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The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's disease

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

THE EFFECT OF CONCURRENT COGNITIVE, LINGUISTIC AND MOTOR TASKS ON SPEECH INTENSITY IN PARKINSON'S DISEASE

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Abstract

This study investigated the effect of concurrent tasks on speech intensity in Parkinson's disease (PD). Thirteen PD participants and twenty-two controls performed three tasks concurrent with a speech task. The speech task involved a repeated carrier phrase and a target word. The concurrent tasks involved math addition (cognitive), verb generation (linguistic), and manual visuomotor tracking (motor) at three levels of difficulty. All three concurrent tasks were associated with reduced speech intensity relative to the isolated speech task. The concurrent motor task was generally associated with the greatest reduction in speech intensity. Task performance measures were not significantly different for the concurrent and isolated tasks. PD participants demonstrated relatively worse performance on the linguistic task. The results of this study failed to support the energizing hypothesis. Instead, the results appear to support a cognitive/attention resource allocation hypothesis with regard to the effect of concurrent tasks on speech intensity regulation in PD.

Keywords Parkinson's disease, concurrent task performance, speech intensity, cognition, verb generation, mathematical addition, visuomotor tracking

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

1 Introduction

Idiopathic Parkinson's disease is a neurodegenerative movement disorder physically characterized by four primary symptoms: tremors, rigidity, bradykinesia, and postural instability (Duffy, 2005). Although there is an overarching lack of biomarkers and neuroimaging signs to aid in both diagnosing and understanding Parkinson's disease, previous research has been able to highlight a depletion of the neurotransmitter dopamine in the substantia nigra as a distinctive defect of this disease. The cause of Parkinson's disease is currently unknown, however, certain risk factors such as environmental triggers and genetic susceptibility have all been considered possible contributors to the onset of the disease (MacPhee, 2008; Marks, Hyland & Fiske, 2008).

The incidence rate of this disease in Canadians is approximately 252 people in every 100 000 (Jones, Wayne Martin, Wieler, King-Jesso & Voaklander, 2012), with 4.6 million cases currently reported globally, a number that is expected to rise to 8.67 million by the year 2030 (Dorsey et al., 2007). Of these individuals, between 80 and 90% suffer from a speech disorder (Adams & Dykstra, 2009). The changes in speech and voice quality caused by this neurological damage can be debilitating, hindering an individual's ability to successfully interact with others.

1.1 Motor Symptoms in Parkinson's Disease

The diagnosis of Parkinson's disease is entirely reliant on clinical examination of the individual's symptoms and is based on the presence of at least two of the four motor symptoms of Parkinson's disease. Tremor is usually the first symptom noticed by individuals with Parkinson's disease, and generally begin in one hand before progressing to the lower limbs and opposite side of the body. The tremor often originates as a rhythmic movement of the thumb and index finger, occurring while the hand is at rest (Samii, 2008). Rigidity is observed as increased muscle tone and resistance to passive movements and is independent of the direction and speed of movement. This resistance is generally felt throughout the entire range of the joint and is often described as "lead pipe" when it is smooth, or "cogwheel" when it is intermittent across the range of a movement (MacPhee, 2008; Marks et al., 2008; Samii, 2008). The slowness of voluntary movements, characteristic of those with Parkinson's disease, is called bradykinesia. Bradykinesia is often observed in this patient population concurrent with akinesia, the reduction in spontaneous voluntary movements (MacPhee, 2008; Marks et al., 2008; Samii, 2008). The final motor symptom of Parkinson's disease is postural instability. This symptom is rarely seen during the early stages of Parkinson's disease except in older populations. Postural instability and gait disturbance can be observed as short, shuffled steps. The worsening of this symptom can lead to an increased number of falls for the individual, as well as freezing when trying to initiate walking or when turning (Giladi & Nieuwboer, 2008; Marks et al., 2008; Samii, 2008).

1.2 Hypokinetic Dysarthria in Parkinson's Disease

Hypokinetic dysarthria is a motor speech disorder that is typically associated with Parkinson's disease. Approximately 75% of individuals with Parkinson's disease will develop a speech or voice issue related to this neurological disorder (Dykstra, 2007; Sapir, Ramig, Hoyt, Countryman, O'Brien & Hoehn, 2002). The characteristics of this disorder can be observed in the respiratory, phonatory, resonatory and articulatory processes of speech production, with its predominant symptoms being found in voice articulation and prosody (Duffy, 2005; Sapir, Ramig & Fox, 2008). Darley, Aronson and Brown (1969) initially classified the following characteristics as the most prominent features of hypokinetic dysarthria: monopitch, monoloudness, reduced stress, rate abnormalities, imprecise consonants, harshness in voice quality, breathy voice, and inappropriate silences. Reduced speech intensity and fast speech have also been identified as important features of hypokinetic dysarthria. Reduced speech intensity, or hypophonia, is a common characteristic that occurs in more than 40% of individuals with hypokinetic dysarthria (Adams & Dykstra, 2009; Dykstra, 2007; Gamboa, Jimenez-Jimenez, Niet, Montojo, Orti-Pareja, Molina et al., 1997; Ludlow & Bassich, 1984). Fast speech is observed in about 20% of individuals with hypokinetic dysarthria (Adams & Dykstra, 2009).

1.3 Hypophonia in Parkinson's Disease

Hypophonia is one of the most common speech symptoms in Parkinson's disease. The low speech intensity associated with hypophonia can have a negative effect on a person's ability to communicate and interact with others. This speech disorder results in an average intensity that is approximately two to four decibels lower than that of healthy adults. This difference in intensity equates to a 40% perceptual change in loudness (Adams & Dykstra, 2009; Dykstra, 2007; Fox & Ramig, 1997). The clinically significant difference in speech intensity for those with hypophonia compared to normal healthy adults has been attributed to laryngeal and respiratory abnormalities co-morbid with Parkinson's disease (Fox & Ramig, 1997; Schulz & Grant, 2000).

Ho, Iansek and Bradshaw (2002) suggested that hypophonia is similar to hypokinesia of the limbs and that it reflects a progressive decline in the amplitude of movements. It has also been suggested that hypohonia may be linked to a sensorimotor integration deficit in Parkinson's disease. In this context, the reduction in speech intensity is believed to be linked to a deficit in the perception or sensation of one's own speech loudness. In a study assessing this deficit, Ho, Iansek and Bradshaw (2000) found that patients with Parkinson's disease exhibited problems accurately perceiving the volume of their speech and consistently overestimated the loudness of their speech. These results were in support of their initial hypothesis, stating that inaccurate speech perception may result in reduced speech intensity. In turn, the authors concluded that there is a relationship between speech production (primary) and speech perception (secondary) in the scaling of speech intensity. These authors suggest that it is the faulty interaction of these two systems that results in the hypophonic speech of Parkinson's disease (Ho, Iansek, & Bradshaw, 2000).

Hypophonia has been examined in the context of isolated conversations as well as in situations involving background noise (Adams, Haralabous, Dykstra, Abrams, & Jog, 2005). In studies evaluating the effect of background noise on conversational speech intensity, individuals with hypophonia have been found to speak two to three decibels lower than healthy age-matched controls, a perceptually detectable difference (Adams et al., 2005). A study conducted by Adams, Moon, Dykstra, Abrams, Jenkins and Jog

(2006) asked participants to engage in conversation when presented with five levels of multi-talker background noise, imitate three speech intensity targets, and produce their maximum speech intensity. All participants showed an increase in speech intensity as the multi-talker background noise increased, however, participants with Parkinson's disease had significantly lower speech intensities at each level, of approximately two to three decibels. In addition, the individuals with Parkinson's disease also had significantly lower speech intensity during the imitation task, approximately three to four decibels lower, and had a lower maximum speech intensity, lower by six to seven decibels. This study provided preliminary support for the notion that individuals with Parkinson's disease follow a similar pattern of increasing speech intensity when presented with background noise as control participants, but the individuals with Parkinson's disease appear to consistently underestimate their speech intensity. It appears that individuals with Parkinson's disease seem to believe that they are speaking louder than they actually are speaking (Adams et al., 2006).

1.4 Cognitive Dysfunction in Parkinson's Disease

Individuals with Parkinson's disease will often experience a decline in cognitive functioning as a result of cholinergic, dopaminergic, and noradrenergic innervations deficits in the substantia nigra (Braak, Rüb, Gai and Del Tredici, 2003; Emre, 2004). Irregular activity in the frontal and associated parietal regions, such as in the dorsal premotor cortex and the inferior parietal lobule, has indicated that cognitive dysfunction in Parkinson's disease is not domain-specific but occurs globally as the disease spreads (Braak et al., 2003; Huang, Mattis, Tang, Perrine, Carbon and Eidelberg, 2007). In addition, cognitive decline may result as a side effect of certain medications used to treat other parkinsonian symptoms (Zesiewicz, Sullivan and Hauser, 2006). Approximately 40% of individuals with Parkinson's disease will develop dementia, with the chance of onset increasing as the duration of the disease lengthens. For example, individuals who survive with Parkinson's disease for longer than ten years have a 75% chance of developing dementia. The incidence rate of developing dementia in this population is four to six times greater than in normal healthy controls. Certain risk factors for dementia for those with Parkinson's disease have been identified, including more severe cases of Parkinson's disease, older age, and evidence of mild cognitive impairment (Bronnick, 2010; Marder & Jacobs, 2008). The deficits caused by cognitive decline do not appear to be restricted to any particular cognitive domain, but instead are widespread with problems arising in attention and executive functioning, visuospatial functioning, memory, and language (Bronnick, 2010; Crescentini, Mondolo, Biasutti, & Shallice, 2012; Marder & Jacobs, 2008; Rodríguez-Ferreiro, Cuetos, Herrera, Menéndez & Ribacoba, 2010).

An individual's ability to plan, initiate and execute actions for goal-directed behavior is the responsibility of attention and executive functioning. Problems with these functions draw into question the ability for one to perform normal activities of daily living and the capacity to take care of oneself. This issue becomes even more relevant especially as the individual's mental capacity declines from mild cognitive impairment to dementia. Previous research has indicated that this may not be the result of fewer attentional resources for allocation, but instead the individual's perceived difficulty of the task. Individuals with Parkinson's disease have been found to use more resources for the same task as healthy older adults due to this increase in perceived difficulty (Brown & Marsden, 1991; Goldenberg, 1990). A two-part study by Brown and Marsden (1991) was conducted to determine if there was a significant difference in performance due to the process of sharing attentional resources in participants with Parkinson's disease as compared to healthy older adults. This study raised questions as to whether or not the differences found in performance could be attributed to attentional resource depletion in the Parkinson's disease group or a deficit in the processes related to resource-switching. In the first experiment of the study, 40 healthy adult subjects were recruited to perform a cued and non-cued version of the Stroop task while performing one of three various secondary tasks; foot tapping, articulatory suppression or random number generation. A fourth group served as controls by having no secondary task to perform. Brown and Marsden found that the non-cued Stroop task caused greater demands on the limited capacity central processer within the supervisory attentional system of the working memory framework. In light of this, the more demanding of the secondary tasks would have shown a greater deterioration in performance as even more demands were placed on the supervisory attentional system. This trend was observed for the random number generation task which was hypothesized to be the most demanding secondary task. The second experiment asked 18 participants with idiopathic Parkinson's disease to perform the cued and non-cued Stroop task and each of the secondary tasks in a balanced order. For the control group, there were no significant differences between the reaction times reported for the three different tasks, whereas the subjects with Parkinson's disease had a significantly greater increase in reaction time for the random number generation task than they did for the foot tapping and articulatory suppression secondary tasks. From the results of these two studies, Brown and Marsden (1991) concluded that the supervisory attentional system, a major component of executive functioning and schema activation, is impaired in those with Parkinson's disease.

This conclusion was also reached by Goldenberg (1990) in a study that looked at the performance of non-motor concurrent tasks in Parkinson's disease. Participants were asked to perform a memory task in isolation, and then perform it concurrently with a second non-motor task. Two types of tasks were used in isolation and in combination with a secondary task; a verbal task and a visual task. Although these researchers did not find that the introduction of a concurrent non-motor task affected the performance of either the group of participants with Parkinson's disease without dementia subjects or the healthy controls, the results did indicate that there was a deficit in cognitive functioning related to attentional control (Goldenberg, 1990).

Visuospatial functioning has been found to be impaired in individuals with Parkinson's disease and dementia, to a greater degree than those with Alzheimer's dementia and no co-morbid neurological disease. This could be a result of the inter-related nature of visuospatial processes with executive functioning and fine motor control (Bronnick, 2010; Zesiewicz et al., 2006). Kemps, Szmalec, Vandierendonck and Crevitis (2005) demonstrated that individuals with Parkinson's disease performed worse on a visuospatial task than healthy older adults. These individuals were asked to complete the Corsi blocks task in isolation, then perform this task concurrent with a spatial tapping task, and, finally, concurrent with a random interval repetition task. No difference in performance was found between groups for the secondary tasks, however, performance degraded in both groups for the Corsi blocks task (a visuospatial task) when it was performed concurrently with the secondary tasks. The participants with Parkinson's disease did not experience a significant difference in performance dependent on the type of secondary task, indicating that the visuospatial deficit is closely linked with a central executive deficit in manipulating information. Kemps et al. (2005) did identify various factors that may have contributed to the severity of this deficit based on their results, including severity of the disease and advancement of age. This research provided evidence that impairments of the central executive function occur during the initial stages of Parkinson's disease, whereas visuospatial deficits appear during the moderate stages of this neurological disease, a function of both aging and disease progression. Dalrymple-Alford, Kalders, Jones and Watson (1994) found a similar result in their study analyzing visuomotor tracking performance and forward digit span performance in isolation and concurrent settings. Individuals with Parkinson's disease were less able to perform the visuomotor tracking task and the forward digit span task concurrently than the control group. This was observed through their degrading tracking performance. In addition, the dual task impairment was only observed for the visuospatial task and was not seen in the verbal task. Dalrymple-Alford et al. (1994) provided numerous explanations for this trend, including the process of learning the tasks and fatigue levels. However, the explanation of greatest interest involves the concept that the tracking task was more difficult, as it required greater effort and cognitive resources to complete, as opposed to the verbal task. This would indicate that a visuospatial deficit may be highly related to a central executive impairment (Dalrymple-Alford et al., 1994).

As cognitive function declines, patients with Parkinson's disease, as well as their family members and friends, may report difficulty with short-term memory, whereas long-term memory remains fairly unaffected (Zesiewicz et al., 2006). This may be a result of poor encoding abilities and retention of the material, as research on recognition capabilities appears to be inconclusive (Bronnick, 2010). The inability to properly encode and retain memory traces may be a result of an impaired supervisory attentional system of working memory, affecting the distribution and allocation of attentional resources. In addition, dysfunction in working memory will cause problems with manipulation of information and subsequent slowing of information processing (Theodoros & Ramig, 2011). These memory deficits may be further exacerbated in those with Parkinson's disease due to certain mood disorders, such as apathy and depression (Butterfield, Cimino, Oelke, Hauser & Sanchez-Ramos, 2010; Pagonabarraga & Kulisevsky, 2012).

Current research suggests that linguistic impairments for those with Parkinson's disease can be attributed to attention and executive functioning deficits as well as limitations due to motor control impairment, affecting their speech abilities (Theodoros & Ramig, 2011; Zesiewicz et al., 2006). Previous studies analyzing speech-motor influence on linguistic abilities has shown that increased linguistic demands can cause disruptions and dysfluency in the speech system. In assessing linguistic complexity on speech production in Parkinson's disease, Walsh & Smith (2011) devised a study that used behavioural and physiological measures to determine the effects on speech response latency, interarticulatory coordinative consistency, accuracy of speech production, response latency and response accuracy. They found that individuals with Parkinson's disease had greater motor speech variability for all the sentence conditions, took longer to initiate speech, and made more speech errors on the speaking tasks. These results could indicate longer and less controlled speech planning processes, an effect of the attentional demands of the tasks being completed. This is similar to the findings found in a study conducted by Dromey and Benson (2003) researching lip kinematics for concurrent task performance. The linguistic impairments found in Parkinson's disease are not limited to the physical production of speech, but are also found in the comprehension of language. Semantic and phonemic verbal fluency have been found to be impaired in non-demented individuals with Parkinson's disease (McDowd, Hoffman, Rozek, Lyons, Pahwa, Burns & Kemper, 2011; Theodoros & Ramig, 2011). Much work has been conducted evaluating sentence comprehension deficits in Parkinson's disease, which have been linked to grammatical comprehension deficits as well as executive functioning challenges (Colman, Koerts, Stowe, Leenders & Bastiaanse, 2011). All of these factors may contribute to the impaired pragmatic communication, verbal and nonverbal social skills, found in individuals with Parkinson's disease (Hall, Ouyang, Lonnquist & Newcombe, 2011).

1.5 Speech and Concurrent Task Research

Humans have the remarkable ability to produce speech, a highly complex behaviour, while simultaneously performing a diverse number of concurrent cognitive and motor activities. Numerous theories have been proposed to account for this remarkable ability to perform concurrent speech, motor and cognitive tasks. One of the most widely accepted theories of attention was presented by Daniel Kahneman (1973), detailing the allocation of a limited number of cognitive resources among competing tasks. In this model, a finite amount of cognitive resources can be divided and distributed to each task, based on the demands needed for each to be carried out. This model remains nonspecific and flexible, allowing the individual to have considerable control over the allocation of these resources to each task. As the demands of one task increases, cognitive resources may be drawn from other areas and reallocated as seen fit (Reed, 2007).

Kinsbourne and Hicks (1978) supplemented a neurophysiological model to the pre-existing psychological process of resource allocation provided by Kahneman in proposing the functional distance hypothesis for dual interference. In this theory, Kinsbourne and Hicks state that the more separate the activated brain regions, the less interference there will be for each task. Consequently, the closer the activated brain regions are, the greater the interference for the two tasks. In this manner, tasks that seem to utilize the same processes would overlap and compete for the same cognitive resources, whereas tasks that were very distinct from one another would provide less interference as they would be using separate neural pathways (Kinsbourne & Hicks, 1978).

The use of speech in concurrent task experiments has the potential to reveal important information about the attentional resources and the distinct cognitive and motor processes that are involved in speech production (Dromey & Bates, 2005). Dromey and Benson (2003) examined the effect of the performance of several concurrent tasks on the speech of healthy adults. Utilizing four conditions, a speech task and either a cognitive, linguistic or motor concurrent task, Dromey and Benson (2003**)** were able to evaluate the effect of distractor tasks on the duration, displacement, velocity and the spatio-temporal coordination of the speech-related movements of the upper lip, lower lip and jaw. They found that whereas the motor task produced smaller lower lip displacement values and a significant decrease in velocity, the cognitive and linguistic task produced a significant increase in the spatiotemporal index for the lower lip. These results by Dromey and Benson (2003) demonstrate that concurrent tasks can have a significant effect on speech kinematics and that these kinematic effects can be dramatically influenced by the nature of the concurrent task.

In a related concurrent speech task study involving healthy control participants, Dromey and Bates (2005) found increased speech intensity in both concurrent linguistic and cognitive task conditions, and no significant change for intensity in a concurrent motor task condition. These results were thought to provide support for the functional distance hypothesis but they also felt that their results could also reflect a generalized increase in performance effort that was caused by attempting to perform a concurrent task. The motor task results for this study directly contrast with the results obtained by Dromey and Shim (2008) in a subsequent concurrent speech task study. Dromey and Shim (2008) conducted a study to investigate the applicability of the functional distance hypothesis through concurrent task performance of 20 young adults. The participants were asked to perform a speech task, a verbal fluency task, a right-handed task, and a left-handed task, in isolation and then concurrently. In this study, Dromey and Shim (2008) found that the concurrent limb motor task significantly increased the participants' speech intensity.

The results of previous preliminary research related to the effect of concurrent tasks on speech in Parkinson's disease have been inconsistent. One previous study by Ho et al. (2002) found that a concurrent manual motor task was associated with a significant reduction in the speech intensity of participants with Parkinson's disease. In contrast, a recent preliminary study by Adams, Winnell and Jog (2010) found that a concurrent manual task was associated with a significant increase in conversational speech intensity in participants with Parkinson's disease. Based on this result and the similar results that were obtained in Dromey and Bates (2005), an energizing hypothesis was proposed by Adams et al (2010). This hypothesis suggests that certain concurrent motor, linguistic, and cognitive tasks can be associated with an overall increase in effort level which in turn can have an energizing or enhancing effect on concurrent speech intensity levels. Based on the preliminary results from Adams and colleagues of a concurrent motor task in Parkinson's disease, it is hypothesized that individuals with Parkinson's disease will show a relatively greater energizing effect of concurrent tasks than control participants. The effects of concurrent linguistic and cognitive tasks on speech intensity have not been examined in Parkinson's disease. Thus, the energizing hypothesis has not been systematically evaluated in previous studies of speech intensity regulation in Parkinson's disease.

1.6 Task Development

To determine the effect of various concurrent tasks on speech intensity for those with Parkinson's disease, a speech, cognitive, linguistic and motor task needed to be developed to evaluate these processes. The developed tasks referenced previous studies in their design and were modified for the purpose of providing novel tasks with a varying level of difficulty.

Speech Task. The nature of this study requires an individual to repeat a carrier phrase a minimum of 60 times throughout its completion. For this study, the phrase "The next word I am going to say is" was selected as the carrier phrase because it is a natural sentence that could be spoken prior to responding with the supplied target word "peach", or with the individual's own generated answer. The target word "peach" was chosen as it was not related in any manner to the nouns presented in the linguistic task, therefore no priming could occur, and the word initial voiceless bilabial stop allowed for a clear analysis as to where the carrier phrase ended and the target word began.

Cognitive Task. Previous research has used mathematical questions in order to manipulate cognitive abilities in the participant population (Dromey & Bates, 2005). For the purpose of this study and maintaining consistency with previous research, mathematical addition questions were used for the cognitive task. Three difficulty levels were determined for the task based on ease of the question presented. The first level of difficulty consisted of single digit – single digit questions, such as 3 + 3. The second level of difficulty, posing more difficult questions, required the addition of double digit – single digit questions, such as 45 + 8. The final level of difficulty, with the hardest questions, consisted of double digit – single digit – single digit addition, for example 52 + 6 + 4. The questions were generated randomly using an online random integer generating database (Haahr, 1998). The parameters for each level were input into the generator, and then the resulting 15 integers were paired up, left to right, to create a novel mathematical addition question. Fifteen math questions were selected for the isolation cognitive task with five questions at each difficulty level, and 15 math questions were selected for the concurrent speech + cognitive task with five questions at each difficulty level (refer to Appendix C for the questions used in the isolation cognitive task and Appendix D for the questions used in the concurrent speech + cognitive task).

Linguistic Task. In order to determine the effect of a linguistic task on concurrent performance, previous research has used various tasks in order to best capture the nature of this relationship. In the past, linguistic tasks such as spontaneous monologues, phonemic fluency tasks, and counting have been used. This study referenced the work of Del Missiers and Crescentini (2011) in noun and verb generation for individuals with Parkinson's disease to devise a linguistic task suitable for the methodology of the study.

A pilot study was conducted using the 67 noun stimuli from the study conducted by Del Missiers and Crescentini (2011). Each noun was translated from the original presentation in Italian to English. The noun stimuli were randomized and displayed in hard copy. The questionnaire was distributed to a fourth year undergraduate class, asking them to provide an associated verb for each noun stimuli. Fifty questionnaires were returned completed (refer to Appendix E for the questionnaire). The verb responses for each noun were collected and tallied, and then divided into 3 groups; strong association-low selection, strong association-high selection, and weak association-high selection. A noun is classified as strong association if a stimulus has a high activation for a particular verb response, as can be observed in the relationship between "book" and "read". In contrast, a noun is categorized as weak association if there is no verb response that is strongly related to the noun, such as in the case of the word "comet". The selection strength of the noun is determined by the number of different verbs that could be associated with the noun stimuli, independent of the strength of the association of the verb (Del Missiers & Crescentini, 2011). After division into these three categories, 30 nouns were chosen for use in the study, 15 noun stimuli for the isolation linguistic task with five questions for each difficulty level and 15 noun stimuli for the concurrent speech + linguistic task with five questions for each difficulty level (refer to Appendix F for the questions used in the isolation linguistic task and Appendix G for the noun stimuli used in the concurrent speech + linguistic task).

Motor Task. Various visuomotor tasks have been used in previous studies to simulate motor movements. Dromey and Bates (2005) used a visuomotor task in which the participant was asked to click on random targets when they appeared on a display screen. In another study conducted by Dromey and Shim (2008), participants were asked to place pegs in a pegboard. Finger tapping and manipulating nuts and bolts are two of many other motor tasks that have been used to examine dual-task speech motor performance (Dromey and Benson, 2003; Galletly & Brauer, 2005). The task used in this study needed to be challenging for both the healthy older adults and the individuals with Parkinson's disease, without having cause for confounding results due to the fine motor control constraints of the neurological disease. This study utilized the visuomotor tracking task created by Adams et al. (2010) which required the participant to track a continuous vertical sinusoidal target on a display screen by manipulating a handheld pressure bulb. The exerted pressure on the hand held bulb causes a horizontal line to rise and fall, allowing the participant to track the generated moving band as accurately as possible. Levels of difficulty for the visuomotor tracking task in this study were defined by the movement speed and frequency of the computer generated visual target. The initial speed was 0.25 Hz for the first difficulty level. This speed increased for the second difficulty level to 0.5 Hz, and to 0.75 Hz for the third difficulty level. Each tracking trial lasted approximately 24 seconds in the isolation motor task condition. In the concurrent condition, the trial consisted of the duration of the participant's repetition of the spoken carrier phrase sentence.

1.7 Objectives and Hypotheses

The goal of this study was to investigate the effect of three concurrent tasks on speech intensity in individuals with Parkinson's disease. The three concurrent tasks included a concurrent linguistic task (verb generation), a concurrent cognitive task (math addition), and a concurrent motor task (manual visuomotor tracking). Each task was examined across three levels of increasing difficulty. Based on the energizing hypothesis, it was predicted that each of the concurrent tasks would be associated with an increase in speech intensity. It was further predicted that the energizing effect of the concurrent tasks would be relatively greater in the Parkinson's disease participants than in healthy control participants. Thus, the following specific hypotheses were examined in this study:

1) Performing a concurrent cognitive, linguistic, or motor task while speaking will result in an increase in speech intensity in both experimental groups.
2) Participants with Parkinson's disease will show a relatively greater increase in concurrent speech intensity than control participants.
3) As the difficulty of the specific concurrent task increases across three levels there will be a corresponding increase in concurrent speech intensity.
4) There will be reciprocal energizing effects of the concurrent speech task on the concurrent cognitive, linguistic and motor tasks. This prediction is examined by obtaining performance scores for each of the cognitive, linguistic and motor tasks in isolation and during the concurrent speech task. Thus, it is hypothesized that, relative to the performance scores obtained in isolation, the cognitive, linguistic and motor tasks will show improved performance scores when they are performed concurrently with the speech task.
5) There will be greater interference for performance on the linguistic and cognitive concurrent tasks than for the motor concurrent task based on the predictions of the functional distance hypothesis. The cognitive and linguistic tasks are believed to both engage phonological processes and therefore they are predicted to interfere with the speech task. The limb motor task will engage visuospatial processes which are believed to be distant from the auditory motor

processes involved in the speech task and therefore should have a minimal dual task interference effect.

Chapter 2

2 Methods

2.1 Participants with Parkinson's Disease

Participants with mild to moderate idiopathic Parkinson's disease (stage 1-3 of the Hoehn & Yahr Parkinson's disease severity scale) who were attending the Movement Disorders program at the London Health Sciences Centre, University Hospital in London, Ontario were recruited by neurologist Dr. Mandar Jog for the purposes of this study. Sixteen individuals with idiopathic Parkinson's disease participated in this study. One individual was removed from the study based on their limited understanding of English, and two others were removed as they were not found to have hypophonic speech. Therefore, 13 individuals with Parkinson's disease were considered in this study; 12 males and 1 female with an age range of 57 to 78 years (*M*=72.85, *SD*=7.49). See Table 1 for participant demographics on the individuals with Parkinson's disease. Participants were required to be fluent in English and demonstrate functional literacy by reading aloud The Grandfather Passage (Darley et al., 1975). All participants with Parkinson's disease were stabilized on anti-parkinsonian medication and tested approximately one to two hours after receiving a regular dose of medication. Two of the participants with Parkinson's disease were not currently prescribed any anti-parkinsonian medication. The other 11 participants were on a variety of anti-parkinsonian medications including (but not limited to): Levodopa-Carbidopa (Sinemet), Pramipexole (Mirapex), or Levodopa. There was no prior treatment of hypophonia by a speech-language pathologist for the participants with Parkinson's disease. Participants were excluded from the study if there was a history of a speech, language or hearing impairment, or an additional neurological disorder. All included participants passed a 30 dB HL hearing screening at 500, 1000, 2000 and 4000 Hertz in both ears. The Montreal Cognitive Assessment (MoCA; Nasreddine, 2003) was administered to all of the participants with Parkinson's disease. Each participant was provided with a letter of information (Appendix H) and asked to sign a consent form (Appendix I) prior to participation in the study.

Table 1. *Description of participants with Parkinson's disease*

Participant ID	Group	Age	Gender	Year of Diagnosis	MoCA Score
23	2	71	Male	2007	21
24	2	60	Male	2007	22
25	2	68	Male	1996	22
26	2	61	Male	2007	27
27	2	76	Male	2011	25
28	2	57	Male	2010	24
29	2	77	Male	2004	15*
30	2	73	Male	2011	28
31	2	78	Male	2008	17
32	2	67	Male	2010	24
33	2	58	Male	2012	25
34	2	59	Female	2002	22
35	2	74	Male	1997	25

*Participant 29 did not complete the drawing components of the MoCA. The final MoCA score for this individual was scored out of 25.

