task performance will be significantly limited by an individual's cognitive capacity (e.g., O'Shea, Morris, & Iansek, 2002). This theory is usually tested by modifying characteristics of the secondary task, rather than by covarying out cognitive capacity, as might be done with the use of an independent measure of information processing speed.

In this study, the motor, speech, and language components of a cognitive verbal secondary task were experimentally manipulated, thus enabling an evaluation of the effects of motor, articulatory, and lexical demands of that verbal task on balance. The goal of this research was to evaluate the extent to which word length, non-speech movement, articulation, and lexicality contribute to dual-task interference. To this end, two different word lengths were used (monosyllabic words and bisyllabic words) across four conditions: (a) baseline (no secondary speech task); (b) non-speech movement (wherein movement of the articulatory structures was required of the participant, in the absence of speech or language); (c) spoken non-word (in which a speech component was added to the motoric demands by asking the participant to repeat a nonsense word); and (d) spoken word (in which lexical demands were added to the speech and motor demands of the task by asking the participant to repeat a meaningful word). Cognitive capacity was estimated through the use of a non-motoric measure of information processing speed, and then removed from the analysis as a covariate.

It is hypothesized that increasing levels of complexity (both motoric and cognitive) will have successively greater effects on the length of the centre-of-pressure pathway. Furthermore, the capacity-sharing model of dual-task interference was tested, by controlling for the effects of information processing speed within the analysis.

Method

Forty healthy young participants (20 women and 20 men) were recruited for participation in this study, as part of a larger study in which gait also was evaluated (Davie, et al., in preparation). All participants: (a) were fluent in English (written and spoken); (b) were able to maintain an independent upright posture for 10 seconds at a time, and (c) reported no history of any speech or language disorders. Participants ranged in age from 21 to 29 years of age (M = 23.90, SD = 2.02).

The stimuli that comprise the independent variable (and the methods used in their construction) are described in detail in Davie et al. (in preparation). In brief, stimuli consisted eight words, eight non-words, and eight non-speech movements . Half of the stimuli in each set were monosyllabic, and half were bisyllabic. All phonemes were easy to visualize to facilitate correct imitation in the non-speech condition, which contained equal numbers of words and non-words. The 24 stimuli were arranged in eight experimental blocks (four trials in each) that crossed word length (monosyllabic and bisyllabic) and condition (baseline, non-speech, spoken non-word, and spoken word).

Postural stability for each participant was assessed quantitatively using a model OR6-5 biomechanics force platform (Advanced Mechanical Technology Inc., Watertown, USA), oriented so that the x-axis was aligned in the direction of forward stance. The force platform consists of an aluminum plate with embedded electronic force sensors. The outputs were analyzed using the BioAnalysis software package (version 2.2) produced by the force platform manufacturer. The length of the centre of pressure pathway was measured using an internal algorithm within this program.

Individual differences in information processing capacity were estimated using inspection time (IT), a non-motoric measure of information processing speed that reflects the speed at which a stimulus can be presented on a computer screen before a participant is no longer able to correctly identify salient characteristics (Nettelbeck, 1982). The IT task used in this study was identical to the task described by Johnson et al. (2004).

Within each of the four conditions (baseline, non-speech movement, spoken non-word, and spoken word), participants were asked to repeat the stimuli (which were presented both visually and aurally), while standing on the force platform for periods of 10 seconds at a time. A Bluetooth wireless microphone recorded the participant's vocal utterances, for analysis in a subsequent study.

Results

Data were analyzed within a 2 x 4 x 2 factorial split-plot analysis of variance (ANOVA), with word length (monosyllabic versus bisyllabic), condition (baseline, non-speech, spoken non-word, and spoken word), and sex as independent variables. Descriptive statistics for all variables are presented in Table 3.1.

Table 3.1.

Means (and standard deviations) for the length of the centre-of-pressure pathway, separated by sex and condition

		Mean (SD) in cm		
		Women	*Men*	*Total*
Monosyllabic	Baseline	12.40	11.65	12.03
		(1.69)	(1.45)	(1.60)
	Non-speech	13.38	11.85	12.61
		(1.87)	(1.28)	(1.76)
	Non-word	14.26	13.08	13.67
		(2.30)	(2.24)	(2.32)
	Word	14.32	13.5	13.91
		(2.12)	(3.18)	(2.70)
Bisyllabic	Baseline	12.36	11.62	11.99
		(1.66)	(1.34)	(1.53)
	Non-speech	13.23	12.04	12.63
		(1.69)	(1.93)	(1.89)
	Non-word	14.31	13.9	14.11
		(2.11)	(3.85)	(3.07)
	Word	14.95	13.14	14.05
		(3.16)	(1.79)	(2.69)

The only statistically significant effect found was the main effect of condition [$F(3, 114) = 22.040$, $p < 0.05$]. Post hoc comparisons were conducted on this significant main effect, using repeat contrasts within the GLM calculation, and these post hoc analyses are presented in Table 3.2. These results indicated that the length of the centre-of-pressure pathway was significantly longer for the non-speech motor condition, as compared with the baseline condition, as well as being significantly longer when vocalization demands (i.e., spoken task) were added in the spoken non-word condition. No significant change in dual-task interference was seen when lexicality demands were added (i.e., when the stimulus was a "real word").

Table 3.2.

F-ratios (and partial eta-squares) for post hoc comparisons within the condition factor

Comparison	F ($\eta^2_{partial}$)
Baseline vs. Non-speech	* 9.628 (0.202)
Non-speech vs. Non-word	* 22.501 (0.372)
Non-word vs. Word	0.140 (0.004)

*Note: * denotes a contrast that is statistically significant, p < 0.05*

Furthermore, the largest effect was seen when comparing the non-word condition to the non-speech movement condition.

To identify the extent to which the aforementioned effects were due to information processing speed, the data were re-analyzed using a 2 x 4 analysis of covariance, with IT as a covariate. None of the main effects or interactions were statistically significant when IT was removed from the analysis.

Discussion

These results demonstrated that the dual-task interference resulting from the introduction of non-speech motor demands, significantly lengthened the centre-of-pressure pathway. Furthermore, the addition of articulation demands produced a further increase in the length of the centre-of-pressure pathway, and the addition of a lexical component to the verbal task produced a further (albeit non-significant) increase to the length of the centre-of-pressure pathway. This consistent increase in the dependent variable, in concert with increases in the demands of the secondary task, provides support for the capacity-sharing model of dual-task interference.

When IT was examined within the analysis as a covariate, the effects of dual-task interference disappeared entirely, suggesting that dual-task interference may be almost entirely dependent upon an individual's information processing capacity. This provides some of the strongest evidence that has been presented to date in favour of the capacity-sharing model of dual-task interference, and is keeping with the findings of Davie et al. (in preparation), who found similar results within an analysis of gait.

When considered in the context of the gait analysis presented by Davie et al. (in preparation), these results demonstrate that the comparatively less complicated biomechanical activity of static balance, is substantially affected by non-speech oral motor activity, and is further affected by speech within this task. This strongly suggests that researchers employing verbal stimuli as a secondary task should use caution when interpreting the cognitive effects of the secondary task, due to the fact that such studies are (in essence) studies of "triple-tasking" (balance, oral-motor activity, and cognitive activity). Furthermore, these results suggest that studies of dual-task interference would do well to consider individual differences in cognitive ability, as this variable is clearly a substantively significant confound within the design.

References

Armieri, A., Holmes, J.D., Spaulding, S.J., Jenkins, M.E., & Johnson, A.M. (2009). Dual task performance in a healthy young adult population: Results from a symmetric manipulation of task complexity and articulation. *Gait and Posture, 29*, 346-348.

Camicioli, R., Oken, B.S., Sexton, G., Kaye, J.A., & Nutt, J.G. (1998). Verbal fluency task affects gait in Parkinson's disease with motor freezing. *Journal of Geriatric Psychiatry and Neurology, 11(4)*, 181-185.

Davie, K.L., Cardy, J.E.O., Holmes, J.D., Hildering, M., Jenkins, M.E., & Johnson, A.M. (in preparation). The effects of word length, oral-motor movement, vocalization, and lexicality, on gait. *Gait and Posture.*

Holmes, J.D., Jenkins, M.E., Johnson, A.M., Adams, S.G., & Spaulding, S.J. (2010). Dual-task interference: The effects of verbal cognitive tasks on upright postural stability in Parkinson's disease. *Parkinson's Disease, 10.4061/2010/696492.*

Johnson, A.M., Almeida, Q.J., Stough, C., Thompson, J.C., Singarayer, R., & Jog, M.S. (2004). Visual inspection time in Parkinson's disease: Deficits in early stages of cognitive processing. *Neuropsychologia, 42(5)*, 577-583.