Previous research has indicated that the MoCA is more sensitive in detecting cognitive impairment in individuals with Parkinson's disease than the Mini-Mental State Examination. In a study assessing cognitive impairment in 131 individuals with Parkinson's disease found the average MoCA score to be 24.9 out of 30, with a score of 26 and higher indicating no cognitive impairment (Nazem, Siderowf, Duda, Have, Colcher, Horn et al., 2009). In this study, the average MoCA score was 23.5, excluding the score from Participant 29 because the test was not fully completed. This sample of individuals with Parkinson's disease is fairly representative of the overall group, as indicated by similar average scores.

2.2 Control Participants

Control participants were recruited through the Retirement Research Association at the University of Western Ontario, by Professor Scott Adams. Twenty-two healthy older adults participated in the study. For the healthy older adults, there was a total of 11 males and 11 females with an age range of 60 to 85 years (*M*=72.73, *SD*=6.77) included in the study. See Table 2 for participant demographics on the control participants. Participants were required to be fluent in English and demonstrate functional literacy, as proven by a reading of the Grandfather Passage. All participants had to pass a 30 dB HL hearing screening at 500, 1000, 2000 and 4000 Hertz in both ears to be included in the study. Each participant was provided with a letter of information (Appendix J) and asked to sign a consent form (Appendix I) prior to participation in the study.

Table 2. *Description of control participants*

Participant ID	Group	Age	Gender
1	1	79	Male
2	1	71	Male
3	1	64	Female
4	1	79	Male
5	1	65	Female
6	1	79	Male
7	1	71	Male
8	1	79	Male
9	1	71	Male
10	1	72	Female
11	1	73	Male
12	1	62	Female
13	1	85	Male
14	1	75	Male
15	1	76	Female
16	1	67	Female
17	1	76	Female
18	1	67	Female
19	1	60	Female
20	1	70	Female
21	1	75	Female
22	1	84	Male

2.3 Apparatus

All testing sessions took place in the Speech Movement Disorders Laboratory located in Elborn College at the University of Western Ontario. Participants were seated in a comfortable chair and wore a headset microphone (AKG c420) attached to a preamplifier (M-Audio preamp USB) and a desktop computer to allow for the audio recording of speech. The microphone was calibrated at the beginning of each testing session. To calibrate the microphone, a sound level meter was placed 15 cm from the participant's mouth while the participant produced a prolonged 'ah' sound at 70 dB as indicated on the sound level meter for approximately 1-2 seconds. A computer screen associated with a laptop computer was placed approximately 30 cm in front of the participants to allow for the presentation of the question stimuli. A sheet with the printed carrier phrase (Times New Roman, font size 80) was placed in front of the participants during each task that required its use. The visuomotor tracking signals were presented on an oscilloscope of a separate device and were controlled by a computer software program called Tracker (Vercher, 1994a) and placed approximately 30 cm in front of the participant. Performing the task required the manipulation of a standard hand held pressure bulb attached to an air pressure transducer system (Glottal Enterprises MS100-A2). Acoustic analysis software called Praat (Boersma & Weenink, 2011) was used to obtain speech intensity and durational measures. Specialized motor tracking analysis software called Sigma (Vercher, 1994b) was used to obtain visuomotor tracking performance scores.

2.4 Procedure

During the first part of the experiment, participants performed each of the four experimental conditions involving the production of the tasks in isolation (simple speech, verb generation, math addition and motor tracking). Each task utilized 15 instances for data collection; 15 sentences repeated, 15 math questions, and 15 nouns presented. The order of these tasks was counterbalanced across all participants. Once these four tasks had been completed, the participant performed three experimental conditions (concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor) involving concurrent tasks. The order of these three concurrent experimental conditions was randomized across the participants.

2.4.1 Experimental Conditions

Condition 1: **Simple Speech Task.** The speech task consisted of the repetition of a carrier phrase. Each participant was asked to repeat the carrier phrase "The next word I am going to say is peach" 15 times consecutively, prompted by the sound of a beep for each repetition.

Condition 2: **Math Addition Task.** The math addition task consisted of 15 mathematical questions. The participant was presented with a mathematical addition question on a computer display and asked to verbally respond with the correct answer. The questions increased in difficulty after every set of 5 problems, beginning with 5 single digit - single digit addition questions (3+3), followed by 5 double digit - single digit addition problems (52+8), and finally, with 5 questions of double digit - single digit - single digit addition questions (42+4+7).

Condition 3: **Verb Generation Task.** In the verb generation task, the participant was presented with a written representation of a noun on a computer display and requested to verbally report a verb action that could be associated with the presented noun. For example, the participant, presented with the noun "book", may have responded with the verb action "read". Fifteen different nouns were displayed in succession, varying in degree of difficulty on two different levels, association and selection, to create a hierarchy of three levels of difficulty; strong association-large selection such as "music", strong association-low selection as for the noun "cup", and weak association-low selection such as for the word "button". The nouns were presented in the following order: 5 nouns of strong association-low selection presented first, followed by 5 nouns designated as strong association-high selection, and finally with 5 nouns delineated as weak association-high selection.

Condition 4: **Motor Task.** The motor task involved a visual-motor tracking task using a standard hand-held blood pressure test bulb attached to an air pressure transducer system. The participant was required to track a continuous vertical sinusoidal target signal on an oscilloscope-like display by increasing and decreasing the pressure exerted on the hand bulb. The sinusoidal target appeared as a horizontal band (5mm) moving rhythmically and vertically across the mid-portion of the screen. The manipulation of the hand bulb was translated onscreen as the rising and falling of a moving horizontal line. The tracking task required the participant to keep the horizontal line (associated with their hand pressure) in the center of the continuously moving horizontal band (sinusoidal target). The difficulty of the task was increased twice throughout the task by increasing the speed of movement for the horizontal band (sinusoidal target). Each tracking trial lasted approximately 24 seconds and was initiated when the participant's performance was observed to normalize. The initial speed was set to 0.25Hz, followed by an increase to 0.5Hz, and the final phase which consisted of the band moving at a speed of 0.75Hz.

Condition 5: **Concurrent speech + cognitive task.** The participant performed the math addition task concurrent with the simple speech task. In this concurrent condition, the participant would solve mathematical addition equations while repeating the carrier phrase "The next word I am going to say is ____". Once the participant had determined the answer to the question, the participant would respond with their answer, inserting it at the end of the carrier phrase. For example, if displayed with the question "3 + 3", the participant would respond "The next word I am going to say is 6". The display of each question was signaled with a tone, prompting the participant to begin by saying the carrier phrase and solving the question. Each trial lasted as long as necessary for the participant to provide their best guess at the correct answer for the mathematical addition equation.

Condition 6: **Concurrent speech + linguistic task.** Each participant performed the simple speech task and the verb generation task concurrently; in which they performed the verb generation task while repeating the phrase "The next word I am going to say is ____". In this concurrent task, the participant would insert their verb action response at the end of the carrier phrase. For example, if the participant was presented with the noun "cup", they might respond "The next word I am going to say is drink". Each trial lasted as long as necessary for the participant to either provide an answer, or indicate that they could not originate one. The presentation of the noun commenced with a short beep, notifying the participant that the trial had begun and to begin repeating the carrier phrase while formulating their answer.

Condition 7: **Concurrent speech + motor task.** The participant performed the simple speech task and the motor task concurrently. The participant manipulated the hand-held pressure bulb while tracking the onscreen sinusoidal target signal and repeating the original carrier phrase, “The next word I am going to say is peach”. The original carrier phrase was repeated 5 times at each tracking speed, with each repetition prompted by the sound of a short beep. After the participant had completed repeating the carrier phrase 5 times, the tracking speed was increased and the task repeated at the faster speed.

2.5 Measures

Data was collected for nine variables and divided into primary and secondary measures. The primary measures consisted of three intensity variables: carrier phrase intensity, target word intensity and overall utterance intensity. The secondary measures were divided into two groups; task performance and durational measures. The task performance variable consisted of the performance scores for the cognitive, linguistic and motor tasks. The five durational variables included overall utterance duration, carrier phrase duration, response time, response latency, and sentence-response latency.

2.5.1 Primary Measures

Intensity. Intensity measurements were obtained for three different variables; carrier phrase intensity, target word intensity and overall utterance intensity (carrier phrase plus target word intensity). For the overall intensity, the average SPL was measured within the spectrogram and was taken from the initial formant onset of the first spoken syllable, defined as the speech onset, to the final formant offset of the last syllable of the sentence, henceforth referred to as the speech offset. In the case of carrier phrase intensity, the average SPL was measured from the speech onset to the speech offset of the final section of the repeated carrier phrase (“say is...”). For target word intensity, the average intensity was measured from the initial speech onset of the provided response “peach”, or the given response to the presented question, to the final speech offset.

2.5.2 Secondary Measures

Task Performance Scores. In the linguistic task, each response that is appropriately associated with the presented noun was scored as correct and received one point. The linguistic task was scored out of 15 with one potential mark per noun presentation. In the cognitive task, each correctly answered mathematical problem was given one point. A perfect score for the cognitive task was 15 with one potential point per question. In the visuomotor manual tracking task, an average tracking error score (in mmHg) was calculated for each participant based on their ability to continuously track the visuomotor target. An error score closer to 0 mmHg indicated a more accurate performance, whereas a greater number signified poorer performance. The task performance scores were used as the dependent measures in the statistical analyses related to objective 4.

Utterance Duration. Utterance duration was measured in two ways; overall utterance duration and carrier phrase duration. The overall utterance duration was measured from speech onset to the speech offset of the entire sentence. Carrier phrase duration measured the section of the sentence that is repeated in each instance, "The next word I am going to say is...". Duration was measured from the speech onset to the speech offset within the last syllable of the repeated section ("say is..."). This measurement indicates whether or not the performance of a concurrent task with the speech task has an effect on the rate of speech production. A slower rate of production would suggest there is a distraction from speaking whereas a faster rate of production could indicate a response to time pressures (Dromey & Bates, 2005). (See Figure 1.)

Response Time. Response time was measured in seconds from the initial presentation of the noun stimuli/mathematical addition equation to the speech onset of the participant's response. This variable was measured in order to have a baseline for participant's cognitive processing times for each task. (See Figure 2.) This variable was measured in the isolation cognitive and isolation linguistic task conditions.

Response Latency. Response latency was measured from the initial display of the noun/addition problem to speech onset. This measurement provides information on whether or not the participant was performing the tasks concurrently. If the response latency is high, there is an increased chance that the participant was not performing the tasks concurrently, whereas a shorter response latency would suggest that concurrent cognitive processing was likely to be occurring concurrently with the speech task. This variable was measured in the concurrent speech + cognitive and concurrent speech + linguistic task conditions. (See Figure 1.)

Sentence-Response Latency. Sentence-response latency was measured from the speech offset of the carrier phrase to the speech onset of the participant's response. This measurement indicates whether or not the participant was performing the tasks concurrently by assessing the delay between the carrier phrase and the target response. A greater sentence-response latency would indicate that the individual was pausing after repeating the phrase and prior to responding in order to determine a response, as opposed to concurrently processing both tasks at the same time. A shorter sentence-response latency would suggest that the individual is performing both tasks concurrently. This variable was measured in the concurrent speech + cognitive and concurrent speech + linguistic task conditions. (See Figure 1.)

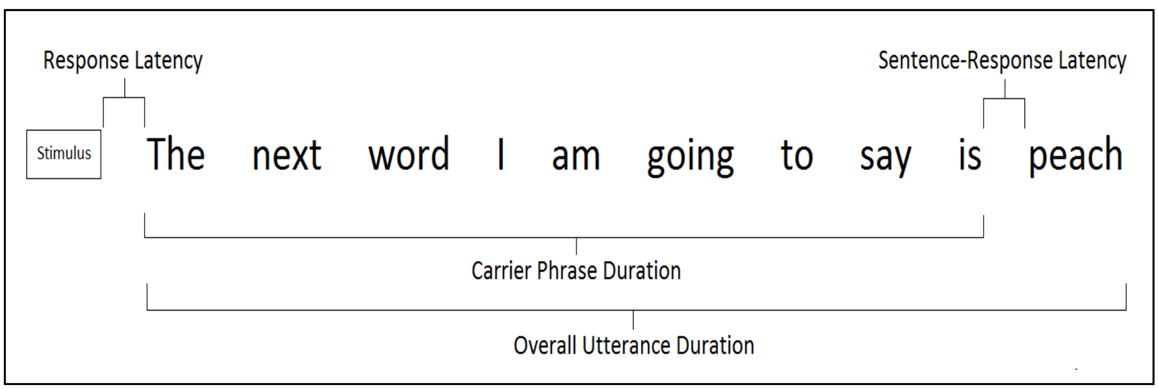

Figure 1. Durational measures for the concurrent cognitive, linguistic and motor tasks.

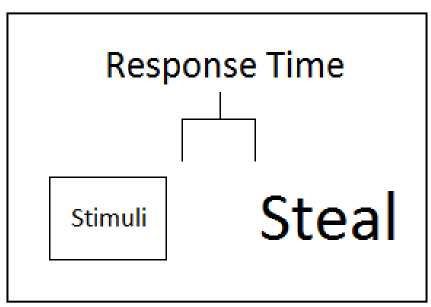

Figure 2. Durational measures for the isolation cognitive and linguistic tasks.

2.6 Analyses

2.6.1 Objectives 1, 2 & 3 – Effect of Task Condition on Speech Intensity for Control Participants and Participants with Parkinson's disease

To address the effect of task condition on speech intensity for the Parkinson's disease and control participant groups, 3 variables were analyzed; carrier phrase intensity, target word intensity and overall utterance intensity. This allowed for examination of the effect of cognitive processing on speech intensity, because it would have occurred concurrently with the spoken carrier phrase. In addition, change in target word intensity values could be indicative of an energizing effect during cognitive processing. Overall utterance intensity analyses would incorporate the intensity of the carrier phrase and the target word, and provide information as to the intensity for the entire duration of the phrase.

Carrier Phrase Intensity: 3 analyses were performed.

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + motor).

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

Target Word Intensity: 2 analyses were performed.

A 3-way, repeated measures ANOVA was performed. The three factors included: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task condition (isolation, concurrent), Factor 3 = task type (speech/motor, cognitive, linguistic).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

Overall Utterance Intensity: 3 analyses were performed.

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + motor).

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

2.6.2 Objectives 4 & 5: Effect of Task Condition and Task Type on Performance for Control Participants and Participants with Parkinson's disease

To address the effect of task condition and task type on performance for the control and Parkinson's disease subject groups, 6 variables were analyzed; task performance score, utterance duration, carrier phrase duration, response time, response latency and sentence-response latency.

Task Performance Score: 2 analyses were performed.

A 4-way, repeated measures ANOVA was performed. The four factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task condition (isolation, concurrent), Factor 3 = task type (cognitive, linguistic), Factor 4 = difficulty level (1, 2, 3).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task condition (isolation motor, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

Utterance Duration: 3 analyses were performed.

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + motor).

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

Carrier Phrase Duration: 3 analyses were performed.

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + motor).

A 2-way, repeated measures ANOVA was performed. The two factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor).

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), Factor 3 = difficulty level (1, 2, 3).

Response Time:

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (isolation cognitive, isolation linguistic), Factor 3 = difficulty level (1, 2, 3).

Response Latency:

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (controls, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic), Factor 3 = difficulty level (1, 2, 3).

Sentence-Response Latency:

A 3-way, repeated measures ANOVA was performed. The three factors included the following: Factor 1 = subject group (control, Parkinson's disease), Factor 2 = task type (concurrent speech + cognitive, concurrent speech + linguistic), Factor 3 = difficulty level (1, 2, 3).

Chapter 3

3 Results

This study examined the effects of concurrent cognitive, linguistic and motor tasks on task performance and selected aspects of speech production in individuals with Parkinson's disease and healthy older adults. To provide a complete picture of the aspects of speech production of interest to this study, the analyses were grouped into three main sections based on the variables being assessed: speech intensity, task performance, and durational measures. Each main section consists of analyses that will evaluate each variable for group, task condition, task type, and difficulty level effects and interactions.

3.1 Speech Intensity Results

To determine the relationship between task condition (isolation or concurrent), task type (speech, cognitive, linguistic, or motor), and difficulty level and the resultant effect on speech intensity, three different intensity variables were considered; carrier phrase intensity, target word intensity, and overall intensity. The results obtained for each dependent variable will be presented in a separate section. Within each of these sections the results of the three separate statistical analyses will be reported.

3.1.1 Carrier Phrase Intensity

The statistical procedures for carrier phrase intensity were divided into three separate analyses. *Statistical Analysis One* focused on the effects of isolation versus concurrent tasks of the dependent variables. For this analysis only the isolated speech task condition and the concurrent speech and motor task condition were included. The other two conditions (concurrent cognitive and concurrent linguistic) were not included because the reported answers consisted of only a target word, with no carrier phrase for comparison. *Statistical Analysis Two* focused on the effects of the four different task types (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor) on the dependent variables. *Statistical Analysis Three* focused on the effects of the three different difficulty levels on the dependent variables.

Because difficulty levels were only examined in the linguistic, cognitive and motor tasks, these tasks were the focus of attention in this analysis procedure.

3.1.1.1 Statistical Analysis One: Isolation versus Concurrent Task Condition

In order to determine the effect of task condition on carrier phrase intensity, carrier phrase intensity values for the isolation speech task was compared to the values for the concurrent speech + motor task. A two-factor, repeated measures ANOVA was performed, with subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task condition (two levels: isolation speech, concurrent speech + motor). In this analysis, the main effects of group and task condition were significant (refer to Appendix K for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 32) = 4.177$, $p = .049$]. The significant main effect for group indicates that the carrier phrase intensity of the subjects with Parkinson's disease was significantly less than that of the control subjects for both the isolation speech and the concurrent speech + motor task. The main effect of task condition was significant [$F(1, 32) = 25.469$, $p = .000$] and is presented in Figure 3 with associated means and standard error scores listed in Table 3. The significant main effect for task condition explains that, in both groups, carrier phrase intensity was much higher for the speech task performed in isolation than the speech task performed concurrent with the motor task.

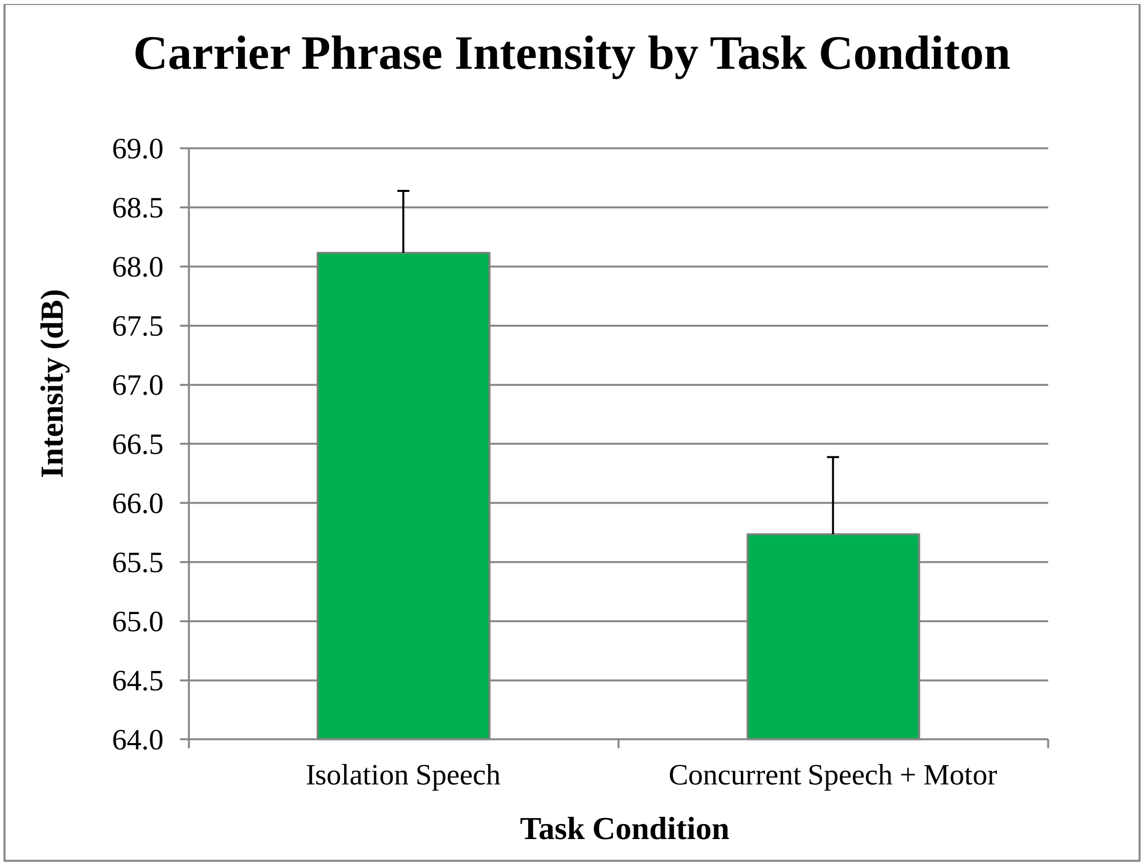

Figure 3. Carrier phrase intensity by task condition for the control and Parkinson's disease participants.

Table 3. *Mean carrier phrase intensity values and standard error by task condition for the control and Parkinson's disease participants.*

	Carrier Phrase Intensity (dB)	Standard Error
Isolation Speech	68.11	0.524
Concurrent Speech + Motor	65.74	0.652

Interactions: Significance was not found for the group by task condition interaction.

3.1.1.2 Statistical Analysis Two: Speech vs. Cognitive vs. Linguistic vs. Motor Task Type

To determine the effect of task type on carrier phrase intensity, the four tasks that utilize carrier phrase intensity were compared; isolation speech, concurrent speech +

cognitive, concurrent speech + linguistic, and concurrent speech + motor. A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task type (four levels: isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor). In this analysis, the main effects of group and task type were significant (refer to Appendix L for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 6.821$, $p = .014$] and is illustrated in Figure 4 with associated means and standard error scores listed in Table 4. The significant main effect for the group indicates that the carrier phrase intensity of the subjects with Parkinson's disease was significantly less than that of the control subjects across all tasks. The main effect of task type was also significant [$F(3, 93) = 15.059$, $p = .000$] and is illustrated in Figure 5 with associated means and standard errors scores listed in Table 5. The significant main effect of task type indicates that the carrier phrase intensity of both subject groups was significantly different across each of the 4 task types. As shown in Figure 5, carrier phrase intensity was greatest in the isolation speech task, followed by the concurrent speech + linguistic task, the concurrent speech + cognitive task, and with the concurrent speech + motor task yielding the lowest carrier phrase intensity values. Bonferroni post-hoc comparisons of the four tasks were conducted. In comparing the isolation speech task with the three concurrent tasks, the isolation speech task ($M = 68.348$, $SD = 3.144$) was found to be significantly higher than the concurrent speech + cognitive task ($M = 67.158$, $SD = 3.834$), the concurrent speech + linguistic task ($M = 67.512$, $SD = 3.491$), and the concurrent speech + motor task ($M = 65.898$, $SD = 3.817$). The concurrent speech + cognitive task ($M = 67.158$, $SD = 3.834$) was found to have a carrier phrase intensity significantly higher than that of the concurrent speech + motor task ($M = 65.898$, $SD = 3.817$). As well, in comparing the carrier phrase intensity of the concurrent speech + linguistic task ($M = 67.512$, $SD = 3.491$) with that of the concurrent speech + motor task ($M = 65.898$, $SD = 3.817$), significance was found with the concurrent speech + linguistic task yielding a higher carrier phrase intensity. No significance was found for carrier phrase intensity between the concurrent speech + cognitive task ($M = 67.158$, $SD = 3.834$) and the concurrent speech + linguistic task (*M* = 67.512, *SD* = 3.491).

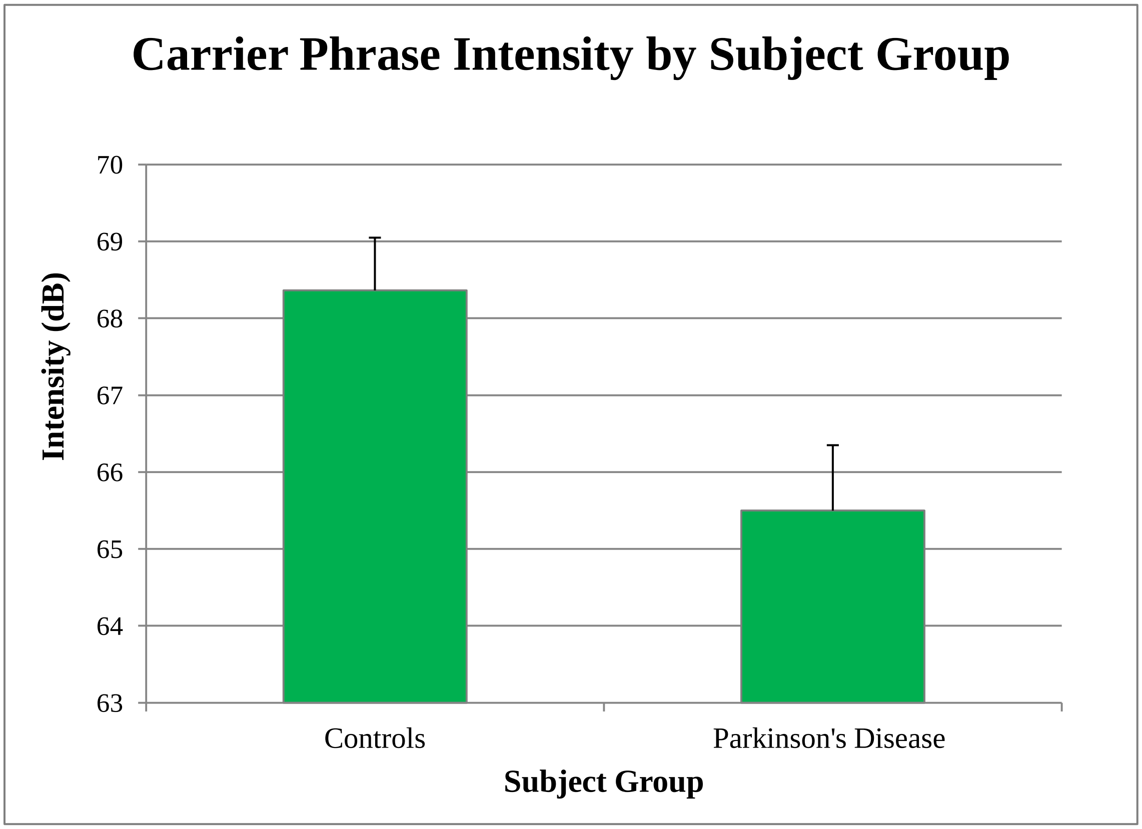

Figure 4. Carrier phrase intensity by subject group (controls and Parkinson's disease).

Table 4. *Mean carrier phrase intensity values and standard error by subject group for the controls and Parkinson's disease participants.*

	Carrier Phrase Intensity (dB)	Standard Error
Controls	68.36	0.687
Parkinson's Disease	65.49	0.852

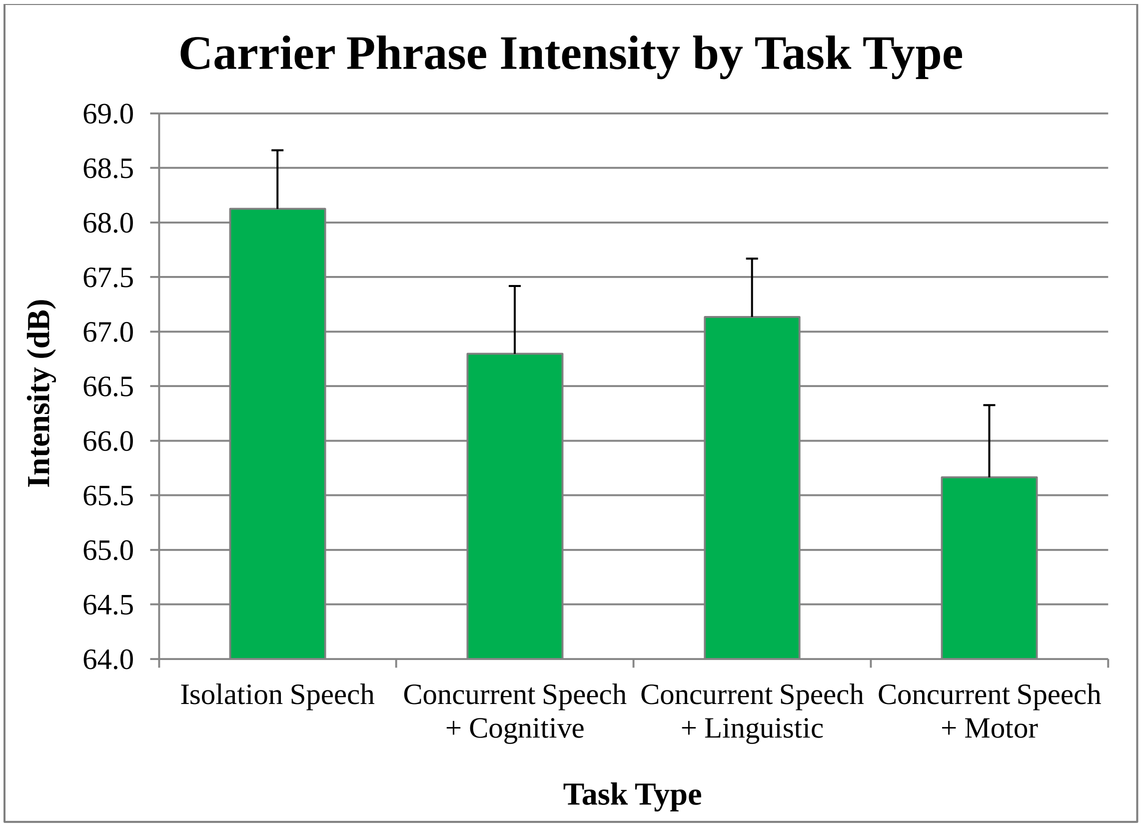

Figure 5. Carrier phrase intensity by task type for the control and Parkinson's disease participants.

Table 5. *Mean carrier phrase intensity values and standard error by task type for the control and Parkinson's disease participants.*

	Carrier Phrase Intensity (dB)	Standard Error
Isolation Speech	68.13	0.537
Concurrent Speech + Cognitive	66.79	0.622
Concurrent Speech + Linguistic	67.13	0.535
Concurrent Speech + Motor	65.66	0.662

Interactions: Significance was not reached for the group by task type interaction.

3.1.1.3 Statistical Analysis Three: Three Difficulty Levels

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease).

The repeated measures independent variable consisted of task type (three levels: concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor). In this analysis, the main effects of group and task type were significant (refer to Appendix M for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 7.410$, $p = .011$. The significant main effect for the group indicates that the carrier phrase intensity of the subjects with Parkinson's disease was significantly less than that of the control subjects across all conditions of the study. The main effect of task condition was significant [$F(2, 62) = 9.409$, $p = .000$]. The significant main effect for task condition suggests that, in both groups, carrier phrase intensity was much higher for the linguistic task, followed by the cognitive task, with the motor task yielding the lowest carrier phrase intensity. No significance was found for the main effect of difficulty level [$F(2, 62) = 2.277$, $p = .111$]. This suggests that the participants in both groups did not vary in speech intensity for the carrier phrase for the different difficulty levels.

Interactions: Significance was not found for the following interactions: group by task type, group by difficulty level, task type by difficulty level, and group by task type by difficulty level.

3.1.2 Target Word Intensity

The statistical procedures for target word intensity were divided into two separate analyses. *Statistical Analysis One* focused on the effects of isolation versus concurrent tasks of the dependent variables as well as the effects of the type of task (cognitive, linguistic, speech/motor) performed on target word intensity. For this analysis, the isolation speech task was considered the isolation condition counterpart for the concurrent speech + motor task for comparison. For the isolation cognitive and isolation linguistic task, their respective concurrent conditions were used for comparison. *Statistical Analysis Two* focused on the effects of the three different difficulty levels on the dependent variables. Because difficulty levels were only examined in the linguistic, cognitive and motor tasks, these tasks were the focus of attention in this analysis procedure.

3.1.2.1 Statistical Analysis One: Isolation versus Concurrent Task Condition and Task Type

To determine the effect of task type on target word intensity, four tasks were compared; isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor. A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task condition (two levels: isolation, concurrent), and task type (three levels: cognitive, linguistic, speech/motor). In this analysis, the main effects of group, task condition and task type were significant (refer to Appendix N for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 30) = 6.922$, $p = .013$] and is illustrated in Figure 6 with associated means and standard error scores listed in Table 6. The significant main effect for the group indicates that the target word intensity of the subjects with Parkinson's disease was significantly less than that of the control subjects for all four tasks. The main effect of task condition was significant [$F(1, 30) = 5.312$, $p = .028$] and is presented in Figure 7 with associated means and standard error scores listed in Table 7. The significant main effect for task condition explains that, in both groups, target word intensity was lower for the concurrent tasks than the tasks performed in isolation. The main effect of task type was significant [$F(2, 60) = 37.918$, $p = .000$] and is presented in Figure 8 with associated means and standard error scores listed in Table 8. The significant main effect for task type shows the difference in target word intensity by task type, with the highest target word intensity recorded for the linguistic task, followed by the cognitive task, and then the speech/motor task.

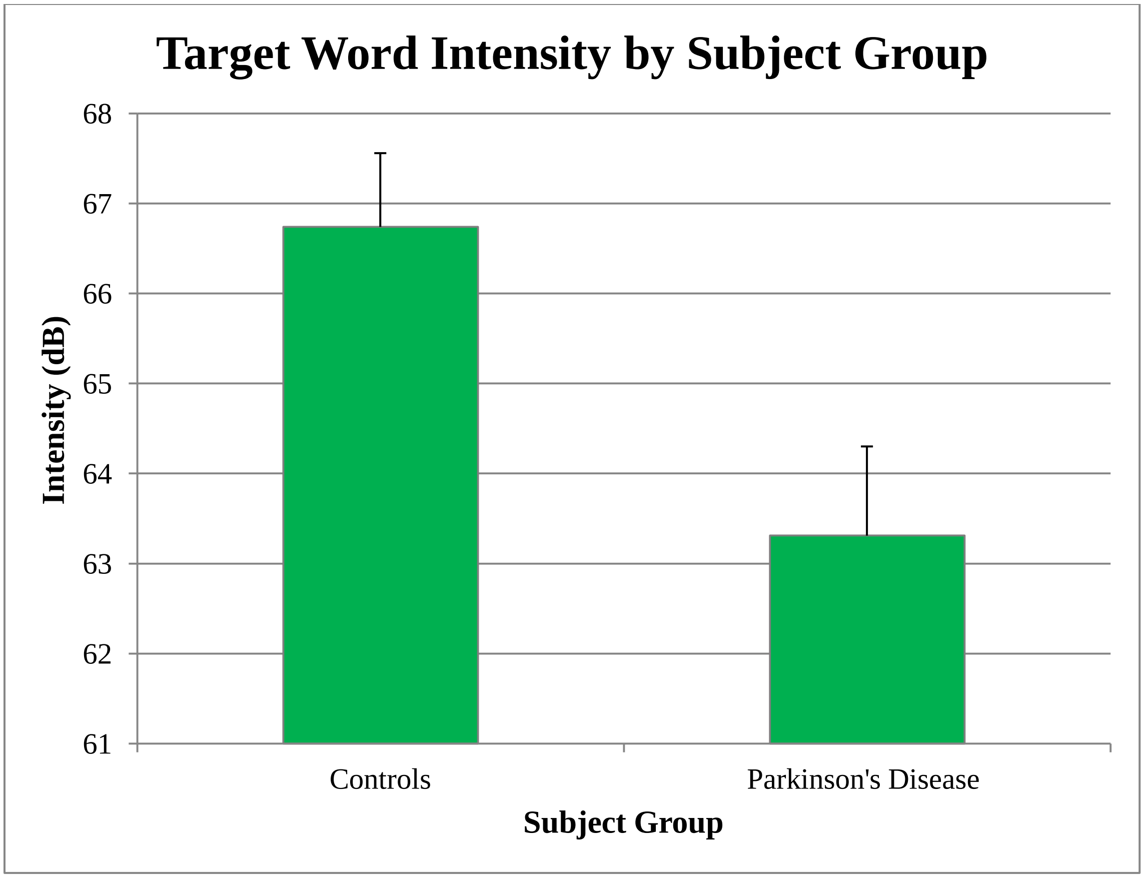

Figure 6. Target word intensity by subject group (control and Parkinson's disease).

Table 6. *Mean target word intensity values and standard error by subject group (control and Parkinson's disease)*.

	Target Word Intensity (dB)	Standard Error
Controls	66.74	0.819
Parkinson's Disease	63.31	0.991

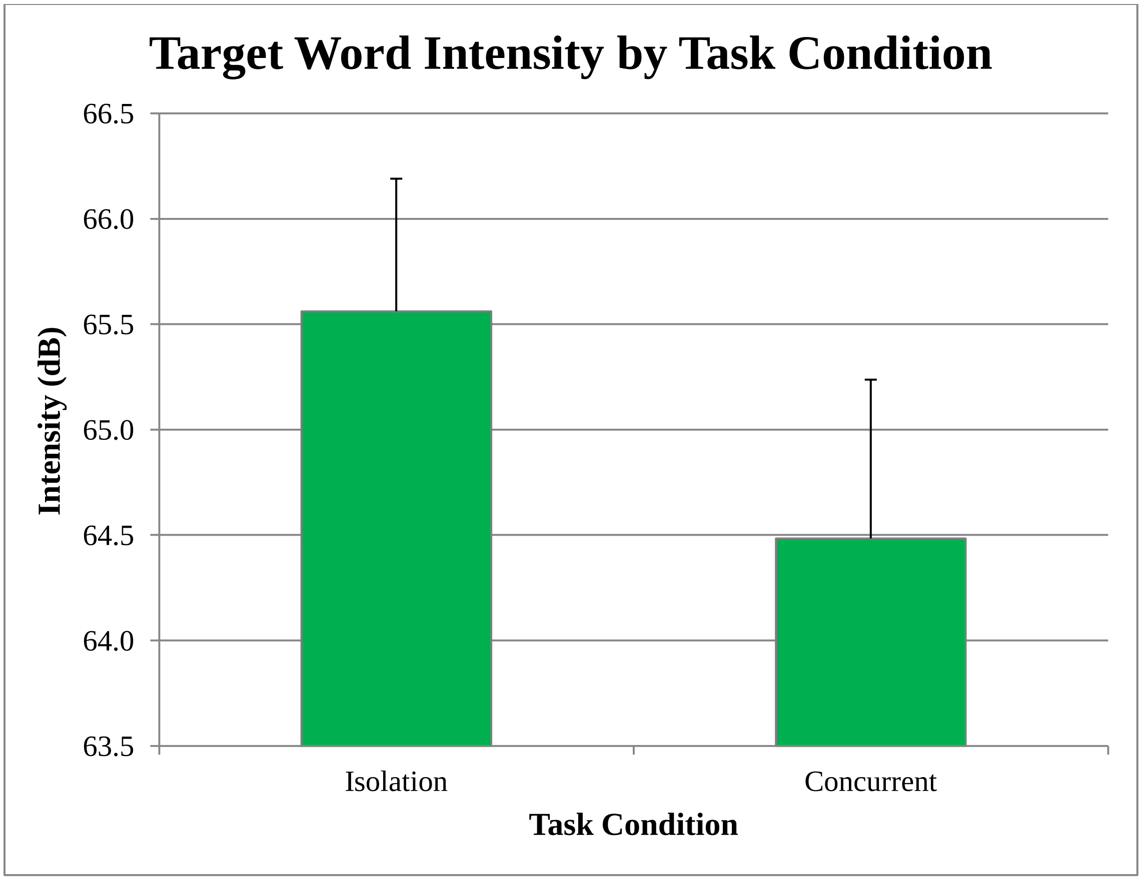

Figure 7. Target word intensity by task condition for the control and Parkinson's disease participants.

Table 7. *Mean target word intensity values and standard error by task condition for the control and Parkinson's disease participants.*

	Target Word Intensity (dB)	Standard Error
Isolation	65.56	0.629
Concurrent	64.48	0.753

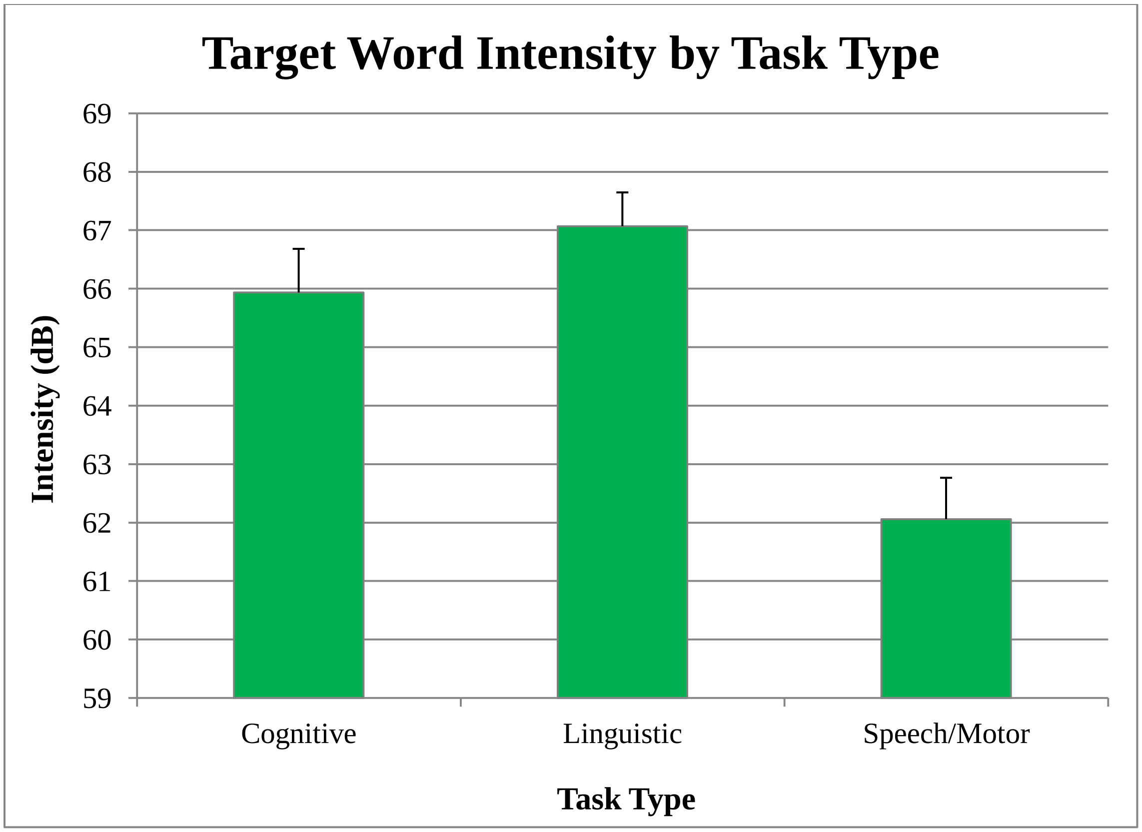

Figure 8. Target word intensity by task type for the control and Parkinson's disease participants.

Table 8. *Mean target word intensity values and standard error by task type for the control and Parkinson's disease participants.*

	Target Word Intensity (dB)	Standard Error
Cognitive	65.94	0.747
Linguistic	67.07	0.577
Speech/Motor	62.06	0.706

Interactions: Significance was not found for the following interactions: group by task condition, group by task type, task condition by task type, and group by task condition by task type.

3.1.2.2 Statistical Analysis Two: Task Type and Difficulty Level

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task type (three levels: concurrent speech + cognitive, concurrent speech + linguistic, isolation speech/concurrent speech + motor) and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group and task type were significant (refer to Appendix O for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 7.233$, $p = .011$]. The significant main effect for group shows that the average target word intensity for the control group was significantly higher in the three concurrent tasks than the reported average target word intensity for the participants with Parkinson's disease. The main effect of task type was significant [$F(2, 62) = 18.822$, $p = .000$]. The significant main effect for task type indicates that target word intensity is highest during the linguistic task, then for the cognitive task, with the isolation speech/concurrent speech + motor task reporting the lowest values for target word intensity. No significance was found for the main effect of difficulty level [$F(2, 62) = 2.123$, $p = .128$]. This result suggests that the participants did not experience a significant change in target word intensity across the three levels of difficulty.

Interactions: No significance was found for the following interactions: group by task type, group by difficulty level, task type by difficulty level, group by task type by difficulty level.

3.1.3 Overall Utterance Intensity

The statistical procedures for overall utterance intensity were divided into three separate analyses. *Statistical Analysis One* focused on the effects of isolation versus concurrent tasks of the dependent variables. For this analysis only the isolated speech task condition and the concurrent speech and motor task condition were included. The other two conditions (concurrent cognitive and concurrent linguistic) were not included because the reported answers consisted of only a target word, with no carrier phrase for comparison. *Statistical Analysis Two* focused on the effects of the four different task types (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor) on the dependent variables. *Statistical Analysis Three* focused on the effects of the three different difficulty levels on the dependent variables. Because difficulty levels were only examined in the linguistic, cognitive and motor tasks, these tasks were the focus of attention in this analysis procedure.

3.1.3.1 Statistical Analysis One: Isolation versus Concurrent Task Condition

A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task condition (two levels: isolation speech, concurrent speech + motor). In this analysis, the main effects of group and task condition were significant (refer to Appendix P for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 32) = 5.294$, $p = .028$]. The significant main effect for the group explains that the overall utterance intensity for the subjects with Parkinson's disease was significantly less than that of the control subjects for both the isolation speech and the concurrent speech + motor task. The main effect of task condition was significant [$F(1, 32) = 32.053$, $p = .000$] and is presented in Figure 9 with associated means and standard error scores listed in Table 9. The significant main effect for task condition indicates that, in both groups, overall utterance intensity was much higher for the speech task performed in isolation than the speech task performed concurrent with the motor task.

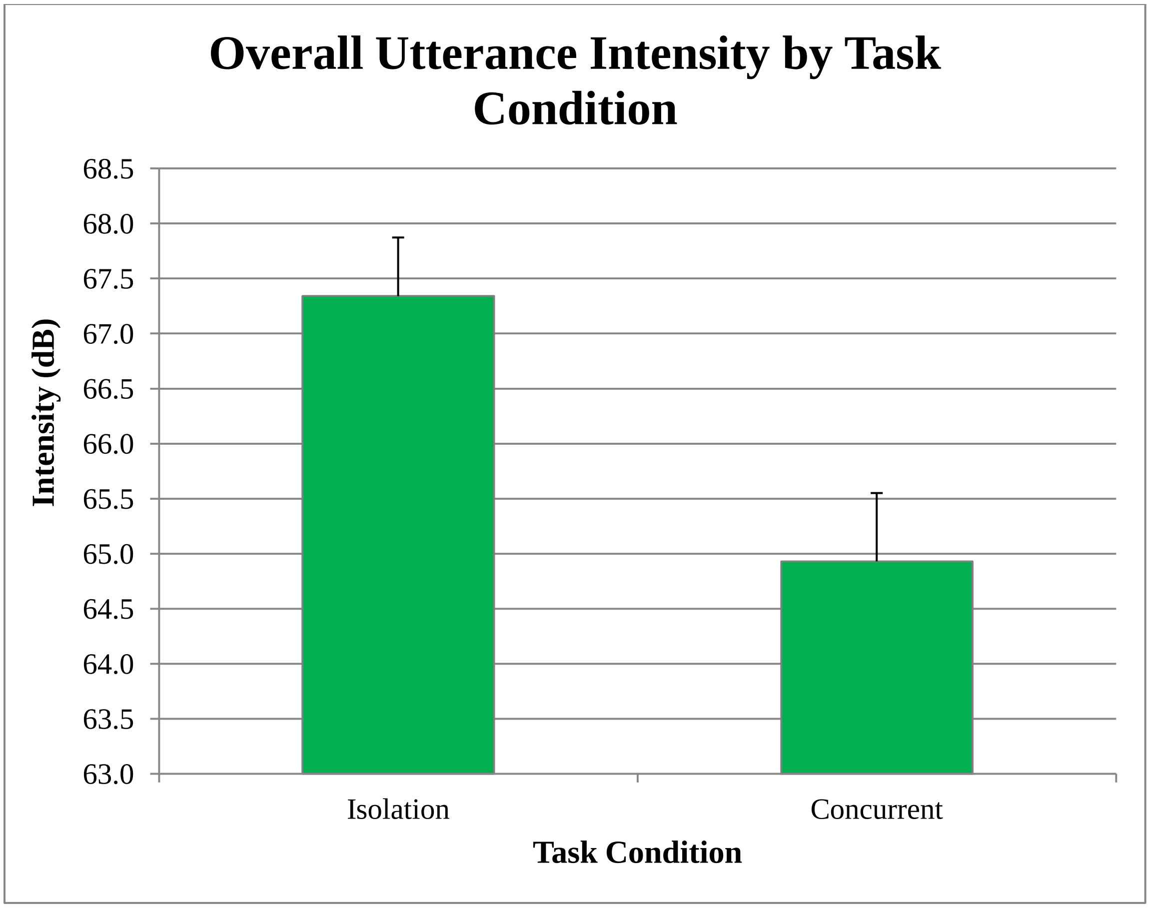

Figure 9. Overall utterance intensity by task condition for the control and Parkinson's disease participants.

Table 9. *Mean overall utterance intensity values and standard error task condition for the control and Parkinson's disease participants.*

	Overall Intensity (dB)	Standard Error
Isolation	67.34	0.533
Concurrent	64.93	0.621

Interactions: No significance was found for the group by task condition interaction.

3.1.3.2 Statistical Analysis Two: Speech vs. Cognitive vs. Linguistic vs. Motor Task Type

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task type (four levels: isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor). In this analysis, the main effects of group, task type and difficulty level were significant (refer to Appendix Q for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 8.896$, $p = .006$]. The main effect is depicted in Figure 10 with the associated means and standard error scores listed in Table 10. This effect of group explains that the control participants produced a significantly higher overall utterance intensity than the subjects with Parkinson's disease. A significant main effect was found for task type [$F(3, 93) = 15.235$, $p = .000$] and is illustrated in Figure 11 with the associated means and standard error scores listed in Table 11. The highest overall utterance intensity was recorded for the isolation speech task, followed by the concurrent speech + cognitive task, the concurrent speech + linguistic task, and the lowest overall utterance intensity produced during the concurrent speech + motor task. Bonferroni post-hoc comparisons of the four tasks were conducted. In comparing the isolation speech task with the three concurrent tasks, the isolation speech task (M =67.581, SD = 3.213) was found to have a significantly higher overall utterance intensity than the concurrent speech + cognitive task (M = 66.238, SD = 3.951), the concurrent speech + linguistic task (M = 66.349, SD = 3.904), and the concurrent speech + motor task (M = 65.132, SD = 3.716). The concurrent speech + cognitive task ((M = 66.238, SD = 3.951) was found to have an overall utterance intensity significantly higher than that of the concurrent speech + motor task (M = 65.132, SD = 3.716). As well, in comparing the overall utterance intensity of the concurrent speech + linguistic task (M = 66.349, SD = 3.904) with that of the concurrent speech + motor task (M = 65.132, SD = 3.716), significance was found with the concurrent speech + linguistic task yielding a higher overall utterance intensity. No significance was found for overall utterance intensity between the concurrent speech +

cognitive task (*M* = 66.238, *SD* = 3.951) and the concurrent speech + linguistic task (*M* = 66.349, *SD* = 3.904).

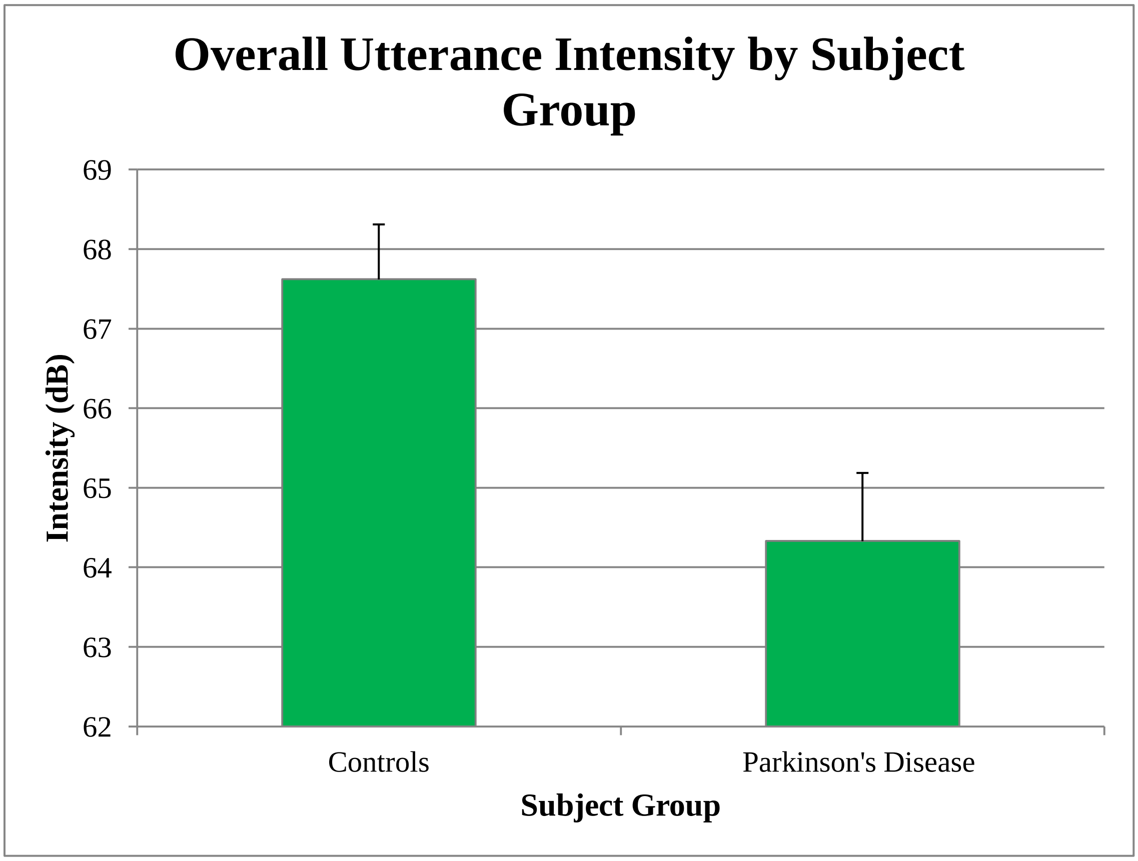

Figure 10. Overall utterance intensity by subject group (control and Parkinson's disease).

Table 10. *Mean overall utterance intensity values and standard error by subject group (control and Parkinson's disease).*

	Overall Intensity (dB)	Standard Error
Controls	67.62	0.692
Parkinson's Disease	64.33	0.858

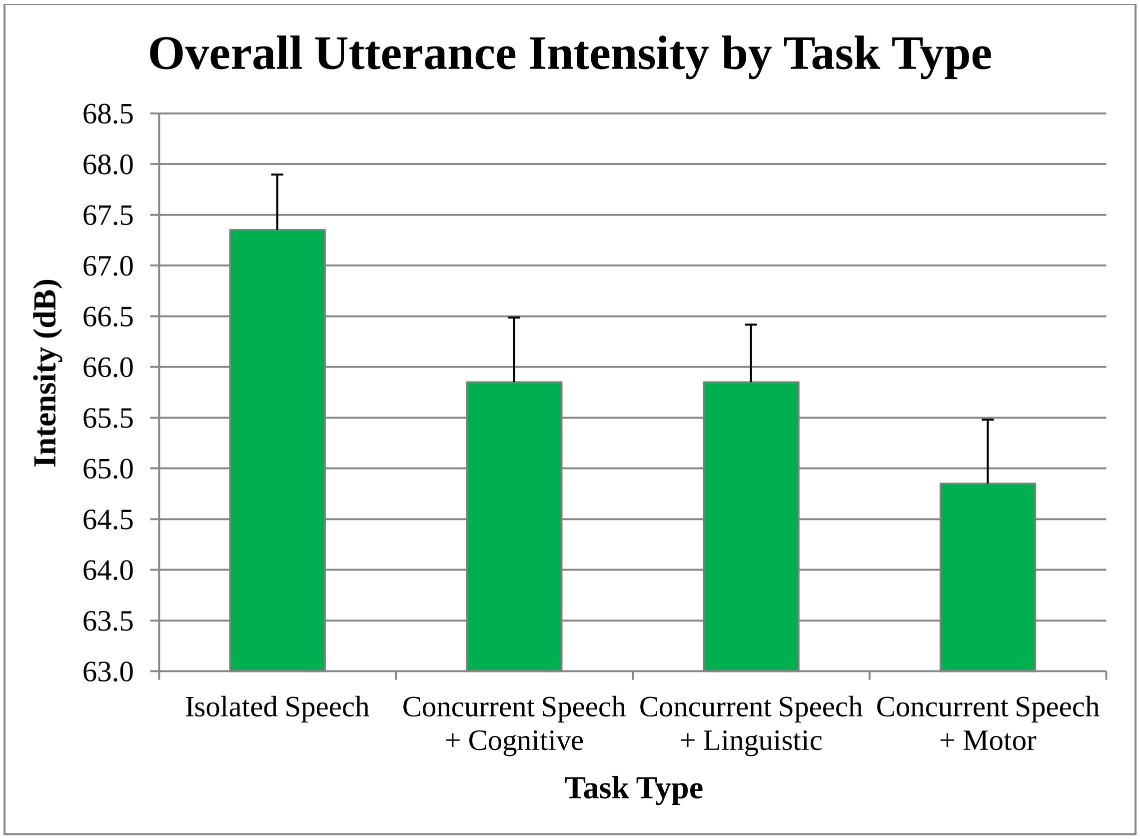

Figure 11. Overall utterance intensity by task type for the control and Parkinson's disease participants.

Table 11. *Mean overall utterance intensity values and standard error by task type for the control and Parkinson's disease participants.*

	Overall Intensity (dB)	Standard Error
Isolated Speech	67.35	0.547
Concurrent Speech + Cognitive	65.85	0.637
Concurrent Speech + Linguistic	65.85	0.567
Concurrent Speech + Motor	64.85	0.630

Interactions: Significance was found for the group by task type interaction [$F(2, 62) = 4.485$, $p = .006$]. This interaction is illustrated in Figure 12 with associated means and standard error scores presented in Table 12. This interaction suggests that the two groups present different trends for overall utterance intensity for task type. The control subjects produced the highest overall utterance intensity for the concurrent speech + linguistic task, concurrent speech + cognitive task, and then the concurrent speech + motor task. The participants with Parkinson’s disease produced the highest overall utterance intensity for the concurrent speech + cognitive task, the concurrent speech + motor task, and then the concurrent speech + linguistic task.