Kerr, B., Condon, S.M., & McDonald, L.A. (1985). Cognitive spatial processing and the regulation of posture. *Journal of Experimental Psychology: Human Perception and Performance, 11(5)*, 617-622.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M. (1993). Attentional demands for static and dynamic equilibrium. *Experimental Brain Research, 97(1)*, 139-144.

Morris, M., Iansek, R., Smithson, F., & Huxham, F. (2000). Postural instability in Parkinson's disease: a comparison with and without a concurrent task. *Gait and Posture, 12(3)*, 205-216.

Nettelbeck, T. (1982). Inspection time: an index for intelligence? *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 34(2)*, 299-312.

O'Shea, S., Morris, M.E., & Iansek, R. (2002). Dual task interference during gait in people with Parkinson's disease: Effects of motor versus cognitive secondary tasks. *Physical Therapy, 82(9)*, 888-897.

Pellecchia, G.L. (2003). Postural sway increases with attentional demands of concurrent cognitive task. *Gait and Posture, 18(1)*, 29-34.

Pellecchia, G.L. (2005). Dual-task training reduces impact of cognitive task on postural sway. *Journal of Motor Behavior, 37(3)*, 239-246.

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

CHAPTER 4

Discussion

The research conducted for this thesis is presented in two separate chapters: one examining the effects of dual-task interference on gait, and the second examining the effects of dual-task interference on balance. This was done to illustrate the chronology of the research, spanning the initial conceptualization of the study, to the final study in which we evaluated both gait and balance. The initial pilot study evaluated spatial-temporal parameters of gait, due to the fact that gait is considerably more complex than balance. In fact, gait may be described as *dynamic balance*, comprising not only balance, but also timing (cadence), visual-spatial awareness, and speed regulation (Lajoie, Teasdale, Bard, & Fleury, 1993). The use of this more complicated biomechanical activity increased the power of the study, as it made it more likely that the secondary task(s) would produce a statistically significant effect. Following the refinement of the stimuli used in the project, the research was extended to examine the effects of a verbal task on a balance task. This allowed us to deconstruct the gait task, to a certain extent, by isolating the effects of dual-task interference on balance.

The majority of previously completed research in this area has examined the effects of dual-task interference on older adult populations (Bootsma-van der Wiel, et al., 2003) as well as neurologically or cognitively impaired populations (e.g., Camicioli, Oken, Sexton, Kaye, & Nutt, 1998; O'Shea, Morris, & Iansek, 2002). While in general, this research explores a wide variety of types of primary and secondary tasks, the secondary tasks have rarely been deconstructed to evaluate their elemental components – and they have never truly been deconstructed from a speech-language perspective. Furthermore, research has been limited in its exploration of the cognitive mechanisms that underlie dual-task interference. The studies presented in this thesis thus make two key contributions to the literature: (a) they present a methodology for deconstructing (and considering) the relative contributions of speech and language to dual-task interference; and (b) they present a method for controlling individual differences in information processing speed that allows for a direct assessment of the capacity-sharing model of dual-task interference.

Determination of the interference model that is most appropriate for the explanation of dual-task interference is best done within a young healthy population, due to the fact that members of this population are not significantly impaired in their gait, balance, or (presumably) their cognition. Examination of older (or neurologically impaired) populations may confound the effects of aging or disease, with the basic effects of dual-task interference. Thus, the effects demonstrated within the healthy young population used in the present studies can be considered to be a more accurate representation of the underlying processes that are at work within dual-task interference.

There are few tasks in our daily lives that are more natural and frequent than communication. The previously noted gap in the literature, concerning the lack of consideration of speech and language components within speech tasks is, therefore, particularly important when one considers how common these tasks are – both within the research literature, and within activities of daily living. Thus, the main goal of the studies presented herein was to evaluate the extent to which all the major components of a secondary verbal task interfere with a primary gait or balance task. In order to understand better the exact cognitive mechanisms behind each successive level of a verbal task, and their corresponding effects on dual-task interference, the verbal task was broken down systematically and progressive levels of combined components were examined. These major components of a verbal task included word length, motoric involvement, articulation and lexical complexity.

This research builds upon the research of Armieri, Holmes, Spaulding, Jenkins and Johnson (2009), who attempted to make the separation between non-speech motor aspects of a verbal task, and the articulation aspects of this same task. Unfortunately, their study lacked consideration of most of the speech parameters involved in the performance of the verbal stimuli. The verbal task in the study conducted by Armieri et al. (2009) was digit naming, a verbal task that provides relatively no consideration to the actual oral-motor and articulatory processes involved in the verbal production of digits. In contrast, the stimuli developed for this thesis were constructed after giving consideration to the manner in which the individual phonemes can be visualized, the oral-motor complexity of each phoneme, as well as the vowel/consonant structure of each stimulus word. The articulatory complexity of the words was controlled further through the use of both monosyllabic and bisyllabic words. Additionally, the studies that are included as part of this thesis attempted to separate lexical demands from speech demands through the inclusion of spoken word conditions and spoken non-word conditions.

Another major issue that the present research addressed was statistical control of the system capacity within a dual-task paradigm – a simple method for testing the capacity-sharing model of dual-task interference that does not appear to have been attempted within any other study in the literature. *System capacity* was estimated through the use of a non-motoric information processing speed measure (inspection time), and individual differences in cognitive speed were removed from the other effects within the model, as a covariate within an analysis of covariance (ANCOVA) design. The use of a non-motoric measure of information processing speed is particularly important when attempting to disentangle motor effects from speech and cognitive-linguistic effects, within secondary task performance, because it ensures that the variance removed from the analysis is due to cognitive capacity, and not movement speed.

The first two studies that were completed, both in chapter 2, demonstrated that the introduction of an oral-motor component to a secondary task produces significant dual-task interference with gait, this being the difference between the baseline condition and the non-speech movement condition. Further, the addition of spoken, phonological demands to oral-motor demands produced a significant increase in dual-task interference with some parameters of gait, including step time, swing time, and stance time, but only with the addition of lexical complexity. This increment in cognitive-linguistic complexity also revealed a possible sex difference, in the extent to which lexical demands produced changes in the parameters of gait. Interestingly, only the women (in study #2 of chapter 2) demonstrated significantly greater gait impairment when lexical complexity was increased. Interestingly, increased lexical complexity did not create significantly greater impairments in gait in study #1 of chapter 2, even though it was conducted solely on a female sample. It is unlikely that this occurred due to power issues, since the difference in sample sizes between the two studies was not substantive (*n* = 15 versus *n* = 20). The only other difference in the protocol between study #1 and study #2 that could account for these differences is the changes in the stimuli that occurred between the two studies. This suggests, therefore, that the revised stimuli may be more accurate and efficient at deconstructing speech, and consequently the lexical demands among the verbal stimuli. It also is possible that the revised stimuli are more effective at differentiating between women and men.

There are a number of possible conclusions that can be drawn with regard to the sex differences between increased lexical complexity and dual-task interference in women and men. The three most plausible conclusions are: (a) that there are differences between women and men, in terms of the amount of their susceptibility to dual-task interference (and the results would suggest that men are better at dual-tasking than the women); (b) that there are sex differences in the processing of verbal information that may lead the men to process this information at a more superficial level, thereby increasing the speed at which they can complete the primary task, and reducing the amount of interference caused by the secondary task; and (c) that these differences may be accounted for by sex differences in the prioritization of the primary and secondary tasks.

Previous research with regard to sex differences in cognition has concluded that women perform better at tasks of verbal fluency. Kimura (1999) suggests that women have a better brain representation of the individual sounds of parts of words (phonemes), which would support the conclusion that men may process verbal information at a more superficial level than women, thereby producing less dual-task interference among the men. This also is supported by the finding (presented in chapter 2) that men demonstrate a statistically significant effect of word length, and show an overall impairment of gait when given bisyllabic stimuli, as compared with monosyllabic stimuli. Unfortunately, the bisyllabic stimuli do not appear to produce any other effects, in either sex, on either gait or balance – possibly due to the fact that bisyllabic stimuli are not sufficiently complex as to overwhelm processing resources within this sample. Future research should aim to include three, or even four syllable constructions, as an attempt to increase the variability on this factor.

Interestingly, the results of the study presented in chapter 3, which examined the effects of word length, oral-motor movement, articulation, and lexicality on balance, suggested that there is a significant increase in dual-task interference when motoric complexity is increased, as well as there being a significant increase in interference when speech production is added to motoric action. Despite these results, there is no significant increase in dual-task interference in balance that correlates with increases in the lexical complexity of the stimuli, for either men or women. Also, there were no visible sex differences in dual-task interference in balance. Further research is warranted in this regard, to determine whether the effects of dual-task interference increase as the complexity of the balance task is increased (e.g., with participants asked to alter their stance, to stand with their eyes closed, etc.). It also is likely that investigations that apply this paradigm within an older, or neurologically impaired population, may find that increases in the complexity of the verbal stimuli produce substantively significant impairment of balance. This expectation is supported by the increased likelihood of balance instability within this population, as well as the possibility that this population may (as a whole) demonstrate a reduced system capacity, as compared with the healthy young participants in the present research.