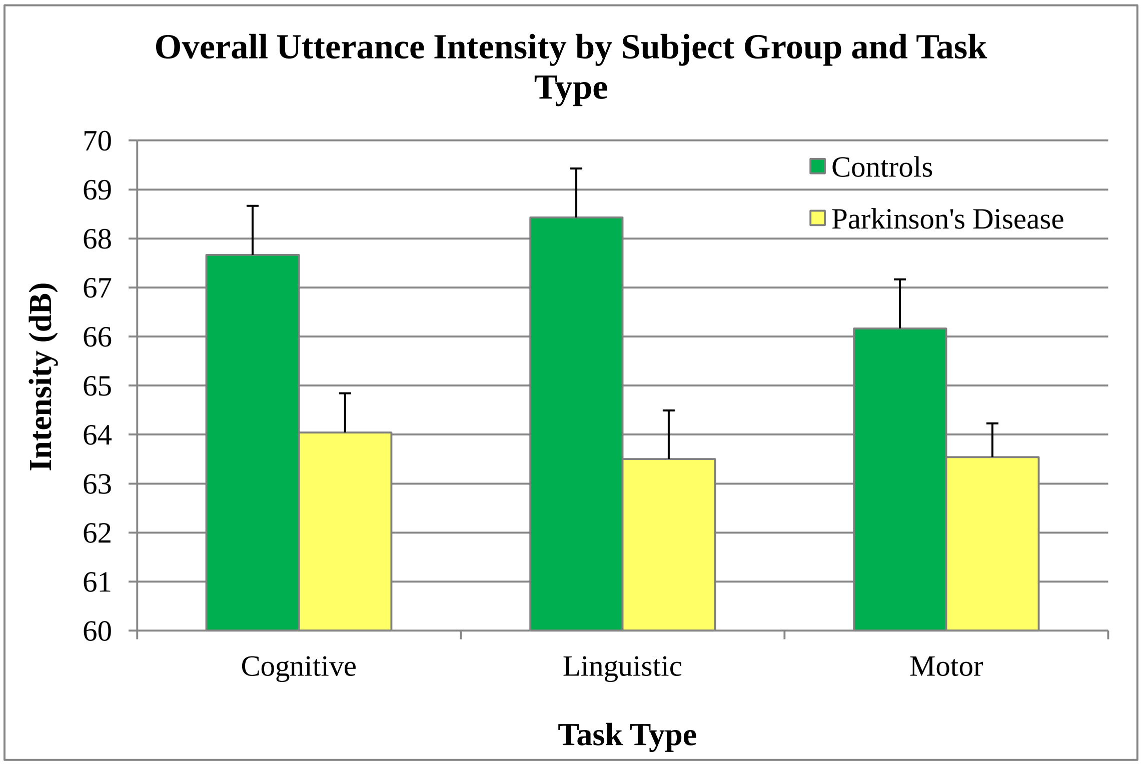

Figure 12. Overall utterance intensity by subject group and task type for the control and Parkinson’s disease participants.

Table 12. *Mean overall utterance intensity values and standard error by subject group and task type for the control and Parkinson’s disease participants.*

		Overall Utterance Intensity (dB)	Standard Error
Cognitive	Controls	67.67	0.799
	Parkinson's Disease	64.04	0.991
Linguistic	Controls	68.43	0.688
	Parkinson's Disease	63.50	0.853
Motor	Controls	66.17	0.791
	Parkinson's Disease	63.54	0.981

3.1.3.3 Statistical Analysis Three: Three Difficulty Levels

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (three levels: concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group, task type and difficulty level were significant (refer to Appendix R for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 10.627$, $p = .003$]. The significant main effect for group shows that the average overall utterance intensity for the control group was significantly higher than the reported average overall utterance intensity for the participants with Parkinson's disease. The main effect of task type was significant [$F(2, 62) = 6.086$, $p = .004$]. The main effect of task type indicates that overall utterance intensity varies based on the type of task performed concurrently, with the concurrent speech + linguistic yielding the highest overall utterance intensity values, followed by concurrent speech + cognitive, and concurrent speech + motor reporting the lowest overall utterance intensity values. The main effect of difficulty level was significant [$F(2, 62) = 6.956$, $p = .002$] and is illustrated in Figure 13 with associated means and standard error scores listed in Table 13. The main effect for difficulty level indicates that overall utterance intensity is dependent on the level of difficulty of the task, and decreases from the first level of difficulty to the second, and then increases from the second level of difficulty to the third.

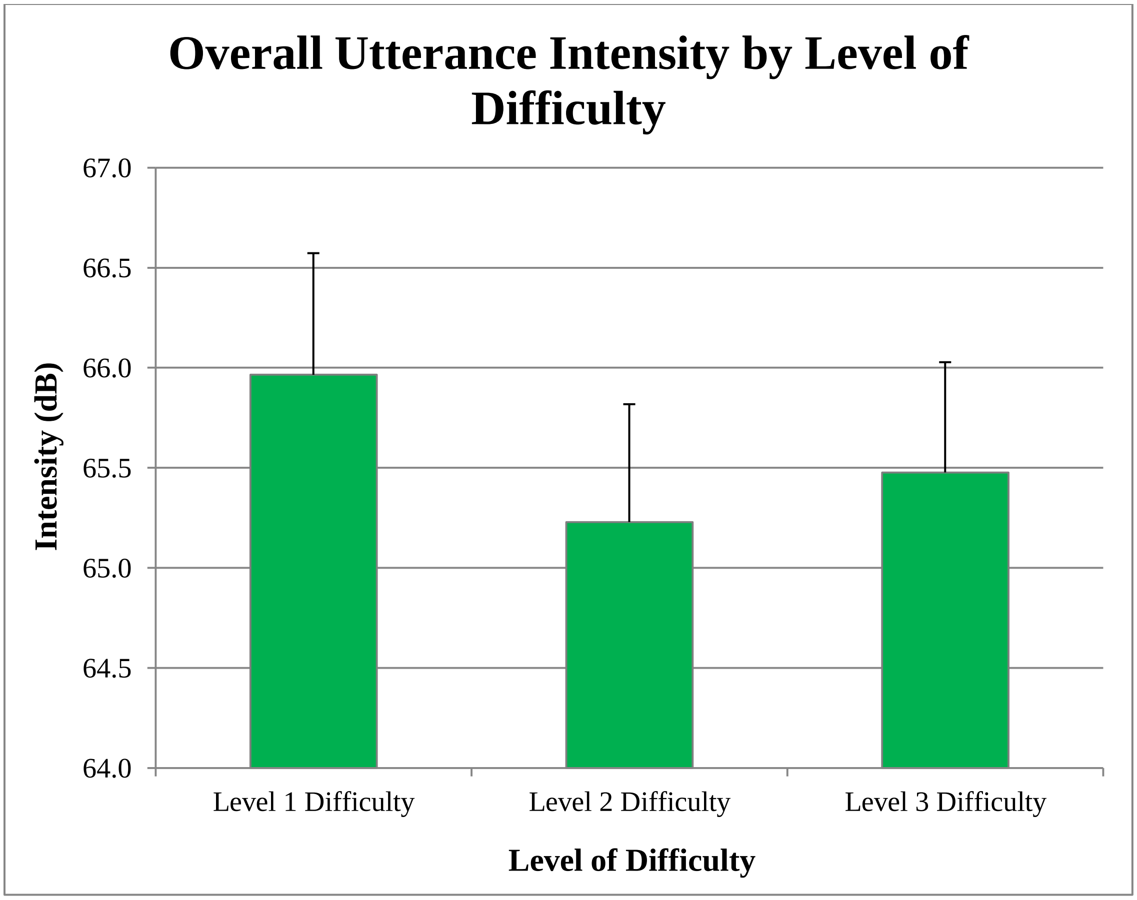

Figure 13. Overall utterance intensity by level of difficulty for the control and Parkinson's disease participants.

Table 13. *Mean overall utterance intensity values and standard error by level of difficulty for the control and Parkinson's disease participants.*

	Overall Intensity (dB)	Standard Error
Level 1 Difficulty	65.97	0.608
Level 2 Difficulty	65.23	0.589
Level 3 Difficulty	65.48	0.551

Interactions: The group by task type interaction was significant [$F(2, 62) = 5.406$, $p = .007$]. This interaction describes the difference in how overall intensity is affected in each group by task type. The control subjects recorded the highest overall utterance intensity for the linguistic task, with the second highest level yielded by the cognitive task, and the lowest overall utterance intensity presented by the motor task. The participants with Parkinson's disease demonstrated a different trend, in that the order of highest to lowest overall utterance intensity by task is as follows: concurrent speech + cognitive task, concurrent speech + motor task, and concurrent speech + linguistic task. The following interactions were not found to be significant: group by difficulty level, task type by difficulty level, and group by task type by difficulty level.

3.2 Task Performance

To determine the relationship between task condition (isolation or concurrent), task type (speech, cognitive, linguistic, or motor), and difficulty level and the resultant effect on task performance, relative performance scores were obtained for each task. For the cognitive and linguistic tasks, each question was marked as either incorrect or correct, yielding a score of zero or one respectively, with the highest possible score for the task being 15. The motor task was scored by average tracking error, in which the closer the average tracking error score was to 0, the more accurate the performance of tracking. The following analyses were performed to determine the effect of concurrent tasks on task performance score.

The statistical procedures for task performance score were divided into two separate analyses. *Statistical Analysis One* focused on the task performance scores of the cognitive and linguistic tasks, comparing the two tasks for task condition, task type, and difficulty level. *Statistical Analysis Two* focused on the motor task for task condition and difficulty level.

3.2.1 Statistical Analysis One: Cognitive and Linguistic Task Scores

A four-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task condition (two levels: isolation, concurrent), task type (two levels: cognitive, linguistic), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group, task type and difficulty level were significant (refer to Appendix S for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 11.540$, $p = .002$] and is shown in Figure 14 with associated means and standard error scores listed in Table 14. The significant main effect for group explains that the control subjects, on average, scored higher at each difficulty level than participants with Parkinson's disease. The main effect of task condition was not found to be significant [$F(1, 31) = .337$, $p = .566$] and is shown in Figure 15 with associated means and standard error scores listed in Table 15. This indicates that the subjects' performance on the cognitive and linguistic tasks was not significantly affected by whether or not the task was performed in isolation or concurrent with the speech task. The main effect of task type was significant [$F(1, 31) = 56.028$, $p = .000$] and is shown in Figure 16 with associated means and standard error scores listed in Table 16. The significant main effect for task type indicates that, for both groups, the average score was higher for the cognitive task per difficulty level as compared to the average score for the linguistic task per difficulty level. The main effect of difficulty level was significant [$F(2, 62) = 30.621$, $p = .000$] and is shown in Figure 17 with associated means and standard error scores listed in Table 17. The significant main effect for difficulty level describes how the average score per difficulty level decreased as the level of difficulty of the task increased from the first to the third level.

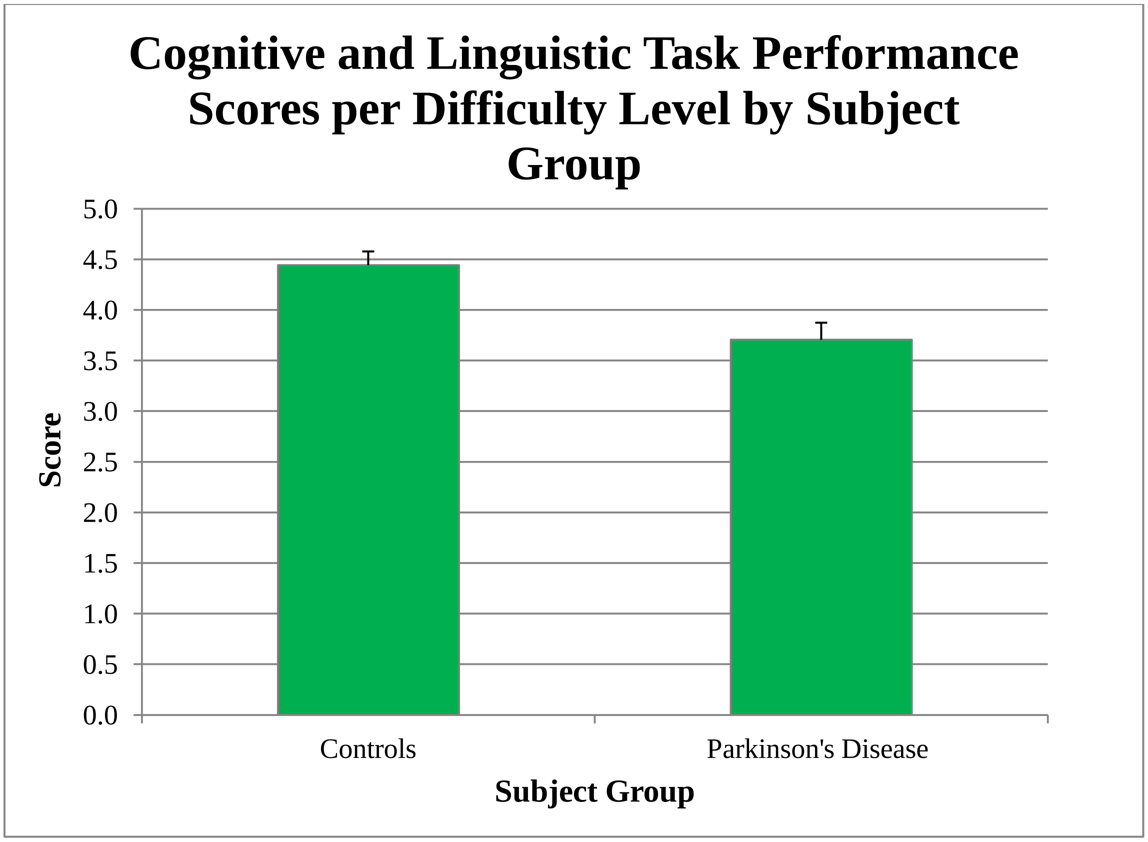

Figure 14. Cognitive and linguistic performance score per difficulty level by subject group (control and Parkinson's disease).

Table 14. *Mean performance score for the cognitive and linguistic task per difficulty level and standard error by subject group (control and Parkinson's disease).*

	Performance Score per Difficulty Level (out of 5)	Standard Error
Controls	4.44	0.136
Parkinson's Disease	3.71	0.169

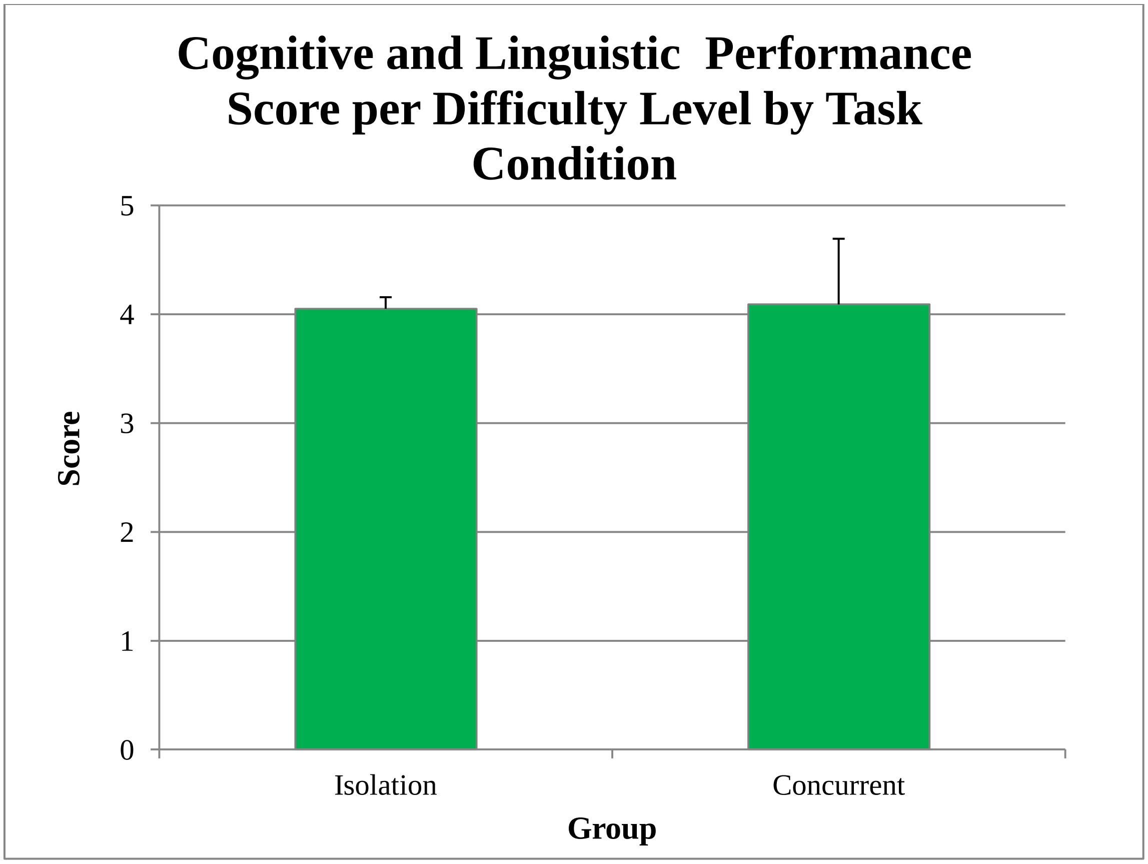

Figure 15. Cognitive and linguistic performance score per difficulty level by task condition.

Table 15. *Mean performance score for the cognitive and linguistic task per difficulty level and standard error by task condition.*

	Performance Score	Standard Error
Isolation	4.05	0.11
Concurrent	4.09	0.60

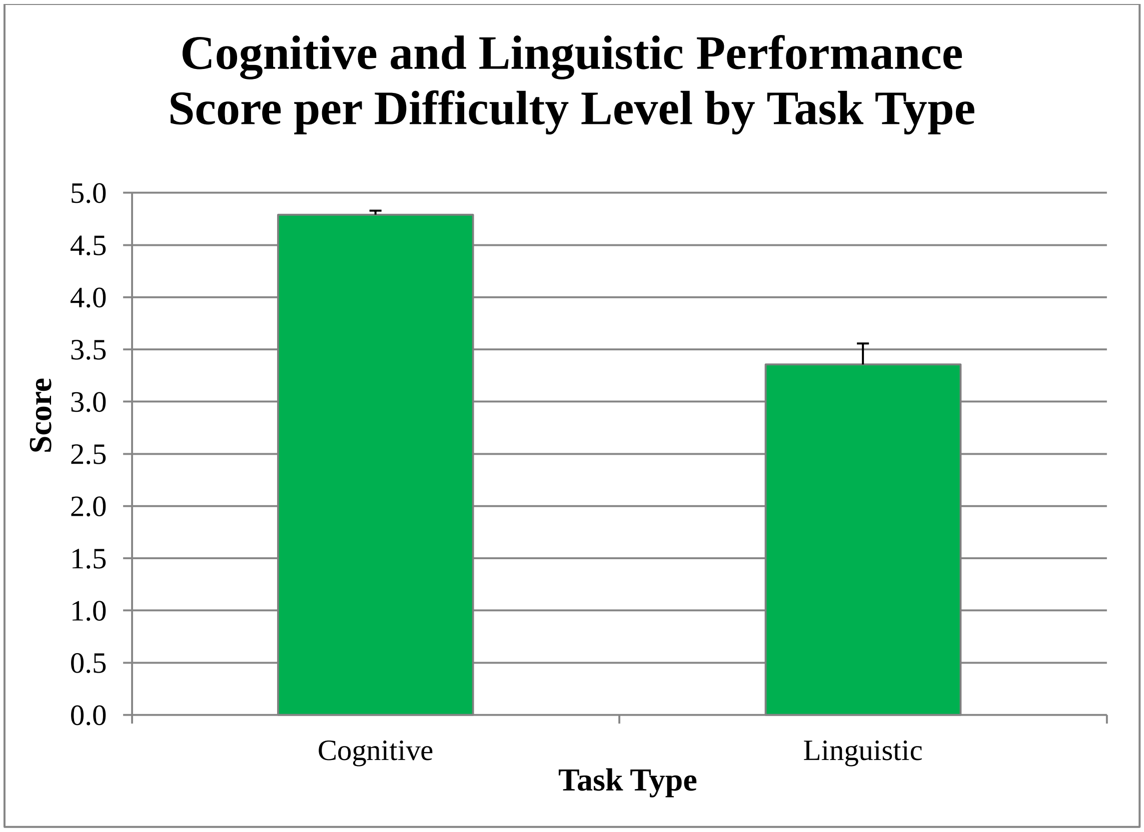

Figure 16. Cognitive and linguistic performance score per difficulty level by task type for the controls and participants with Parkinson's disease.

Table 16. *Mean task performance score for the cognitive and linguistic task per difficulty level and standard error by task type for the controls and participants with Parkinson's disease.*

	Performance Score per Difficulty Level (out of 5)	Standard Error
Cognitive	4.79	0.04
Linguistic	3.36	0.20

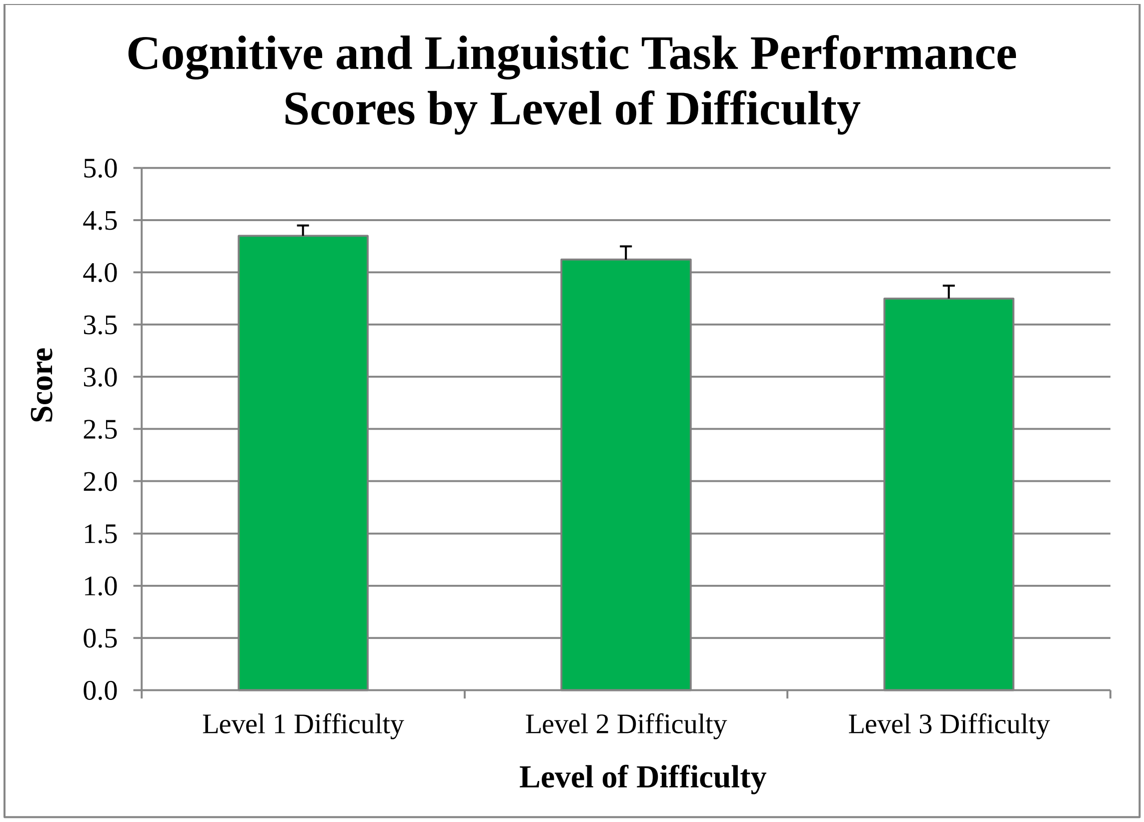

Figure 17. Cognitive and linguistic performance score by level of difficulty for the controls and participants with Parkinson's disease.

Table 17. *Mean task performance score for the cognitive and linguistic task and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Performance Score per Difficulty Level (out of 5)	Standard Error
Level 1 Difficulty	4.35	0.099
Level 2 Difficulty	4.12	0.127
Level 3 Difficulty	3.75	0.124

Interactions: The group by task type interaction was significant [$F(1, 64) = 13.002$, $p = 14.004$]. This interaction is depicted in Figure 18 with associated means and standard error scores presented in Table 18. This interaction shows that while both groups perform comparably in the cognitive task, performance for the linguistic task by the subjects with Parkinson's disease is much worse than the control subjects' performance for the linguistic task. The task type by difficulty level interaction was significant [$F(2, 62) = 12.858$, $p = 0.000$]. This interaction is depicted in Figure 19 with associated means and standard error scores presented in Table 19. This interaction shows that although both groups show a drop in performance score as the difficulty level increases, the decrease in performance for the cognitive task is much less than the decrease in performance for the linguistic task as the level of difficulty of the task increases. Significance was not found for the following interactions: group by task condition, group by difficulty, task condition by task type, task condition by difficulty level, task type by difficulty level, group by task condition by task type, group by task condition by difficulty level, group by task type by difficulty level, task condition by task type by difficulty level, and group by task condition by task type by difficulty level.

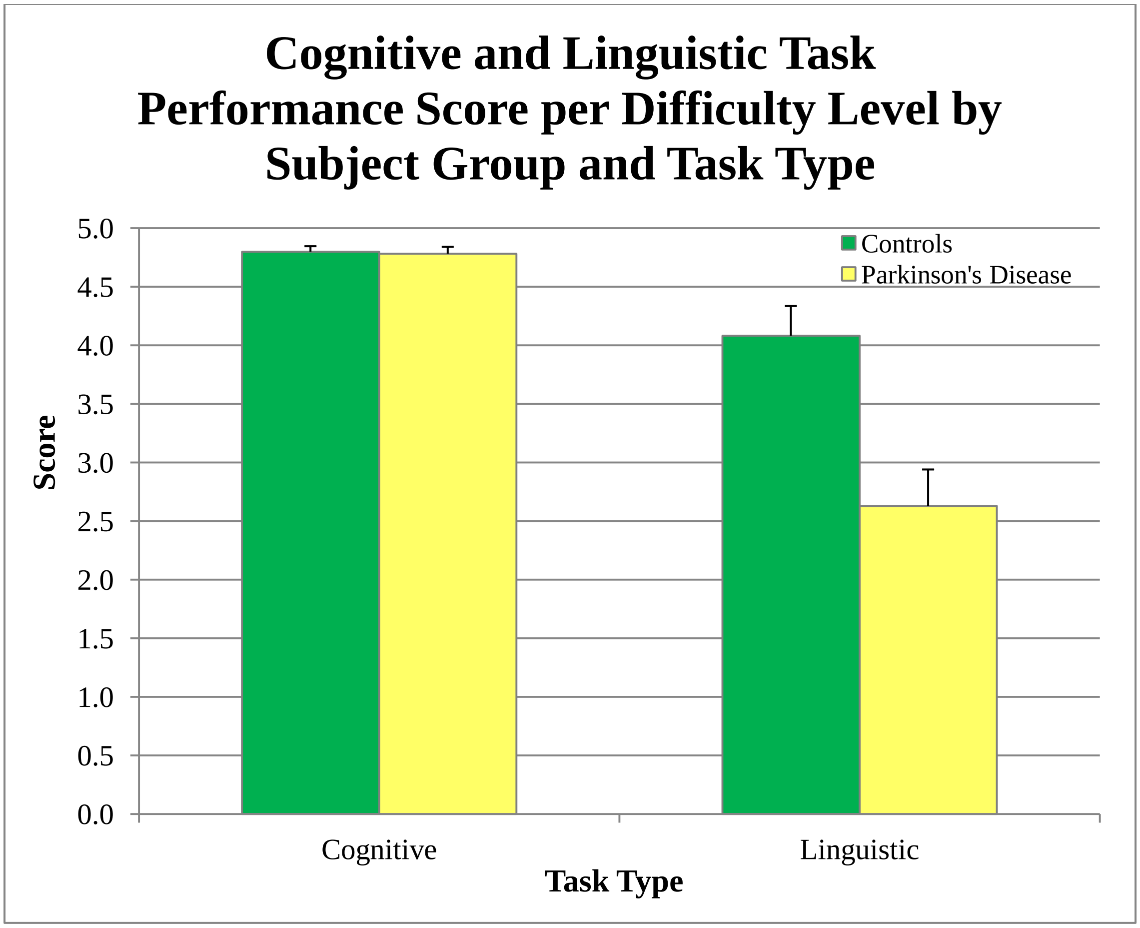

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Figure 18. Cognitive and linguistic performance score per difficulty level by group and task type for the controls and participants with Parkinson's disease.