Findings from both the gait study and the balance study demonstrated that when the effects of information processing speed were removed from the model, no statistically significant dual-task interference remained for any factor (or factor combination). These results were consistent across measures of both gait and balance, suggesting that this effect is not domain-specific (i.e., the effect is not limited to the more complicated activity, gait). This is important evidence that may be used in the identification of the interference model that is most representative of the processes involved in managing the performance of two tasks. The bottleneck model of dual-task interference states that it is the *type of task*, not an individual's *system capacity*, that determines the ability of the individual to cope with secondary task interference. If this were in fact the case, we would not expect to see a general effect when covarying out information processing speed, as the primary and secondary tasks that were utilized in the present study were significantly different from each other, insofar as the primary task was a motor activity (gait or balance), while the secondary task was oral-motor and cognitive-linguistic. Furthermore, the effect (or lack thereof) was evident even when considering the less biomechanically demanding task (static balance). Taken in concert, these factors suggest that the results presented herein represent the strongest evidence to date for the capacity-sharing model of dual-task interference.

Future research should consider examining the same dual-task paradigm that was examined in these studies from an alternate perspective. Although the present research adopted the traditional perspective of examining dual-task interference as being an effect of a less automatic secondary task, on a more automatic primary task, it is plausible that there also might be variability in an individual's performance of the verbal task within the same dual task paradigm. It is possible that gait (or balance) tasks may have an effect on different elements of the verbal tasks that were examined, including differences in rate and volume, as well as overall changes in these two components of speech. Other components of the verbal tasks that could be affected by performance of a motor task include duration and number of pauses, as well as the number of phonemes or total stimuli produced per trial. It would also be of interest to examine differences in performance of the verbal task among different motor tasks, specifically examining whether the effects of the verbal task were the same between the gait task and the balance task. These oral-motor, articulation, and lexical components of the verbal task could all be examined in this manner using the data already collected through the Bluetooth wireless device utilized in the protocols of the presented studies.

In the future, the control that was exerted over the verbal stimuli and the inclusion of information processing speed should be extended to research that is conducted in an older population. The present research was able to consistently demonstrate that control over information processing speed completely eliminated the effects of dual-task interference in a healthy young population. It is, therefore, entirely possible that among older adults, dual-task interference is produced by a combination of information processing speed deficits, differences in priorities within multi-tasking, or an age related decline in dual-tasking ability that is independent of system capacity. Although it is unlikely that the effects of dual-task interference will produce changes in the gait and balance of healthy young adults that will increase their liability for fall and injury, this is not the case for older adults. It is plausible that dual-task interference will increase an older adult's risk of falling. In fact, this claim has been demonstrated and supported by Lundin-Olsson, Nyberg, and Gustafson (1997) who cite a phenomenon termed *stops walking while talking.* Simply put, older adults who demonstrate a tendency (be it conscious or unconscious) to stop walking when engaged in conversation are significantly more likely to be *fallers* (i.e., individuals that have fallen within the previous six months). Thus, this research suggests that individuals with a reduced capacity for dual-task interference face significant risk of falling within their activities of daily living – presumably due to the frequency of dual-tasking demands within our everyday lives.

The research presented in my studies suggests that there may be two key factors associated with an increased risk of falling within situations that require dual-task performance and a verbal task. These factors include the articulatory cognitive-linguistic complexity of the task, as well as the individual's information processing capacity. Future research should focus on identifying the thresholds for risk that might allow for an increase in the precision of predicting which individuals are at an increased risk for a fall when participating in dual-task performance. This would further indicate not only which tasks should be avoided, but also (and possibly more importantly) which individuals should avoid dual-tasking altogether. This research has important implications, therefore, for a number of individuals, including clinicians, who should avoid communicating with those at risk for falls while evaluating their gait or balance, or when treating these individuals for issues in their gait or balance. This also has implications for caregivers, who should understand and be aware of the risks that older populations may be incurring while attempting to walk and talk, or perform two tasks simultaneously. Finally, the most important implication is for the individual themselves who, with the knowledge of their capability to perform in dual-task scenarios, as well as knowledge of the risk that they are being placed at for falling and subsequent injury, would ultimately be given a voice to advocate for themselves about their own capabilities and safe limits of dual-task interference.