Table 18. *Mean task performance score for the cognitive and linguistic task and standard error per difficulty level by group and task type for the controls and participants with Parkinson's disease.*

		Performance Score per Difficulty Level (out of 5)	Standard Error
Cognitive	Controls	4.80	0.047
	Parkinson's Disease	4.78	0.059
Linguistic	Controls	4.08	0.253
	Parkinson's Disease	2.62	0.313

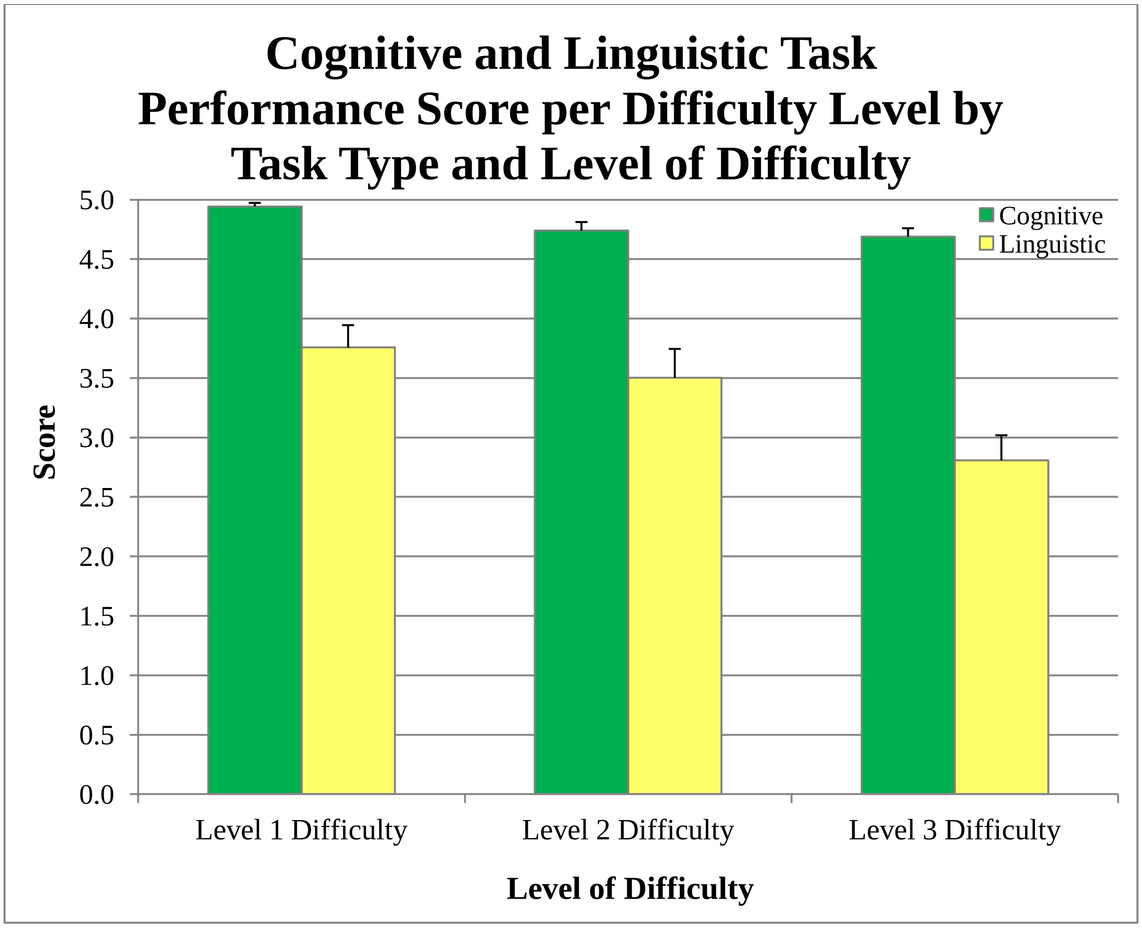

Figure 19. Cognitive and linguistic performance score per difficulty level by task type and difficulty level for the controls and participants with Parkinson's disease.

Table 19. *Mean task performance score for the cognitive and linguistic task and standard error per difficulty level by task type and difficulty level for the controls and participants with Parkinson's disease.*

		Performance Score per Difficulty Level (out of 5)	Standard Error
Level 1 Difficulty	Cognitive	4.94	0.030
	Linguistic	3.75	0.188
Level 2 Difficulty	Cognitive	4.74	0.072
	Linguistic	3.50	0.242
Level 3 Difficulty	Cognitive	4.68	0.071
	Linguistic	2.80	0.211

3.2.2 Statistical Analysis Two: Motor Task Scores

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task condition (two levels: isolation, concurrent), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group and difficulty were significant (refer to Appendix T for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [F(1, 32) = 8.459, p = .007] and is shown in Figure 20 with associated means and standard error scores listed in Table 20. The significant main effect for group explains that the control subjects performed significantly better on the visuomotor tracking task in both task conditions than the individuals with Parkinson's disease, as is observed by the control subject's lower average tracking error score. The main effect of task condition was not found to be significant [F(1, 31) = .337, p = .847] and is shown in Figure 21 with associated means and standard error scores listed in Table 21. This indicates that the subjects' performance on the visuomotor tracking task was not significantly affected by whether or not the task was performed in isolation or concurrent with the speech task. The main effect of difficulty level was significant [F(2, 64) = 5.951, p = .004] and is shown in Figure 22 with associated means and standard error scores listed in Table 22. The significant main effect for difficulty level indicates that performance declined in both groups as the level of difficulty increased.

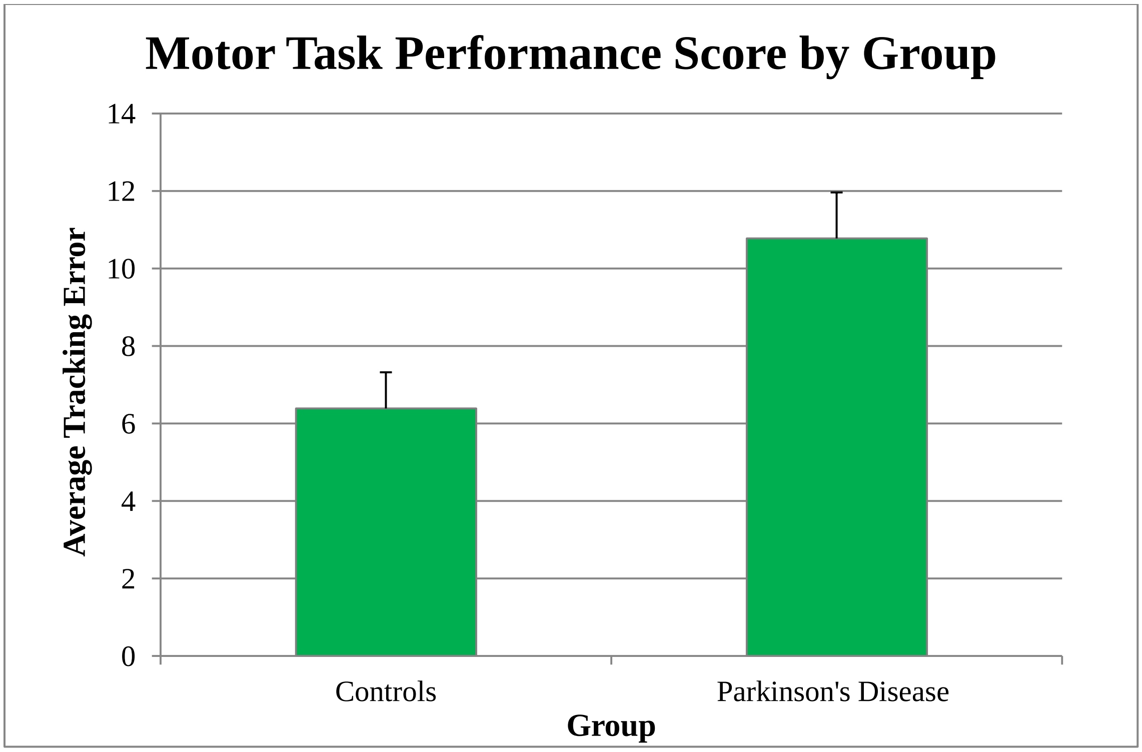

Figure 20. Motor performance score per difficulty level by group (controls and participants with Parkinson's disease).

Table 20. *Mean task performance score for the motor task and standard error per difficulty level per group (controls and participants with Parkinson's disease).*

	Performance Score per Difficulty Level (out of 5)	Standard Error
Controls	6.39	0.933
Parkinson's Disease	10.77	1.186

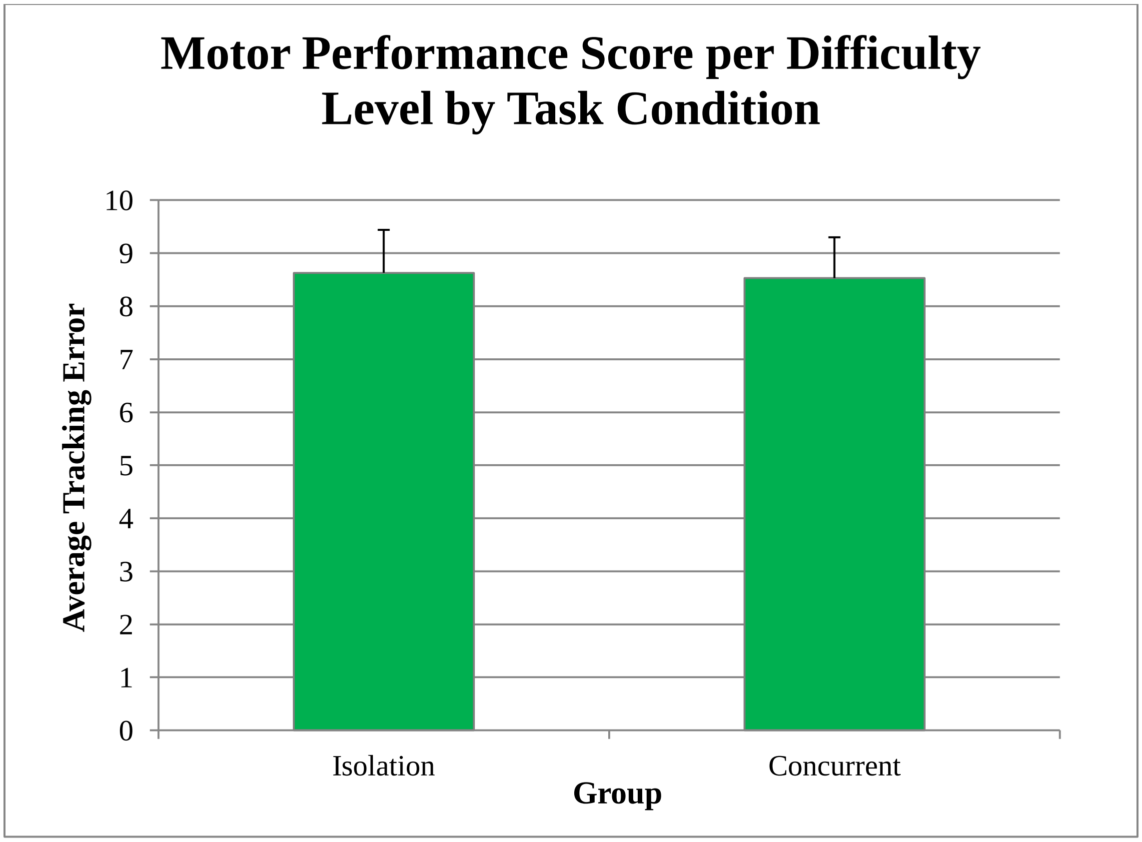

Figure 21. Motor performance score per difficulty level by task condition for the controls and participants with Parkinson's disease.

Table 21. *Mean task performance score for the motor task and standard error per difficulty level per task condition.*

	Performance Score	Standard Error
Isolation	8.63	0.81
Concurrent	8.53	0.77

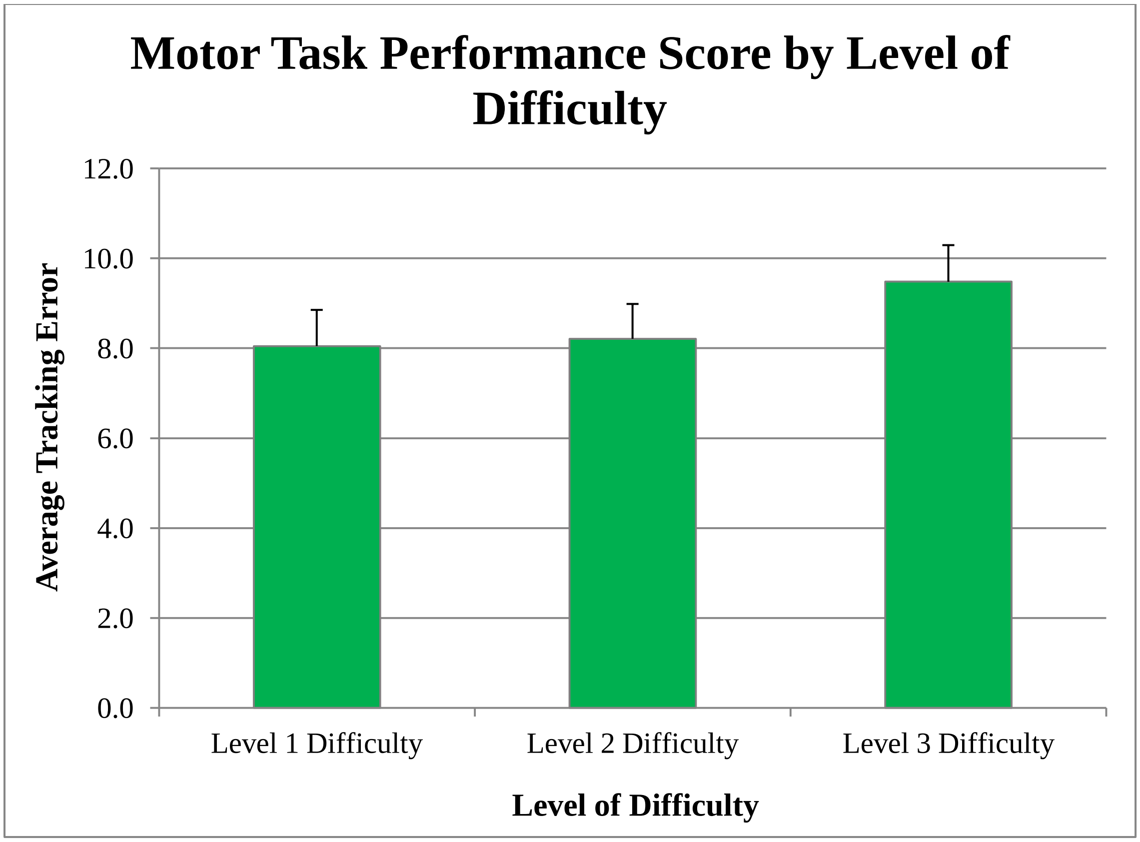

Figure 22. Motor performance score by level of difficulty for the controls and participants with Parkinson's disease.

Table 22. *Mean task performance score for the motor task and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Performance Score per Difficulty Level (out of 5)	Standard Error
Level 1 Difficulty	8.05	0.805
Level 2 Difficulty	8.21	0.775
Level 3 Difficulty	9.48	0.815

Interactions: The group by task condition by difficulty level interaction was significant [$F(2, 1) = 3.293$, $p = 0.044$]. This interaction is depicted in Figure 23 with associated means presented in Table 23 and standard error scores presented in Table 24. This interaction describes how the control and experimental groups perform the visuomotor tracking task during the isolation and concurrent conditions at each difficulty. The control subjects, while performing the visuomotor tracking task in isolation, performed worse on the task as the difficulty of the task increased. However, when performing the task concurrent with the speech task, the control subjects were better at tracking the sinusoidal curve for the second level of difficulty than the first. Performance then dropped for the third level of difficulty. For the isolation visuomotor tracking task, the subjects with Parkinson's disease performed better for the second level of difficulty than the first level of difficulty, however, this performance dropped for the third difficulty level. In contrast, when the visuomotor tracking task was performed concurrent with the speech task, the experimental group's performance decreased as the level of difficulty of the task increased.

The following interactions were not found to be significant: group by task condition, group by difficulty level and task condition by difficulty level.

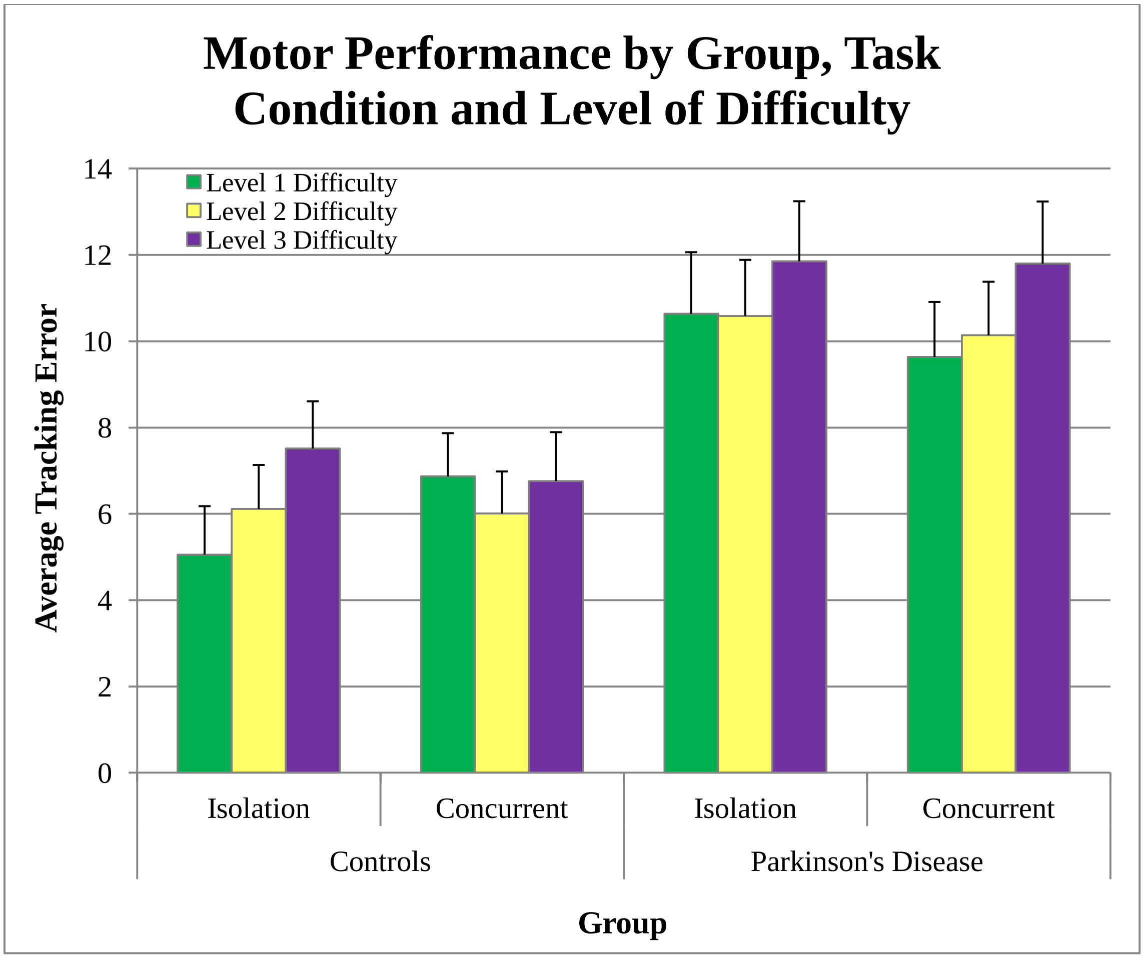

Figure 23. Motor performance score by group, task condition and difficulty level for the controls and participants with Parkinson's disease.

Table 23. *Mean task performance score for the motor task by group, task condition and difficulty level for the controls and participants with Parkinson's disease.*

		Level 1 Difficulty	Level 2 Difficulty	Level 3 Difficulty
Controls	Isolation	5.06	6.11	7.51
	Concurrent	6.87	6.01	6.76
Parkinson's Disease	Isolation	10.64	10.59	11.85
	Concurrent	9.64	10.14	11.79

Table 24. *Standard error by subject group, task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Level 1 Difficulty	Level 2 Difficulty	Level 3 Difficulty
Controls	Isolation	1.12	1.02	1.09
	Concurrent	1.00	0.98	1.13
Parkinson's Disease	Isolation	1.43	1.29	1.39
	Concurrent	1.27	1.24	1.44

3.3 Durational Measures

To determine the relationship between task condition (isolation or concurrent), task type (speech, cognitive, linguistic, or motor), and difficulty level and the resultant effect on duration, 6 variables were considered; utterance duration, carrier phrase duration, response time, response latency, and sentence-response latency.

3.3.1 Overall Utterance Duration

The statistical procedures for overall utterance duration were divided into three separate analyses. *Statistical Analysis One* focused on the effects of isolation versus concurrent tasks of the dependent variables. For this analysis, only the isolated speech task condition and the concurrent speech + motor task condition were included. The cognitive and linguistic tasks were not included in this analysis because the reported answers for the isolation tasks consisted of only a target word, with no carrier phrase. As utterance duration is composed of the carrier phrase, sentence-response latency, and target word, these two tasks were removed from this analysis as they lacked these components in the isolation conditions. *Statistical Analysis Two* focused on the effects of the four different task types (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor) on the dependent variables. *Statistical Analysis Three* focused on the effects of the three different difficulty levels on the dependent variables. Difficulty levels were only examined in the linguistic, cognitive and motor tasks, therefore these tasks were the focus of attention in this analysis procedure.

3.3.1.1 Statistical Analysis One: Isolation versus Concurrent Task Condition

A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measure independent variables consisted of task condition (two levels: isolation speech, concurrent speech + motor). In this analysis, the main effects of task condition was significant (refer to Appendix U for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was not found to be significant [$F(1, 32) = 1.427$, $p = .241$]. This indicates that the two groups produced speech at relatively the same rate. The main effect of task condition was significant [$F(1, 32) = 42.668$, $p = .000$] and is shown in Figure 24 with associated means and standard error scores listed in Table 25. The main effect of task condition explains that overall utterance duration is shorter during the isolation speech task, than when the speech task is performed concurrent with the motor task.

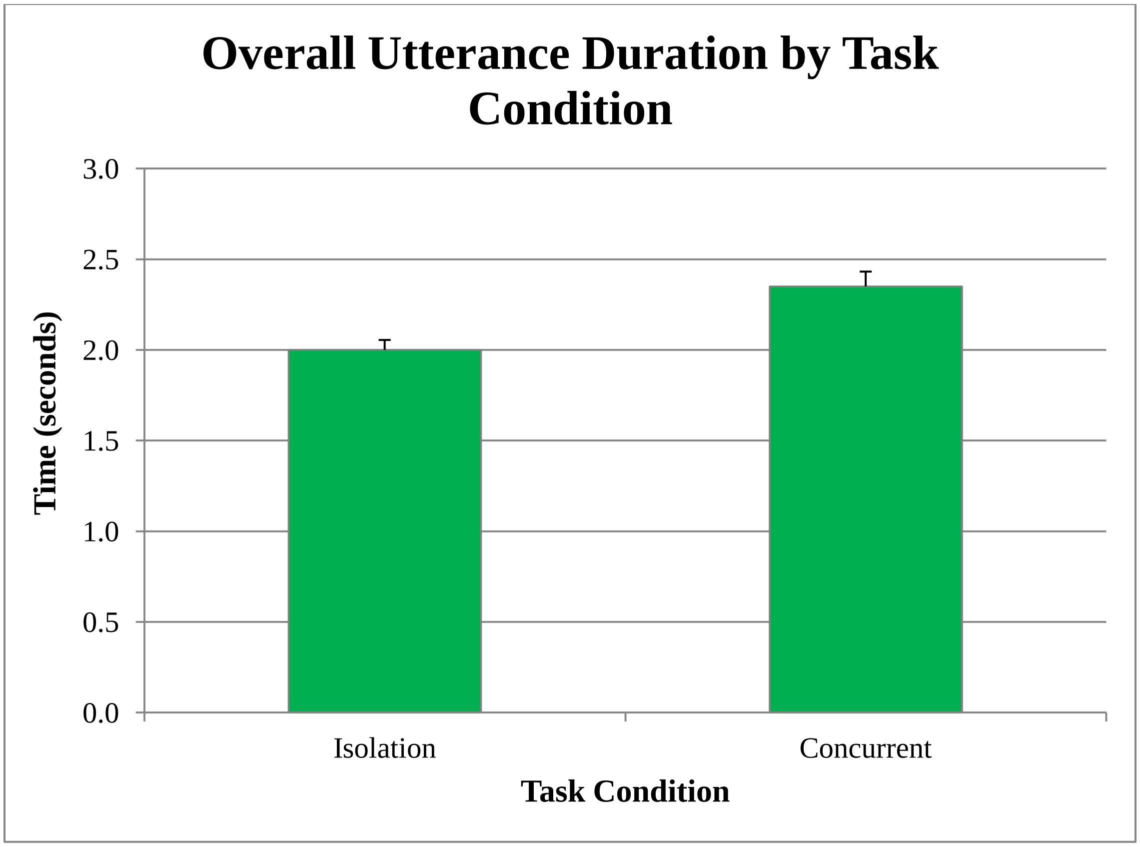

Figure 24. Overall utterance duration by task type for the controls and participants with Parkinson's disease.

Table 25. *Mean overall utterance duration and standard error by task type for the controls and participants with Parkinson's disease.*

	Utterance Duration (seconds)	Standard Error
Isolation	2.00	0.055
Concurrent	2.35	0.085

Interactions: No significance was reached for the group by task condition interaction.

3.3.1.2 Statistical Analysis Two: Speech vs. Cognitive vs. Linguistic vs. Motor Task Type

A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease).

The repeated measures independent variable consisted of task type (four levels: isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor). In this analysis, the main effect of task type was significant (refer to Appendix V for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was not found to be significant [$F(1, 31) = 2.535$, $p = .122$]. This indicates that the subjects' relative speech rate was equal across the two groups. The main effect of task type was significant [$F(1, 31) = 54.864$, $p = .000$] and is shown in Figure 25 with associated means and standard error scores listed in Table 26. The significant main effect for task type indicates that the duration of the overall utterance was dependent on the type of task performed. The length of overall utterance duration from longest to shortest is as follows: concurrent speech + linguistic, concurrent speech + cognitive, concurrent speech + motor, and isolation speech. Bonferroni post-hoc comparisons of the four tasks were conducted. Statistical significance was not found for utterance duration when compared across each of the four tasks.

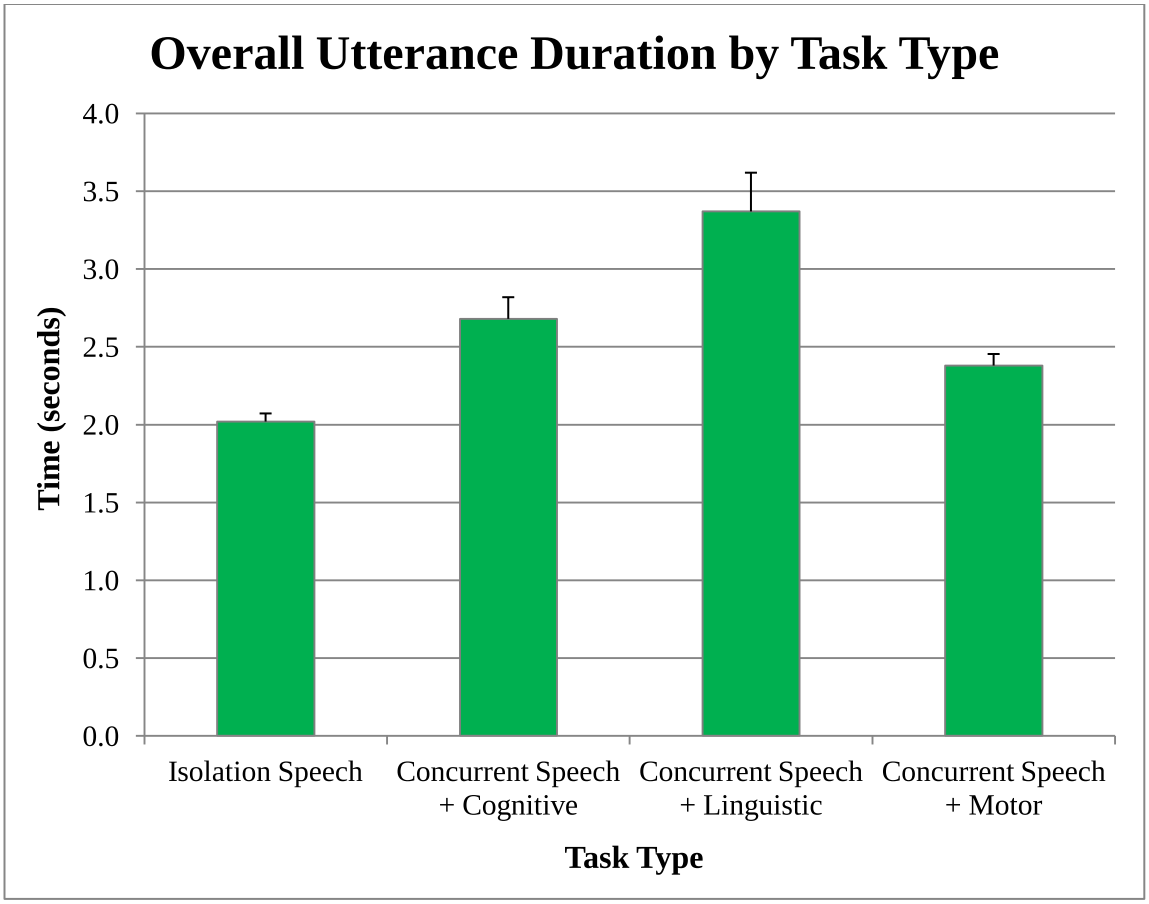

Figure 25. Overall utterance duration by task type for the controls and participants with Parkinson's disease.

Table 26. *Mean overall utterance duration and standard error by task type for the controls and participants with Parkinson's disease.*

	Utterance Duration (seconds)	Standard Error
Isolation Speech	2.02	0.052
Concurrent Speech + Cognitive	2.68	0.139
Concurrent Speech + Linguistic	3.37	0.249
Concurrent Speech + Motor	2.38	0.074

Interactions: Significance was not reached for the group by task type interaction.

3.3.1.3 Statistical Analysis Three: Three Difficulty Levels

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (three levels: concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group, task type and difficulty level were significant (refer to Appendix W for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 31) = 4.486$, $p = .042$] and is shown in Figure 26 with associated means and standard error scores listed in Table 27. The main effect for group indicates that overall utterance duration was shorter when spoken by the control subjects than the participants with Parkinson's disease. The main effect of task type was significant [$F(2, 62) = 32.130$, $p = .000$]. The significant main effect for task type indicates that the duration of the overall utterance was dependent on the type of task performed. In this study, the concurrent speech + linguistic task yielded the longest utterance duration, followed by the isolation speech task, the concurrent speech + cognitive task, and with the concurrent speech + motor task producing the shortest overall utterance duration. The main effect of difficulty level was significant [$F(2, 62) = 10.623$, $p = .000$] and is shown in Figure 27 with associated means and standard error scores listed in Table 28. This significant main effect depicts how utterance duration is affected by the level of difficulty of the task, in which utterance duration increases as the difficulty of the task increases.

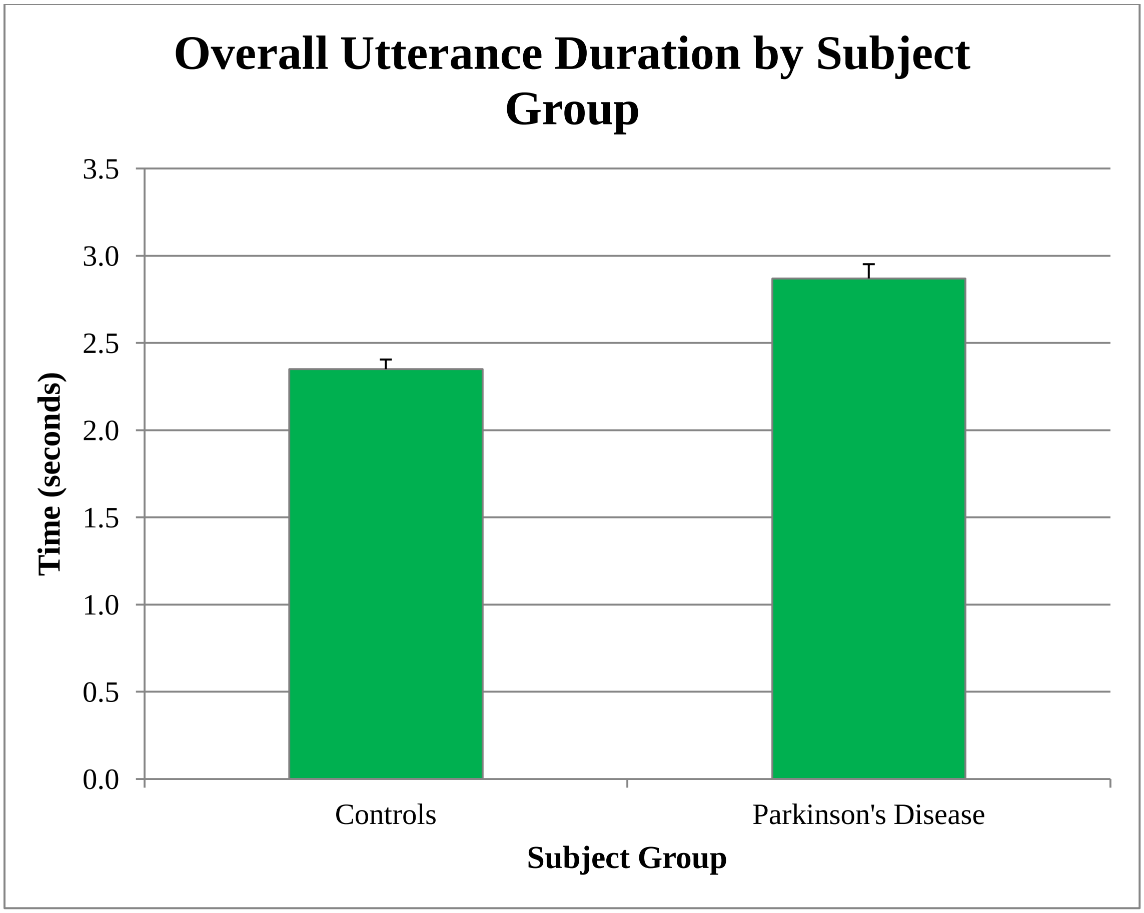

Figure 26. Overall utterance duration by subject group (controls and participants with Parkinson's disease).

Table 27. *Mean overall utterance duration and standard error subject group (controls and participants with Parkinson's disease).*

	Utterance Duration (seconds)	Standard Error
Controls	2.35	0.155
Parkinson's Disease	2.87	0.192

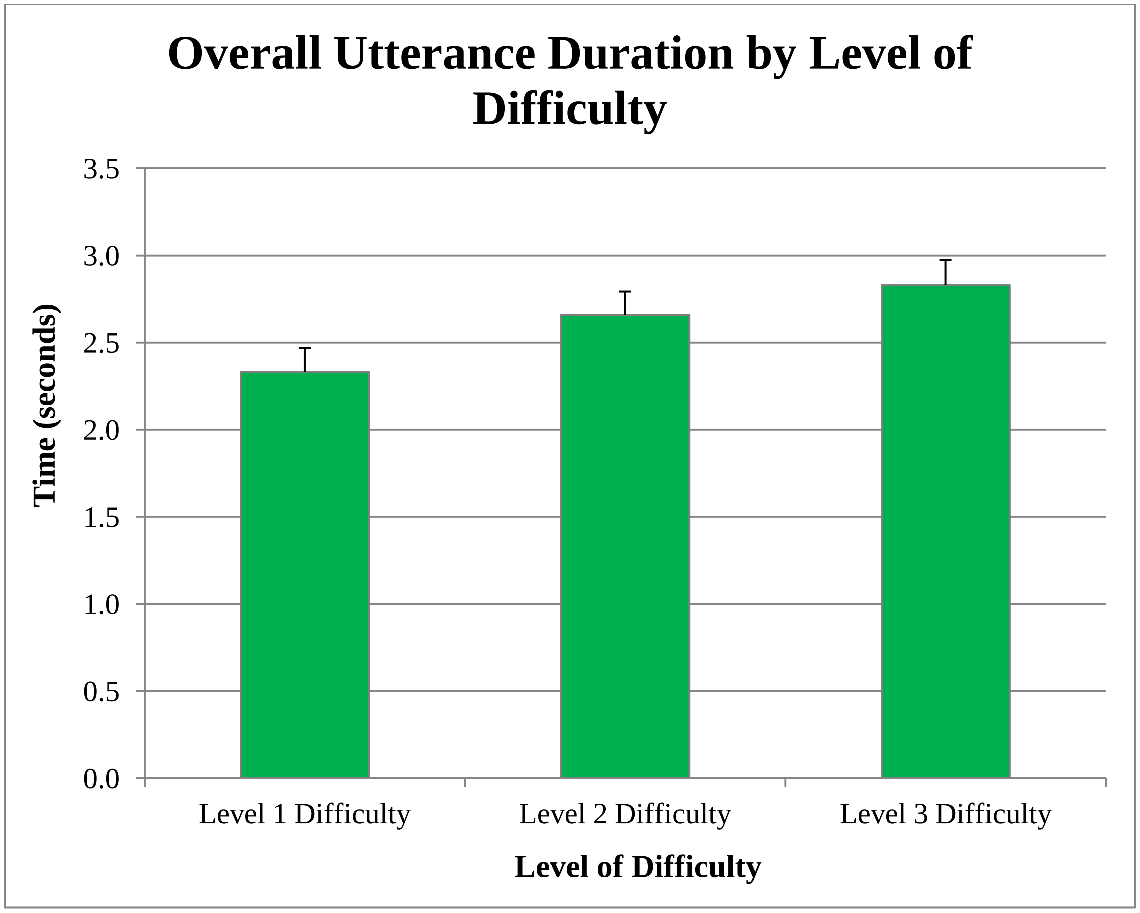

Figure 27. Overall utterance duration by level of difficulty for the controls and participants with Parkinson's disease.

Table 28. *Mean overall utterance duration and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Utterance Duration (seconds)	Standard Error
Level 1 Difficulty	2.33	0.138
Level 2 Difficulty	2.66	0.133
Level 3 Difficulty	2.83	0.144

Interactions: The group by task type interaction was significant [$F(2, 63) = 11.182$, $p = .000$]. This interaction is depicted in Figure 28 with associated means and standard error scores presented in Table 29. The interaction of task type on utterance duration followed the same pattern in both groups, in that utterance duration increased by task as follows: concurrent speech + motor, isolation speech, concurrent speech + cognitive, concurrent speech + linguistic. However, the amount that utterance duration increased between groups differs, as the subjects with Parkinson's disease had a greater change in utterance duration, particularly for the concurrent speech + linguistic task, than the control subjects. Significance was found for the task type by difficulty level interaction [$F(4, 124) = 11.137$, $p = .000$]. This interaction is depicted in Figure 29 with associated means and standard error scores presented in Table 30. This interaction suggests that for the concurrent speech + cognitive task and the concurrent speech + linguistic task, participants increased their overall utterance duration from the first to second level of difficulty before decreasing utterance duration from the second to third level of difficulty. For the concurrent speech + motor task, overall utterance duration decreased as the difficulty level increases. The following interactions did not reach significance: group by difficulty level and group by task type and difficulty level.

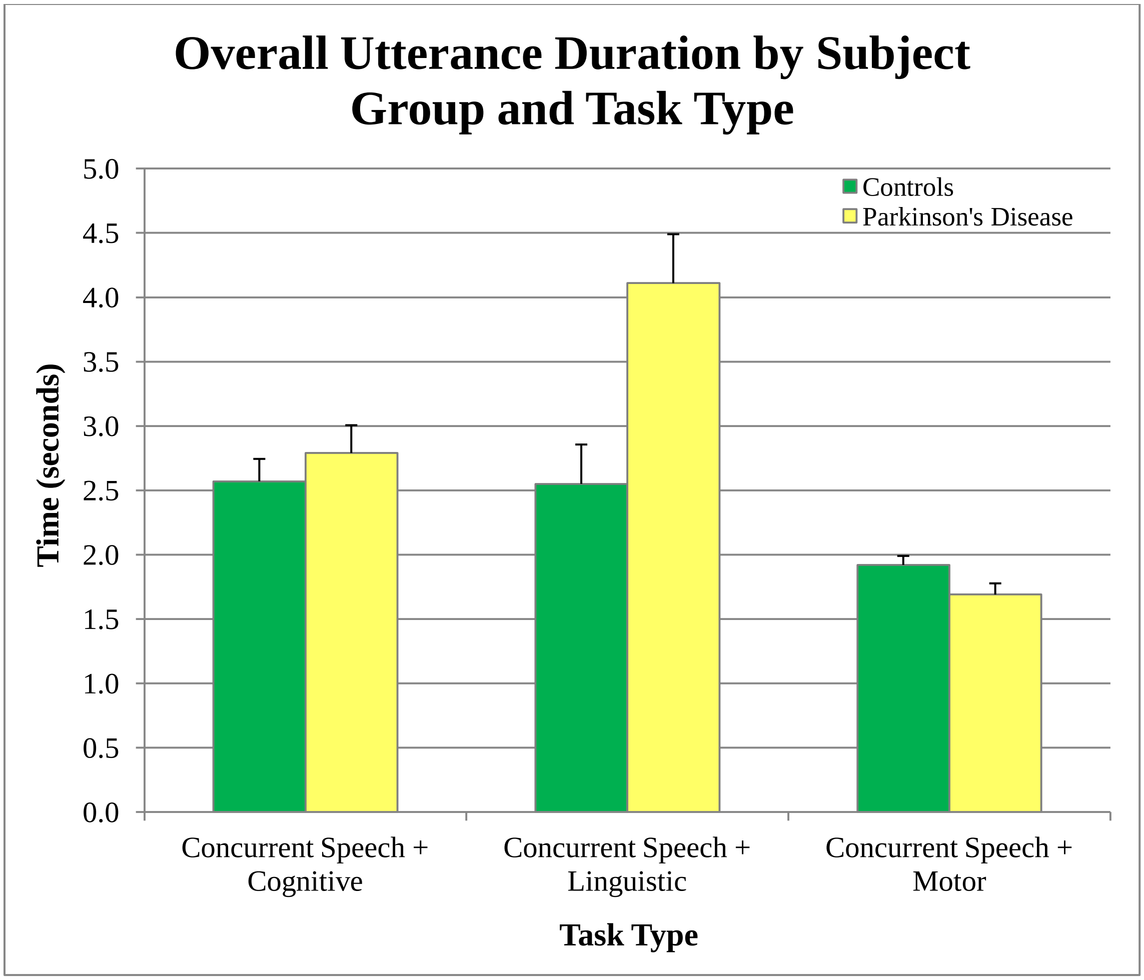

Figure 28. Overall utterance duration by subject group and task type for the controls and participants with Parkinson’s disease.

Table 29. *Mean overall utterance duration and standard error by subject group and task type for the controls and participants with Parkinson’s disease.*

		Utterance Duration (seconds)	Standard Error
Concurrent Speech + Cognitive	Controls	2.57	0.174
	Parkinson's Disease	2.79	0.216
Concurrent Speech + Linguistic	Controls	2.55	0.306
	Parkinson's Disease	4.11	0.380
Concurrent Speech + Motor	Controls	1.92	0.070
	Parkinson's Disease	1.69	0.087

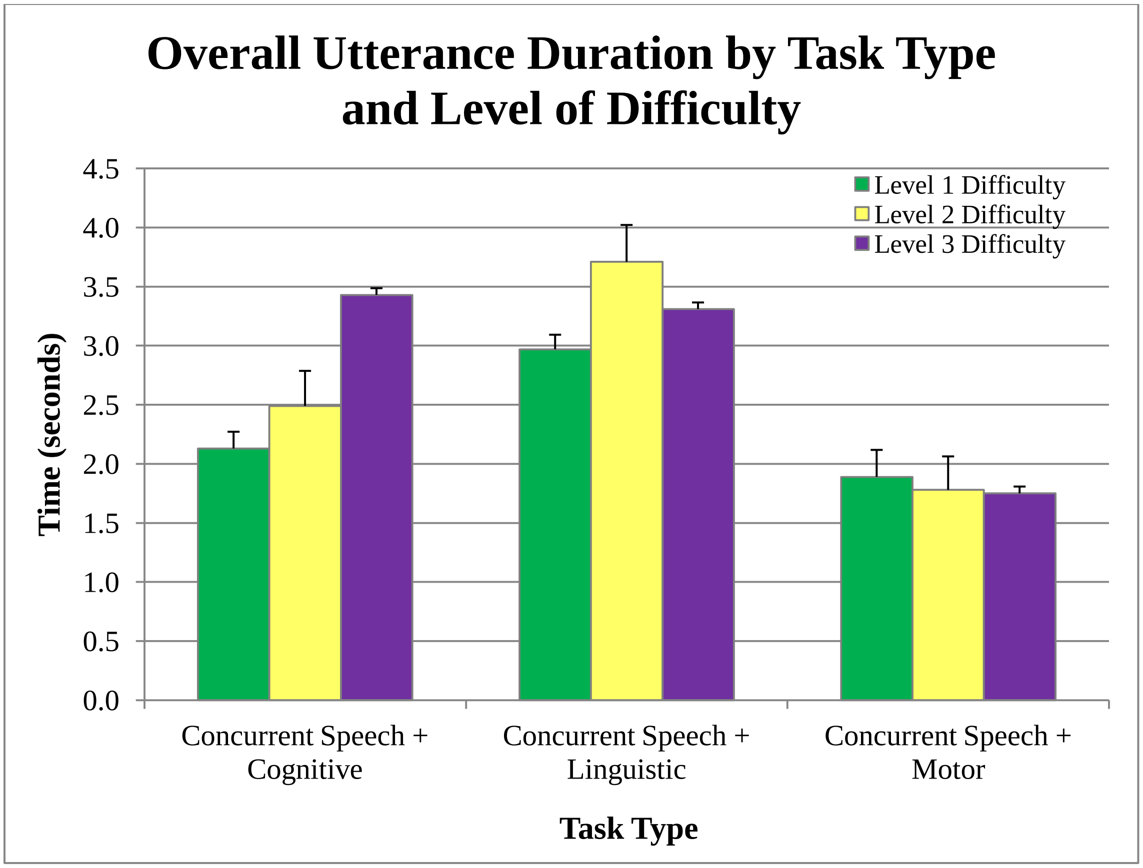

Figure 29. Overall utterance duration by task type and level of difficulty for the controls and participants with Parkinson's disease.

Table 30. *Mean overall utterance duration and standard error by task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Utterance Duration (seconds)	Standard Error
Level 1 Difficulty	Cognitive	2.13	0.142
	Linguistic	2.97	0.297
	Motor	1.89	0.057
Level 2 Difficulty	Cognitive	2.49	0.123
	Linguistic	3.71	0.312
	Motor	1.78	0.056
Level 3 Difficulty	Cognitive	3.43	0.228
	Linguistic	3.31	0.283
	Motor	1.75	0.058

3.3.2 Carrier Phrase Duration

The statistical procedures for carrier phrase duration were divided into three separate analyses. *Statistical Analysis One* focused on the effects of the isolation versus concurrent task conditions of the dependent variables. For this analysis, only the isolated speech task condition and the concurrent speech and motor task condition were included. The other two concurrent tasks (cognitive and linguistic) were not included because the reported answers for the isolation conditions consisted of only a target word, with no carrier phrase for comparison. *Statistical Analysis Two* focused on the effects of the four different task types (isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor) on the dependent variables. *Statistical Analysis Three* focused on the effects of the three different difficulty levels on the dependent variables. Because difficulty levels were only examined in the linguistic, cognitive and motor tasks, these tasks were the focus of attention in this analysis procedure.

3.3.2.1 Statistical Analysis One: Isolation versus Concurrent Task Condition

A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task type (two levels: isolation speech, concurrent speech + motor). In this analysis, the main effect of task condition was significant (refer to Appendix X for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was not found to be significant [$F(1, 31) = 2.535$, $p = .122$]. This indicates that the subjects' relative speech rate was equal across the two groups for the isolation speech task and concurrent speech + motor task. Significance was found for the main effect of task condition [$F(1, 31) = 36.029$, $p = .000$]. This main effect is illustrated in Figure 30 with associated means and standard error scores listed in Table 31. This effect indicates that carrier phrase duration was shorter when repeated during concurrent task performance as opposed to in isolation.

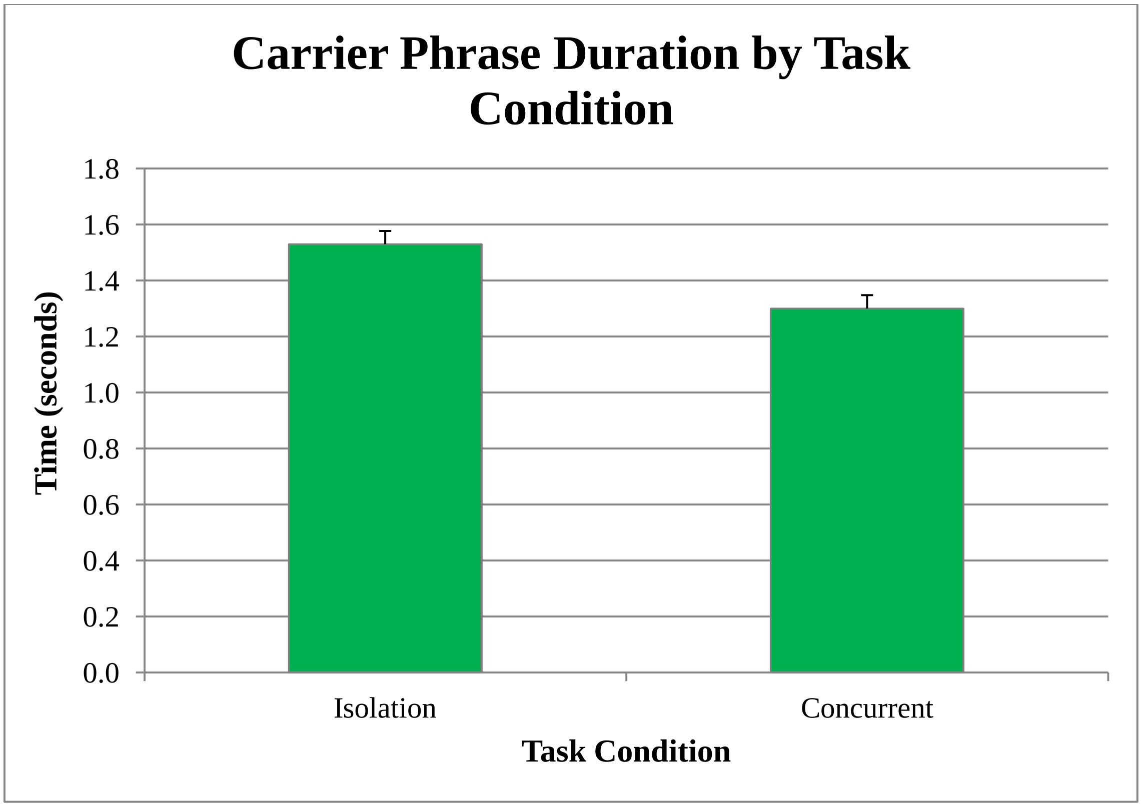

Figure 30. Carrier phrase duration by task type for the controls and participants with Parkinson's disease.

Table 31. *Mean carrier phrase duration and standard error by task type for the controls and participants with Parkinson's disease.*

	Carrier Phrase Duration (seconds)	Standard Error
Isolation	1.53	0.047
Concurrent	1.30	0.048

Interactions: Significance was not reached for the group by task condition interaction.

3.3.2.2 Statistical Analysis Two: Speech vs. Cognitive vs. Linguistic vs. Motor Task Type

A two-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variable consisted of task type (four levels: isolation speech, concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor). In this analysis, the main effects of group and task type were significant (refer to Appendix Y for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group reached significance [$F(1, 31) = 4.746$, $p = .037$]. This effect is depicted in Figure 31 with the associated means and standard error scores listed in Table 32. This result indicates that carrier phrase duration was shorter for individuals with Parkinson's disease than the control subjects. The main effect of task type was significant [$F(3, 93) = 14.306$, $p = .000$] and is shown in Figure 32 with associated means and standard error scores listed in Table 33. The significant main effect for task type indicates that the duration of the spoken carrier phrase was dependent on the type of task performed. In this study, the concurrent speech + linguistic task yielded the longest carrier phrase duration, followed by the isolation speech task, the concurrent speech + cognitive task, and with the concurrent speech + motor task generating the shortest carrier phrase duration. Bonferroni post-hoc comparisons of the four tasks were conducted. In comparing the isolation speech task and the concurrent speech + motor task, it was found that the carrier phrase duration for the isolation speech task (M = 1.544, SD = .266) was significantly greater than the carrier phrase duration for the concurrent speech + motor task (M = 1.322, SD = .281). The concurrent speech + cognitive task (M = 1.471, SD = .313) was found to have a carrier phrase duration significantly lower than that of the concurrent speech + linguistic task (M = 1.604, SD = .378). The concurrent speech + cognitive task (M = 1.471, SD = .313) was found to have a carrier phrase duration significantly higher than that of the concurrent speech + motor task (M = 1.322, SD = .281). As well, in comparing the carrier phrase duration of the concurrent speech + linguistic task (M = 1.604, SD = .378) with that of the concurrent speech + motor task (M = 1.322, SD = .281), significance was found with the concurrent speech + linguistic task yielding a higher carrier phrase duration. No significance was found for carrier phrase duration between the isolation speech task (M = 1.544, SD = .266) and the concurrent speech + cognitive task (M = 1.471, SD = .313), or the isolation speech task (M = 1.544, SD = .266)) and the concurrent speech + linguistic task (M = 1.604, SD = .378).

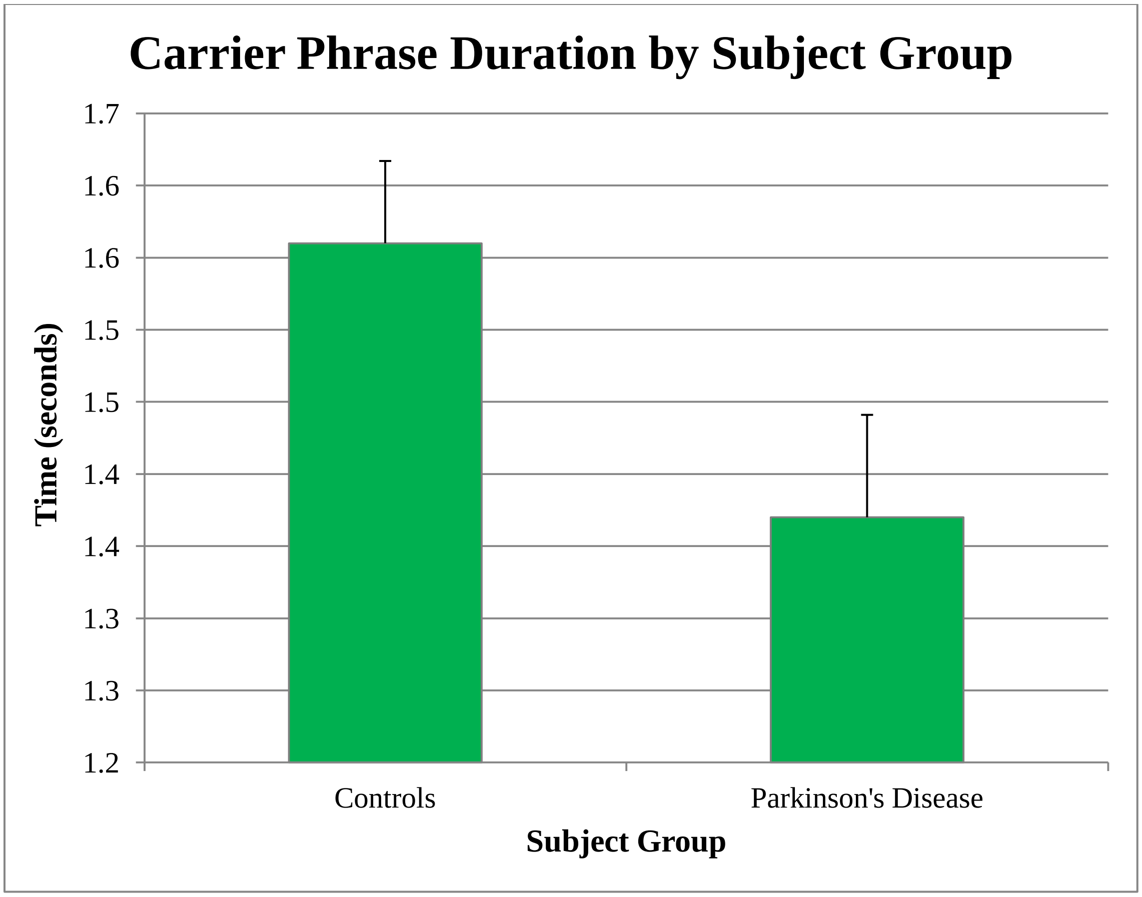

Figure 31. Carrier phrase duration by subject group (controls and participants with Parkinson's disease).

Table 32. *Mean carrier phrase duration and standard error subject group (controls and participants with Parkinson's disease).*

	Carrier Phrase Duration (seconds)	Standard Error
Controls	1.56	0.057
Parkinson's Disease	1.37	0.071

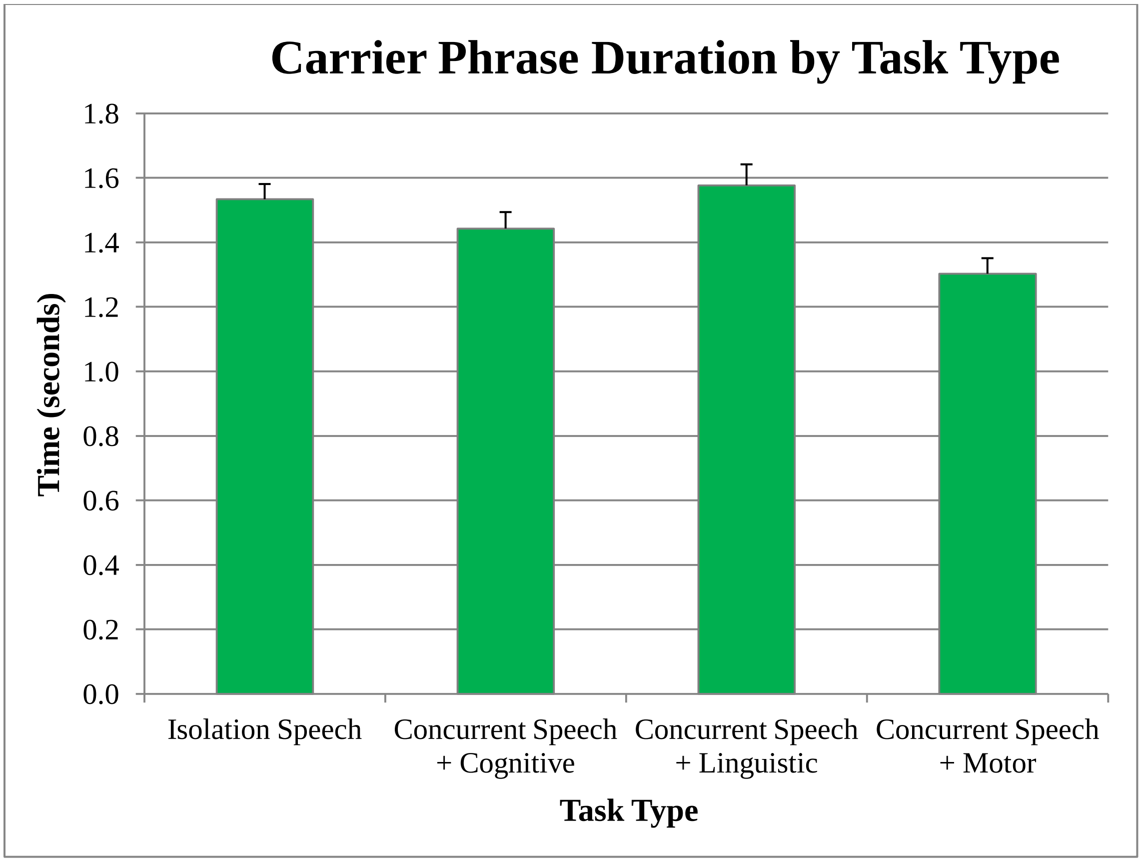

Figure 32. Carrier phrase duration by task type for the controls and participants with Parkinson's disease.