This study has provided considerable contribution to the existing literature regarding the execution of a verbal task and a motor task simultaneously. A set of verbal stimuli has been systematically developed to isolate the effects of each individual, progressive component of a verbal task, including oral-motor movement, articulation, and lexicality. This set of stimuli, and the description of its development, may prove useful in future evaluations of dual-task paradigms that include a verbal task.

The results that have been demonstrated by the present studies suggest that it is possible to account for the level of dual-task interference in individuals on the basis of their performance on an entirely separate measure of information-processing speed. This is valuable in the sense that future implications of performing multiple tasks at once could eventually be evaluated based on conducting a simple, non-motoric measure that is easily carried out without access to a gait and posture laboratory. In order for this to be possible, studies of diagnostic thresholds will need to be carried out, in order to directly relate this measure to a level of dual-tasking risk. This is particularly relevant in populations that are already at an increased risk for falling, such as older populations and motor impaired populations, due to the fact that these individuals may be at increased risk when performing a gait task at levels that are even slightly below their typical performance (i.e., they may have less margin for error in their gait or balance). It is important, therefore, that the potential risks of dual-task performance be conveyed to those individuals most at risk of falling, so that they are empowered to correctly prioritize among competing tasks, and (ultimately) improve their own safety.

References

Armieri, A., Holmes, J.D., Spaulding, S.J., Jenkins, M.E., & Johnson, A.M. (2009). Dual task performance in a healthy young adult population: Results from a symmetric manipulation of task complexity and articulation. *Gait and Posture, 29,* 346-348.

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

Camicioli, R., Oken, B.S., Sexton, G., Kaye, J.A., & Nutt, J.G. (1998). Verbal fluency task affects gait in Parkinson's disease with motor freezing. *Journal of Geriatric Psychiatry and Neurology, 11(4),* 181-185.

Kimura, D. (1999). *Sex and Cognition.* Cambridge, Mass.: MIT Press.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M. (1993). Attentional demands for static and dynamic equilibrium. *Experimental Brain Research, 97(1),* 139-144.

Lundin-Olsson, L., Nyberg, L., & Gustafson, Y. (1997). "Stops walking when talking" as a predictor of falls in elderly people. *Lancet, 349(9052),* 617.

O'Shea, S., Morris, M.E., & Iansek, R. (2002). Dual task interference during gait in people with Parkinson's disease: Effects of motor versus cognitive secondary tasks. *Physical Therapy, 82(9),* 888-897.

Appendix

Ethics Certificates

Western

Office of Research Ethics

The University of Western Ontario
Room 4180 Support Services Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
Website: www.uwo.ca/research/ethics

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			
☐ Janice Sutherland (jsutherl@uwo.ca)	☐ Elizabeth Wambolt (ewambolt@uwo.ca)	☐ Grace Kelly (grace.kelly@uwo.ca)	☑ Denise Grafton (dgrafton@uwo.ca)

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Office of Research Ethics

The University of Western Ontario
Room 4180 Support Services Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
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

Ethics Officer to Contact for Further Information			
☐ Janice Sutherland (jsutherl@uwo.ca)	☐ Elizabeth Wambolt (ewambolt@uwo.ca)	☑ Grace Kelly (grace.kelly@uwo.ca)	☐ Denise Grafton (dgrafton@uwo.ca)

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Room 4180 Support Services Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
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			
☐ Janice Sutherland (jsutherl@uwo.ca)	☐ Elizabeth Wambolt (ewambolt@uwo.ca)	☑ Grace Kelly (grace.kelly@uwo.ca)	

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Research Western

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.

Signature

Ethics Officer to Contact for Further Information

___ Janice Sutherland (jsutherl@uwo..ca)	___ Elizabeth Wambolt (ewambolt@uwo.ca)	✓ ___ Grace Kelly (grace.kelly@uwo.ca)

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The **University** *of* **Western Ontario**
Office of Research Ethics
Room 5150, Support Services Building • London, Ontario • CANADA - N6A 3K7
PH: 519-661-3036 • F: 519-850-2466 • ethics@uwo.ca • www.uwo.ca/research/ethics