Table 33. *Mean carrier phrase duration and standard error by task type for the controls and participants with Parkinson's disease.*

	Carrier Phrase Duration (seconds)	Standard Error
Isolation Speech	1.53	0.047
Concurrent Speech + Cognitive	1.44	0.051
Concurrent Speech + Linguistic	1.58	0.065
Concurrent Speech + Motor	1.30	0.048

Interactions: No significance was found for the group by task type interaction.

3.3.2.3 Statistical Analysis Three: Three Difficulty Levels

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (three levels: concurrent speech + cognitive, concurrent speech + linguistic, concurrent speech + motor), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of task type and difficulty level were significant (refer to Appendix Z for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was not found to be significant [F(1, 32)= 2.739, p=.108). This result indicates that the control subjects and individuals with Parkinson's disease repeated the carrier phrase at a similar speech rate across all three secondary tasks (concurrent speech + cognitive, concurrent speech + linguistic, and concurrent speech + motor). The main effect of task type was significant [$F(2, 64) = 11.532$, $p = .000$]. The significant main effect for task type indicates that the duration of the spoken carrier phrase was dependent on the type of task performed. In this study, the concurrent speech + linguistic task yielded the longest carrier phrase duration, followed by the concurrent speech + cognitive task, and with the concurrent speech + motor task generating the shortest carrier phrase duration. The main effect of difficulty level was significant [$F(2, 64) = 4.540$, $p = .014$] and is shown in Figure 33 with associated means and standard error scores listed in Table 34. This significant main effect describes the relationship between difficulty level and carrier phrase duration, in that the duration of the spoken carrier phrase decreases from the first to the second difficulty level, and then increases from the second to the third difficulty level.

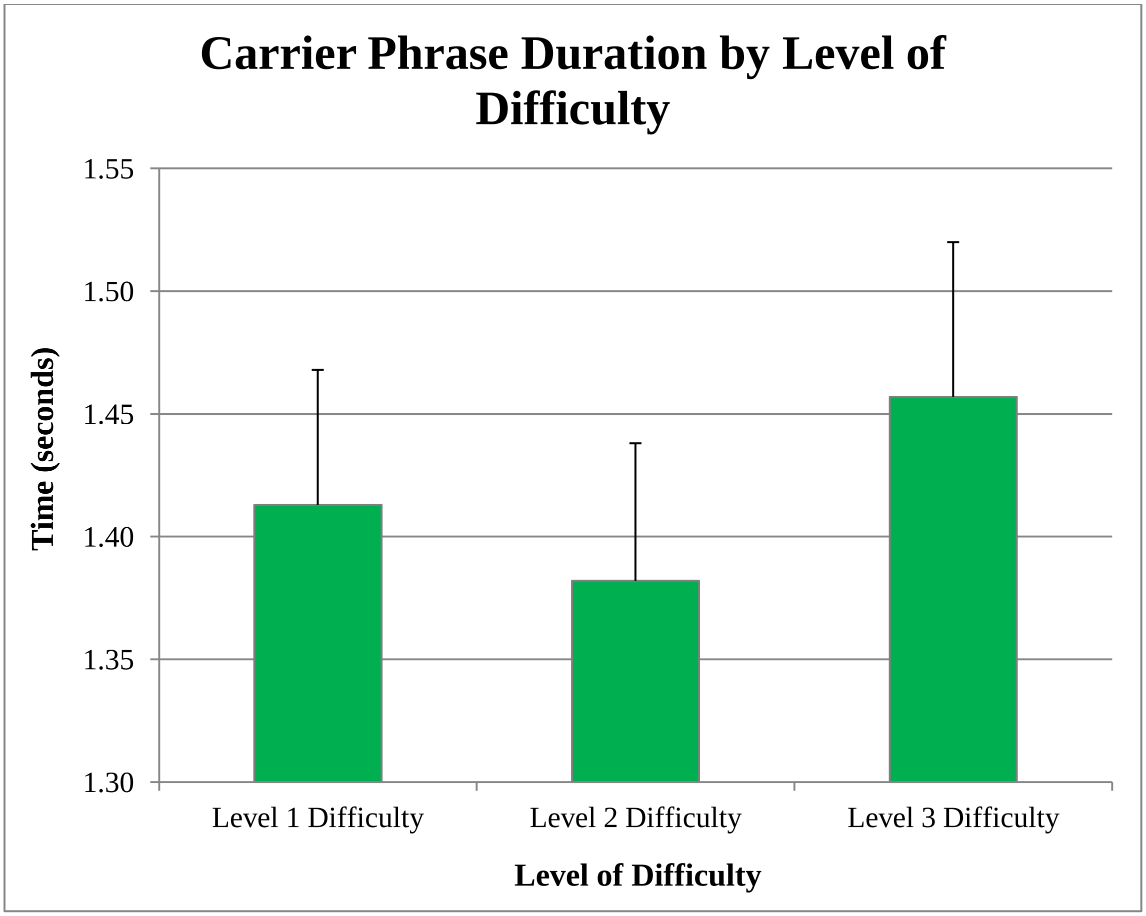

Figure 33. Carrier phrase duration by level of difficulty for the controls and participants with Parkinson's disease.

Table 34. *Mean carrier duration and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Carrier Phrase Duration (seconds)	Standard Error
Level 1 Difficulty	1.41	0.055
Level 2 Difficulty	1.38	0.056
Level 3 Difficulty	1.45	0.063

Interactions: A significant interaction was found for the task type by difficulty level relationship [F(4, 128) = 10.636, p = .000]. This interaction is depicted in Figure 34 with associated means and standard error scores presented in Table 35. This interaction describes how for each task type, the overall utterance duration changes as the difficulty level increases. Overall utterance duration increases as the difficulty level increases for the concurrent speech + cognitive task. For the concurrent speech + linguistic task, overall utterance duration increased from the first to the second level of difficulty, and then decreased from the second to the third level of difficulty. As the difficulty level increased, overall utterance duration decreased for the concurrent speech + motor task. The group by task type by difficulty level interaction was also found to be significant [$F(4, 30) = 2.539$, $p = 0.043$]. This interaction is depicted in Figure 35 with associated means presented in Table 36 and standard error scores presented in Table 37. Figure 35 describes how utterance duration is affected by the difficulty level of each task performed by each group of subjects. For the concurrent speech + cognitive task, both groups of subjects recorded longer overall utterance duration as task difficulty increased. In performing the concurrent speech + linguistic task, both groups of participants presented longer overall utterance durations for the second level of difficulty than the first, and then spoke faster for the third level of difficulty. In addition, the control participants spoke faster for all three difficulty levels than the participants with Parkinson's disease. For the concurrent speech + motor task, both groups of subjects recorded shorter overall utterance duration as task difficulty increased. The subjects with Parkinson's disease spoke faster for all three difficulty levels than the control subjects.

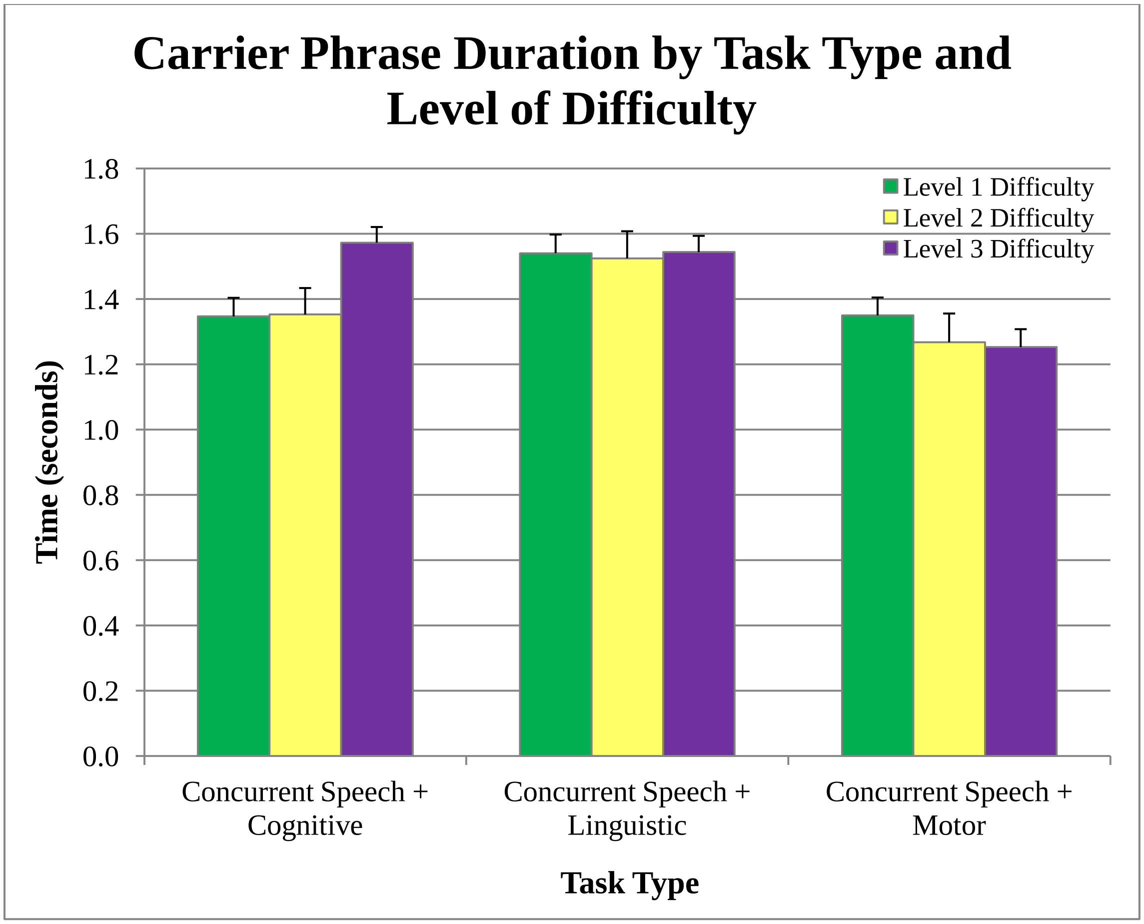

Figure 34. Utterance duration by task type and level of difficulty for the controls and participants with Parkinson's disease.

Table 35. *Mean utterance duration and standard error by task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Carrier Phrase Duration (seconds)	Standard Error
Level 1 Difficulty	Concurrent Speech + Cognitive	1.35	0.057
	Concurrent Speech + Linguistic	1.54	0.081
	Concurrent Speech + Motor	1.35	0.048
Level 2 Difficulty	Concurrent Speech + Cognitive	1.35	0.055
	Concurrent Speech + Linguistic	1.53	0.083
	Concurrent Speech + Motor	1.27	0.050
Level 3 Difficulty	Concurrent Speech + Cognitive	1.57	0.076
	Concurrent Speech + Linguistic	1.54	0.088
	Concurrent Speech + Motor	1.25	0.055

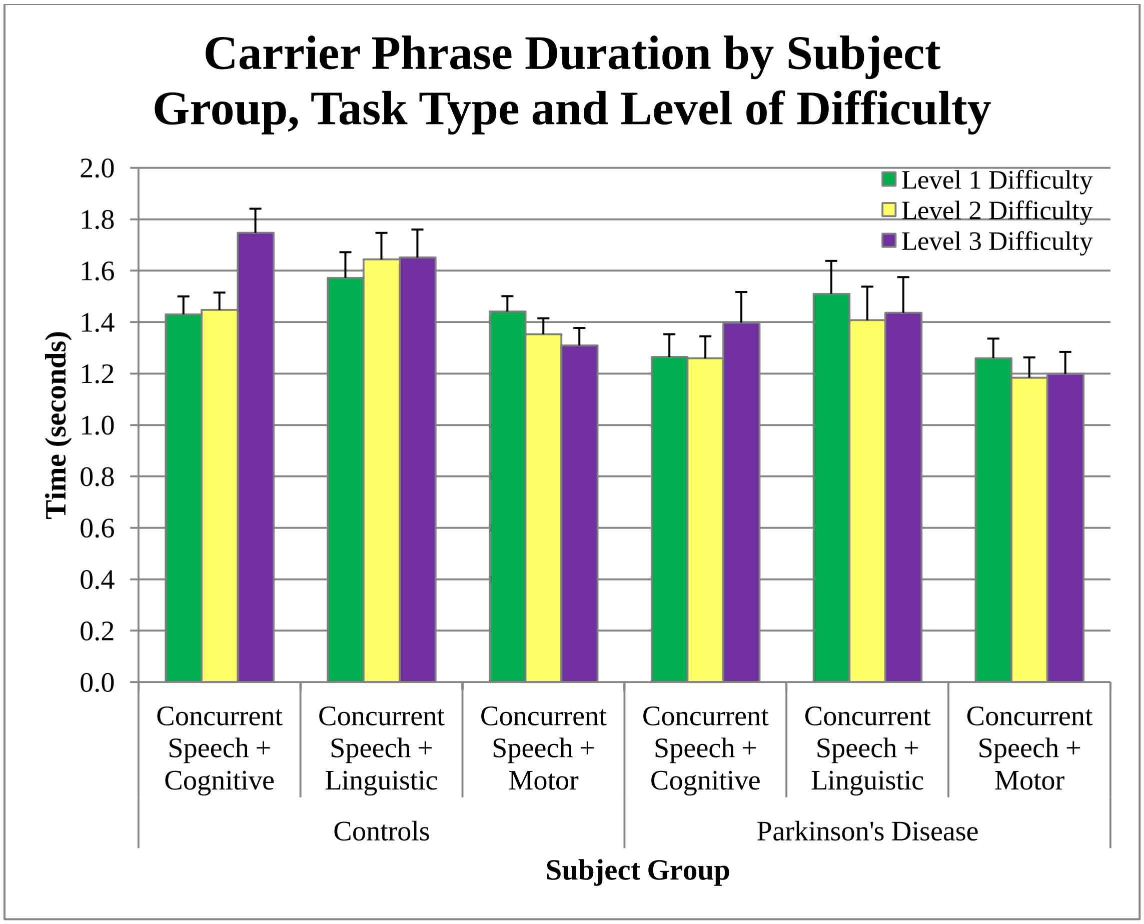

Figure 35. Utterance duration by subject group, task type and level of difficulty for the controls and participants with Parkinson's disease.

Table 36. *Mean utterance duration by subject group, task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Utterance Duration (seconds)		
		Level 1 Difficulty	Level 2 Difficulty	Level 3 Difficulty
Controls	Concurrent Speech + Cognitive	1.43	1.44	1.747
	Concurrent Speech + Linguistic	1.57	1.64	1.651
	Concurrent Speech + Motor	1.44	1.35	1.309
Parkinson's Disease	Concurrent Speech + Cognitive	1.26	1.25	1.398
	Concurrent Speech + Linguistic	1.51	1.41	1.436
	Concurrent Speech + Motor	1.26	1.18	1.198

Table 37. *Standard error by subject group, task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Utterance Duration (seconds)		
		Level 1 Difficulty	Level 2 Difficulty	Level 3 Difficulty
Controls	Concurrent Speech + Cognitive	0.070	0.068	0.094
	Concurrent Speech + Linguistic	0.100	0.103	0.109
	Concurrent Speech + Motor	0.060	0.062	0.068
Parkinson's Disease	Concurrent Speech + Cognitive	0.089	0.086	0.119
	Concurrent Speech + Linguistic	0.128	0.131	0.139
	Concurrent Speech + Motor	0.076	0.079	0.086

3.3.3 Response Time

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (two levels: cognitive, linguistic), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group, task type, and difficulty level were significant (refer to Appendix AA for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 32) = 15.372$, $p = .000$] and is shown in Figure 36 with associated means and standard error scores listed in Table 38. The significant main effect for group explains that the control subjects provided a response, after presented with the stimulus, more quickly than the participants with Parkinson's disease. The main effect of task type was significant [$F(1, 32) = 18.246$, $p = .000$] and is shown in Figure 37 with associated means and standard error scores listed in Table 39. The significant main effect for task type indicates that participants in both groups were much quicker with providing a response after presented with the stimulus for the cognitive task than the linguistic task. The main effect of difficulty level was significant [$F(2, 64) = 40.148$, $p = .003$] and is shown in Figure 38 with associated means and standard error scores listed in Table 40. This significant main effect describes the relationship between response time and difficulty level, in that response time increases as the difficulty of the task increases.

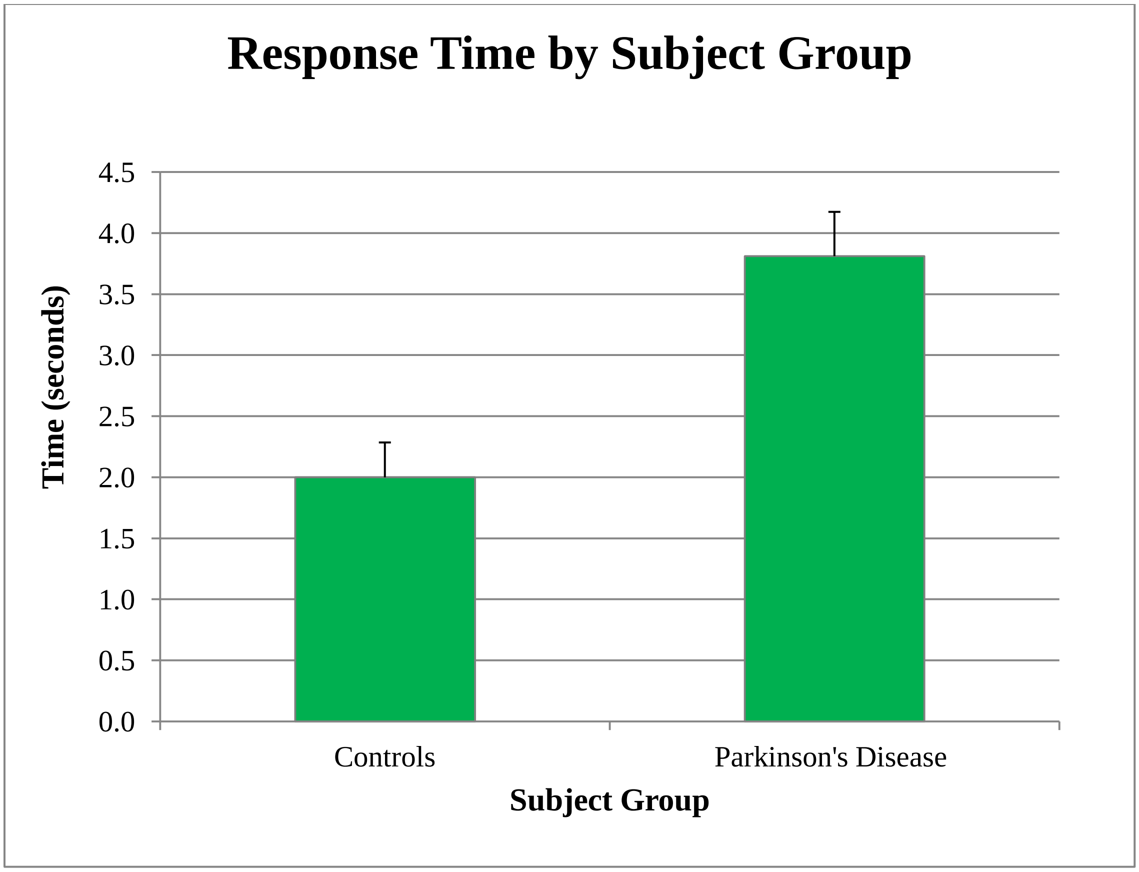

Figure 36. Response time by subject group (controls and participants with Parkinson's disease).

Table 38. *Mean response time and standard error by subject group (controls and participants with Parkinson's disease).*

	Response Time (seconds)	Standard Error
Controls	1.99	0.286
Parkinson's Disease	3.81	0.363

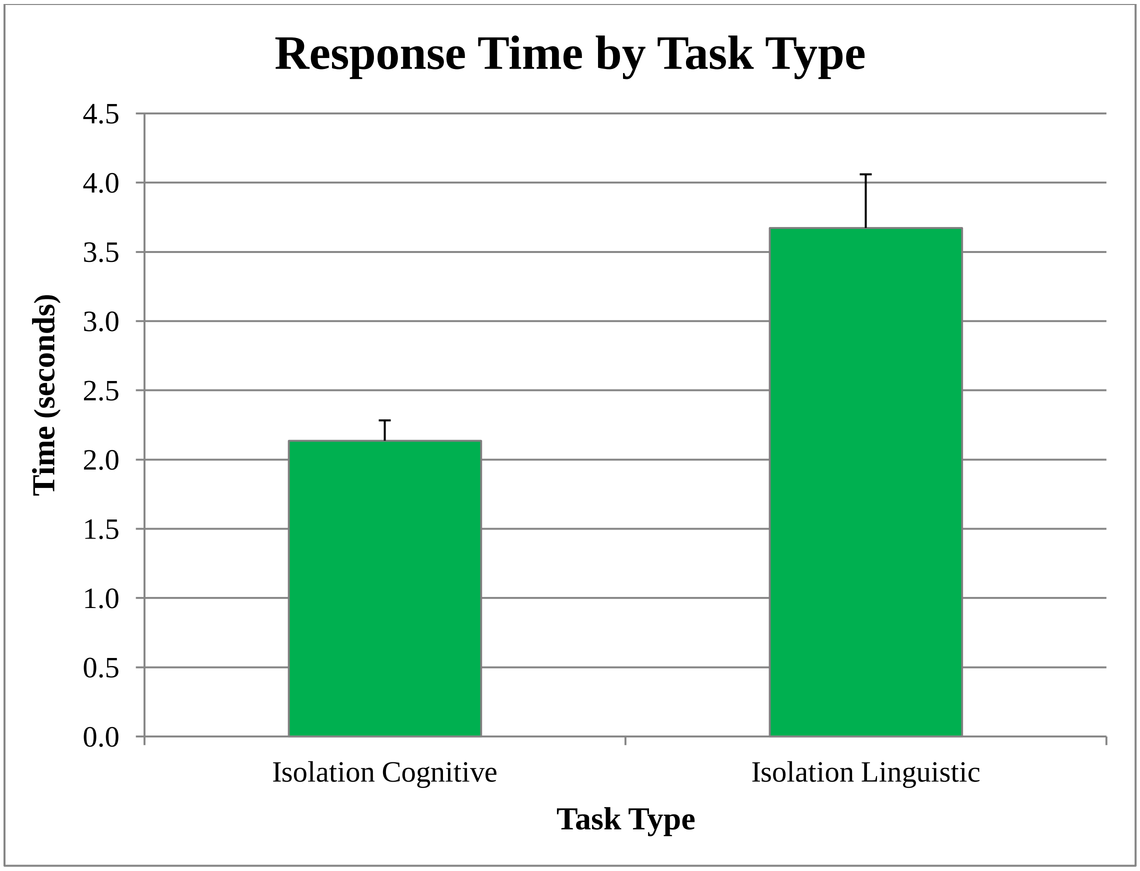

Figure 37. Response time by task type for the controls and participants with Parkinson's disease.

Table 39. *Mean response time and standard error by task type for the controls and participants with Parkinson's disease.*

	Response Time (seconds)	Standard Error
Isolation Cognitive	2.14	0.147
Isolation Linguistic	3.67	0.387

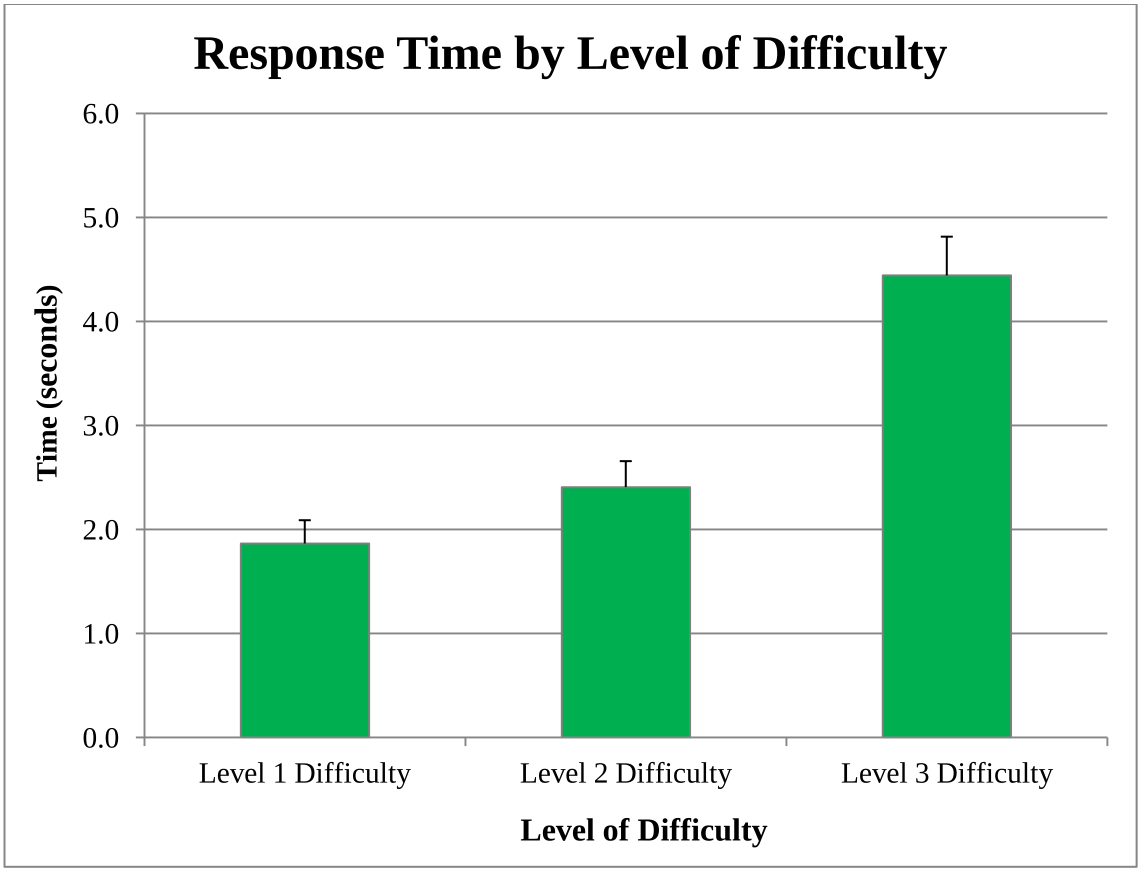

Figure 38. Response time by level of difficulty for the controls and participants with Parkinson's disease.

Table 40. *Mean response time and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Response Time (seconds)	Standard Error
Level 1 Difficulty	1.86	0.224
Level 2 Difficulty	2.41	0.250
Level 3 Difficulty	4.44	0.373

Interactions: The group by task type interaction was significant [$F(1, 66) = 13.002$, $p = 0.000$]. This interaction is depicted in Figure 39 with associated means and standard error scores presented in Table 41. This interaction shows that both groups do experience an increase in response time when performing the linguistic task as compared to the cognitive task, and that the subjects with Parkinson's disease show a much greater difference in response time than the controls between the two tasks. Significance was found for the group by difficulty level interaction [$F(1, 30) = 8.642$, $p = 0.000$] and is presented in Figure 40 with associated means and standard error scores presented in Table 42. This interaction illustrates the relationship between group and difficulty level for response time. Both groups experienced an increase in response time as the difficulty levels increased, however, the subjects with Parkinson's disease showed a much greater increase in response time than the control subjects.

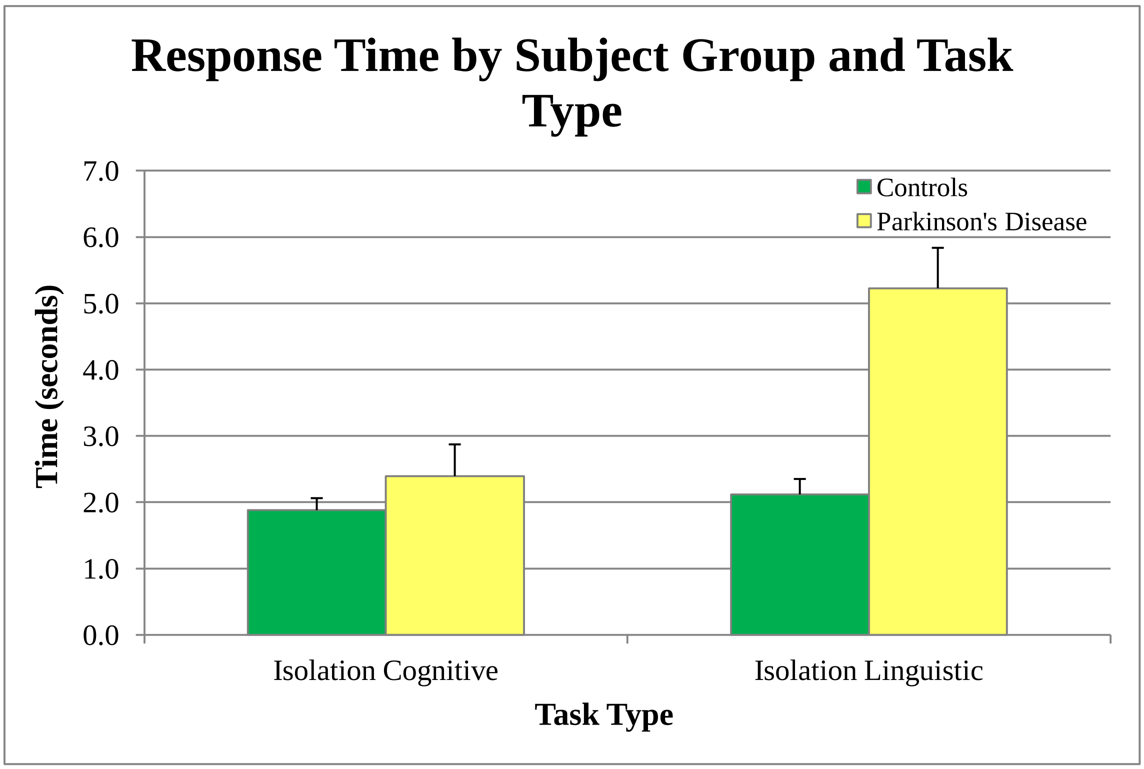

Figure 39. Response time by subject group and task type for the controls and participants with Parkinson's disease.

Table 41. *Mean response time and standard error by subject group and task type for the controls and participants with Parkinson's disease.*

		Response Time (seconds)	Standard Error
Isolation Cognitive	Controls	1.88	0.182
	Parkinson's Disease	2.12	0.479
Isolation Linguistic	Controls	2.39	0.232
	Parkinson's Disease	5.23	0.608

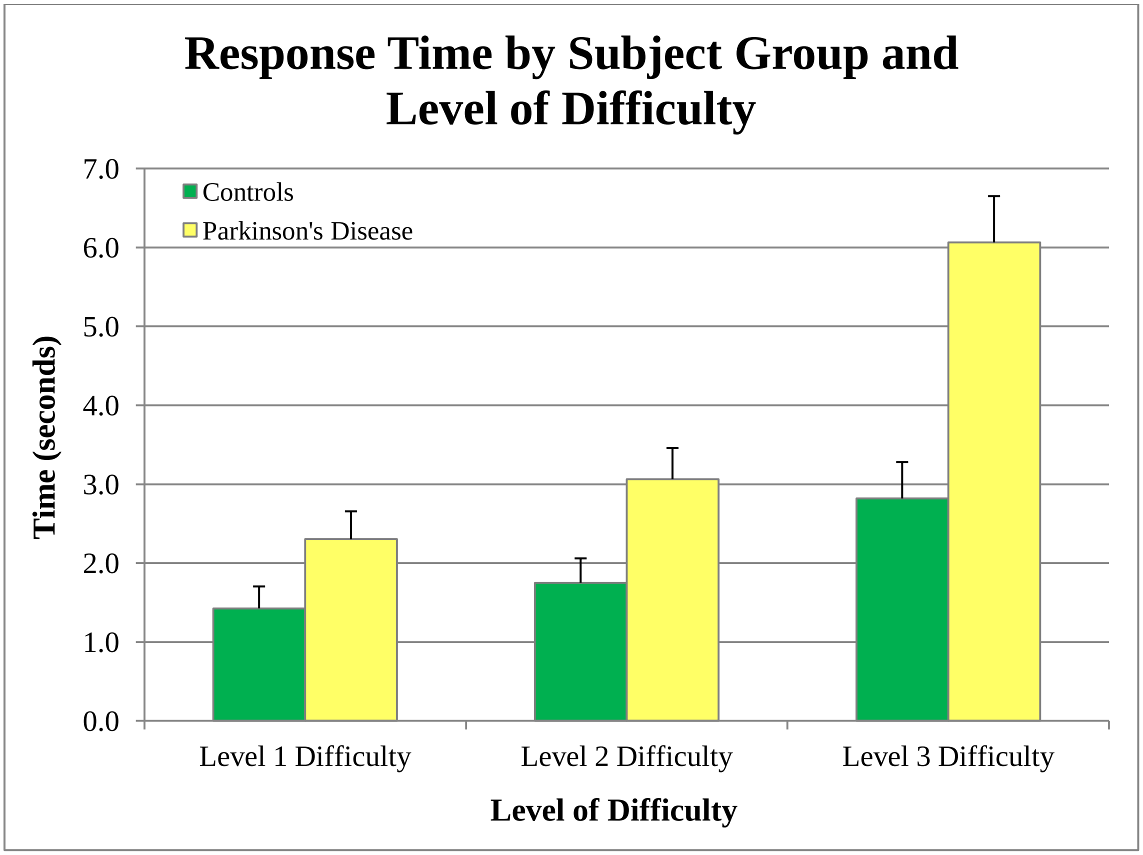

Figure 40. Response time by subject group and level of difficulty for the controls and participants with Parkinson's disease.

Table 42. *Mean response time and standard error by subject group and level of difficulty for the controls and participants with Parkinson's disease.*

		Response Time (seconds)	Standard Error
Controls	Level 1 Difficulty	1.43	0.278
	Level 2 Difficulty	1.75	0.310
	Level 3 Difficulty	2.82	0.461
Parkinson's Disease	Level 1 Difficulty	2.30	0.353
	Level 2 Difficulty	3.06	0.394
	Level 3 Difficulty	6.07	0.586

3.3.4 Response Latency

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (two levels: concurrent speech + cognitive, concurrent speech + linguistic), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effect of group was significant (refer to Appendix AB for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 32) = 10.694$, $p = .003$] and is shown in Figure 41 with associated means and standard error scores listed in Table 43. The significant main effect for group shows that the average response latency for the control group was significantly shorter in all conditions than the reported average response latency for the participants with Parkinson's disease. This suggests that the subjects with Parkinson's disease took longer to respond with the carrier phrase from the presentation of the stimulus than controls.

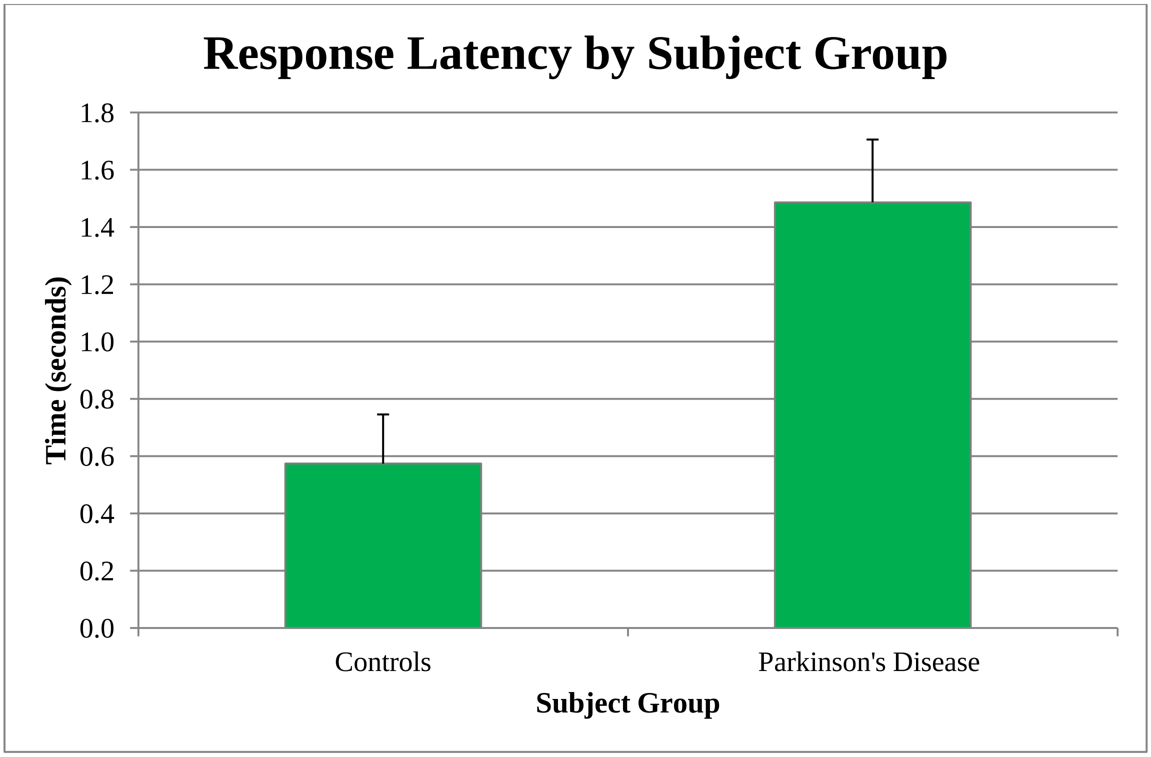

Figure 41. Response latency by subject group (controls and participants with Parkinson's disease).

Table 43. *Mean response latency and standard error by subject group (controls and participants with Parkinson's disease).*

	Response Latency (seconds)	Standard Error
Controls	0.57	0.172
Parkinson's Disease	1.49	0.219

Interactions: Significance was not found for the following interactions: group by task type, group by difficulty level, task type by difficulty level, and group by task type by difficulty level.

3.3.5 Sentence-Response Latency

A three-factor, repeated measures ANOVA was performed, using subject group as the between-groups independent variable with two levels (controls, Parkinson's disease). The repeated measures independent variables consisted of task type (two levels: concurrent speech + cognitive, concurrent speech + linguistic), and difficulty level (three levels: 1, 2, 3). In this analysis, the main effects of group, task type, and difficulty level were significant (refer to Appendix AC for descriptive statistics and ANOVA tables).

Main Effects: The main effect of group was significant [$F(1, 32) = 15.990$, $p = .000$] and is shown in Figure 42 with associated means and standard error scores listed in Table 44. The significant main effect for group explains that the control subjects provided a response, after repeating the carrier phrase, more quickly than the participants with Parkinson's disease. The main effect of task type was significant [$F(1, 32) = 17.122$, $p = .000$] and is shown in Figure 43 with associated means and standard error scores listed in Table 45. The significant main effect for task type indicates that participants in both groups were much quicker with providing a response after repeating the carrier phrase for the concurrent speech + cognitive task than the concurrent speech + linguistic task. The main effect of difficulty level was significant [$F(2, 64) = 6.412$, $p = .003$] and is shown in Figure 44 with associated means and standard error scores listed in Table 46. This significant main effect illustrates the relationship between sentence-response latency and difficulty level, in which the duration between the carrier phrase and the response increases as the task difficulty level increases.

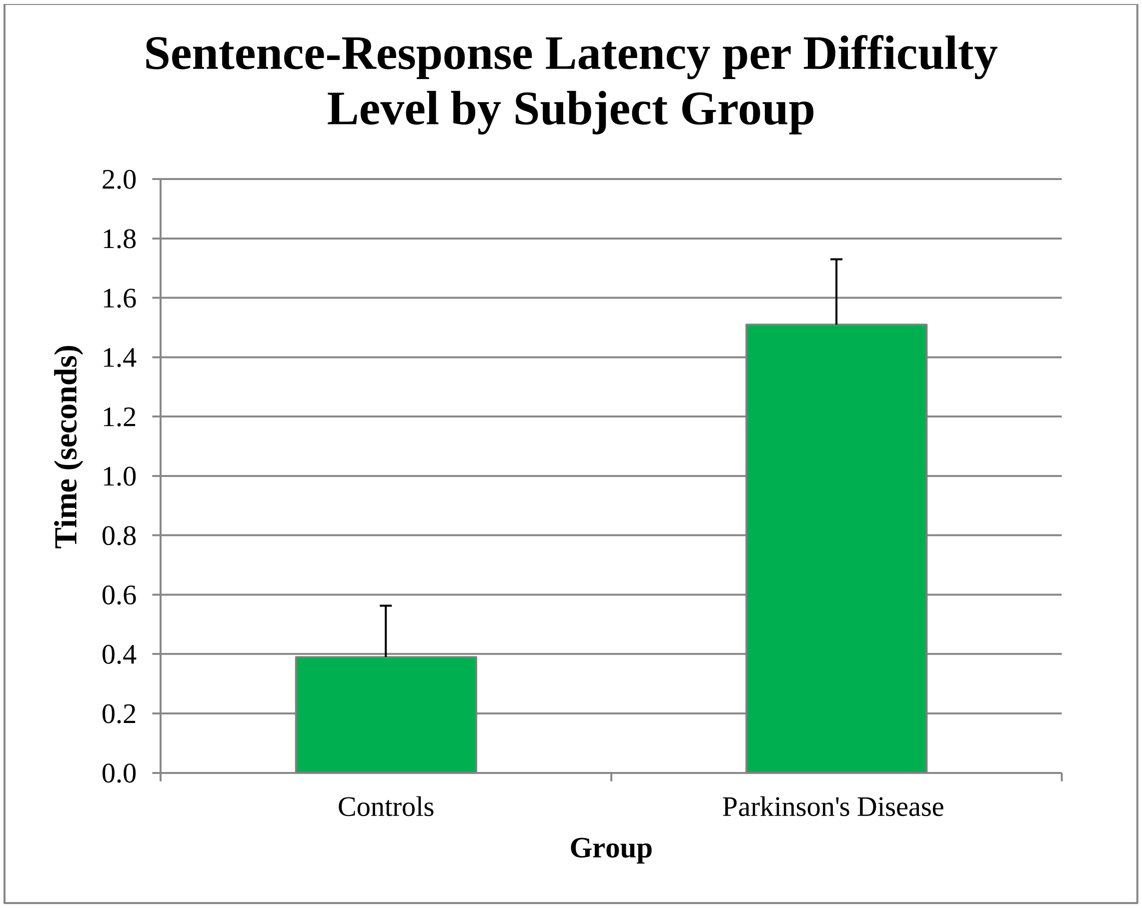

Figure 42. Sentence-response latency by subject group (controls and participants with Parkinson's disease).

Table 44. *Mean sentence-response latency and standard error by subject group (controls and participants with Parkinson's disease).*

	Sentence-Response Latency (seconds)	Standard Error
Controls	0.39	0.173
Parkinson's Disease	1.51	0.220

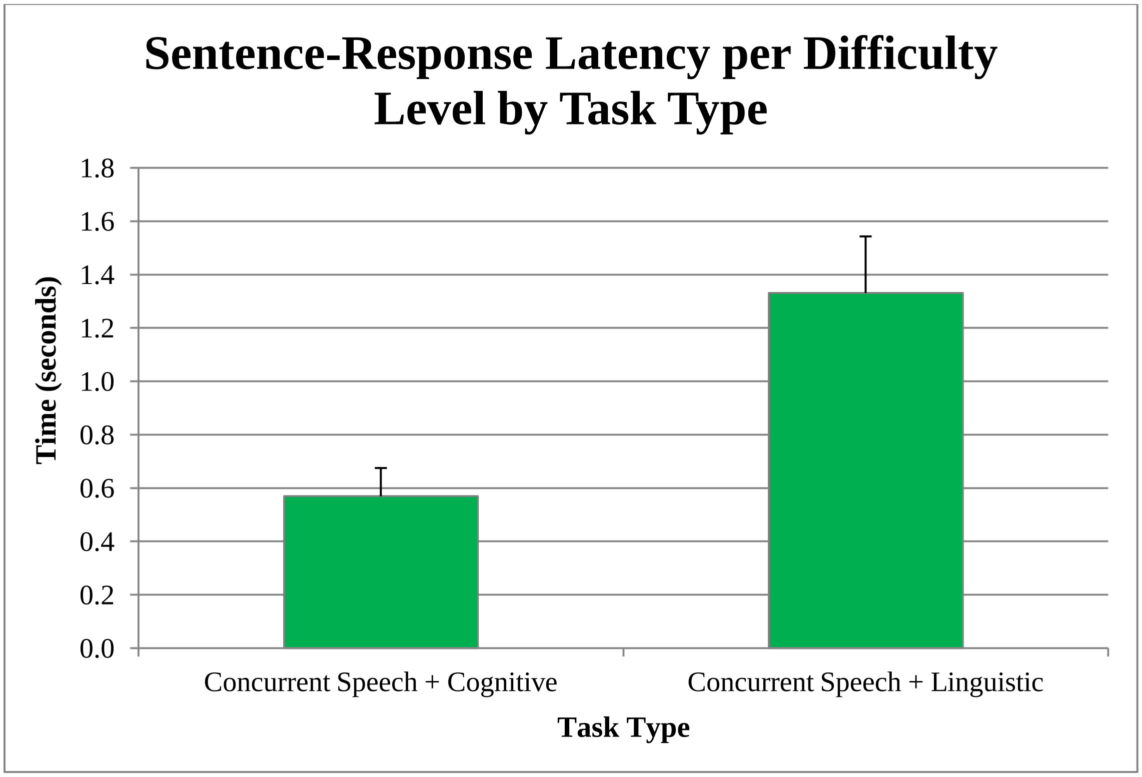

Figure 43. Sentence-response latency time by task type for the controls and participants with Parkinson’s disease.

Table 45. *Mean sentence-response latency and standard error by task type for the controls and participants with Parkinson’s disease.*

	Sentence-Response Latency (seconds)	Standard Error
Concurrent Speech + Cognitive	0.57	0.106
Concurrent Speech + Linguistic	1.33	0.212

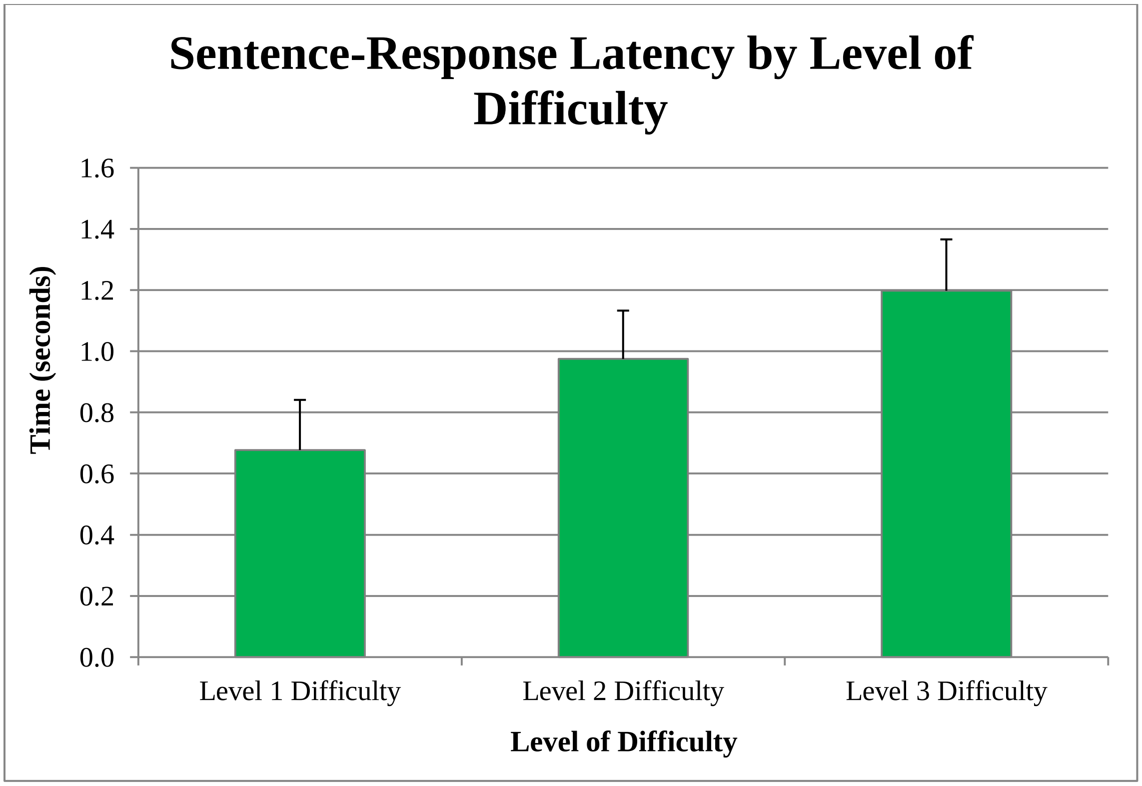

Figure 44. Sentence-response latency time by level of difficulty for the controls and participants with Parkinson's disease.

Table 46. *Mean sentence-response latency and standard error by level of difficulty for the controls and participants with Parkinson's disease.*

	Sentence-Response Latency (seconds)	Standard Error
Level 1 Difficulty	0.6770	0.1640
Level 2 Difficulty	0.975	0.158
Level 3 Difficulty	1.198	0.168

Interactions: The group by task type interaction was significant [$F(1, 66) = 18.544$, $p = 0.002$]. This interaction is depicted in Figure 45 with associated means and standard error scores presented in Table 47. This interaction describes the difference in sentence-response latency per task type for each group. Sentence-response latency for the control group is greater for the linguistic task than for the cognitive task, a pattern that is also observed in the subjects with Parkinson's disease, however, for the experimental group, the difference in sentence-response latency for the two tasks is much greater. The task type by difficulty level interaction was significant [$F(2, 64) = 5.671$, $p = .005$] and is presented in Figure 46 with associated means and standard error scores presented in Table 48. This interaction shows that for the concurrent speech + cognitive task, sentence-response latency increased as task difficulty increased, whereas for the concurrent speech + linguistic task, sentence-response latency increased from the first to second level of difficulty, and then decreased for the third level of difficulty. The following interactions did not reach significance: group by difficulty level, and group by task type by difficulty level.

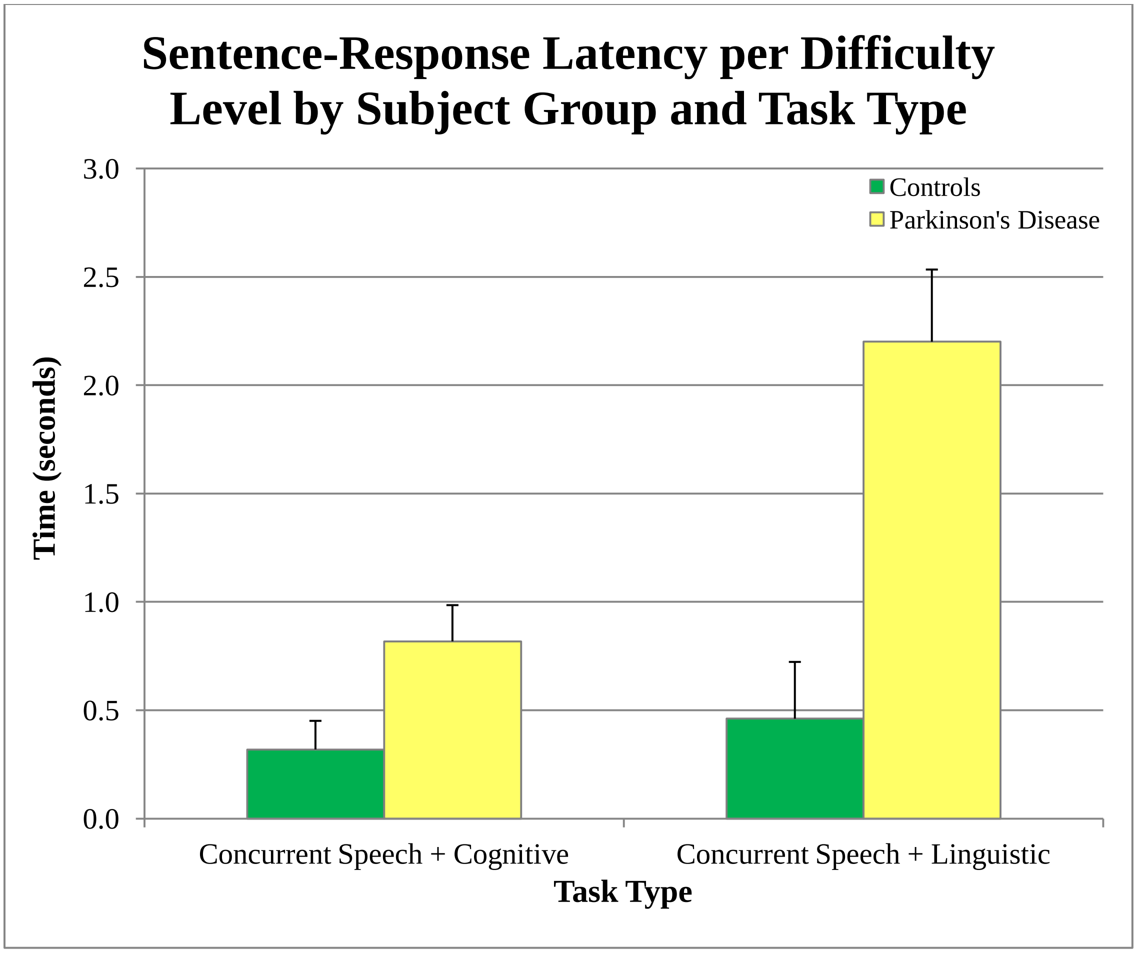

Figure 45. Sentence-response latency time by subject group and task type for the controls and participants with Parkinson's disease.

Table 47. *Mean sentence-response latency and standard error by subject group and task type for the controls and participants with Parkinson's disease.*

		Sentence-Response Latency (seconds)	Standard Error
Controls	Concurrent Speech + Cognitive	0.319	0.132
	Concurrent Speech + Linguistic	0.461	0.262
Parkinson's Disease	Concurrent Speech + Cognitive	0.818	0.167
	Concurrent Speech + Linguistic	2.201	0.333

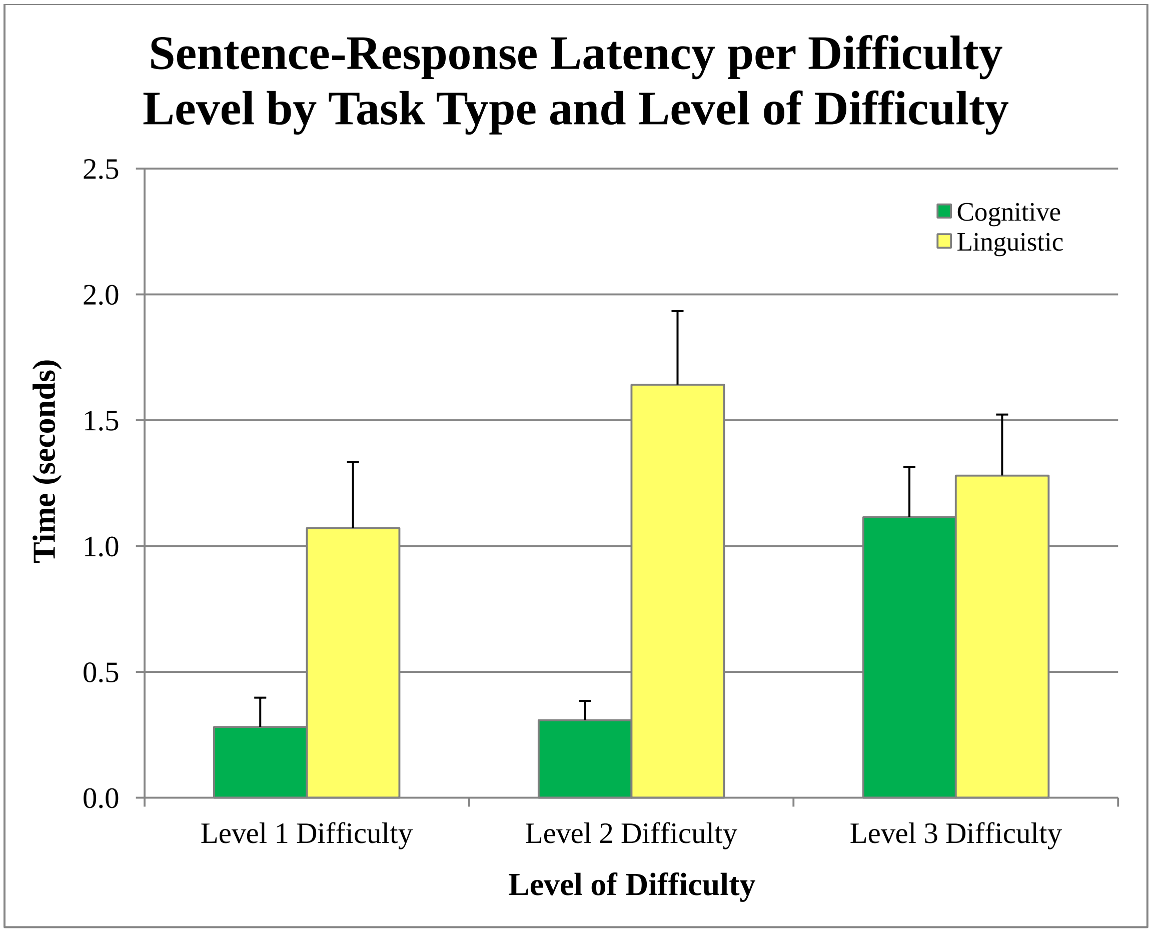

Figure 46. Sentence-response latency time by task type and level of difficulty for the controls and participants with Parkinson's disease.

Table 48. *Mean sentence-response latency and standard error by task type and level of difficulty for the controls and participants with Parkinson's disease.*

		Sentence-Response Latency (seconds)	Standard Error
Concurrent Speech + Cognitive	Level 1 Difficulty	0.282	0.116
	Level 2 Difficulty	0.309	0.076
	Level 3 Difficulty	1.115	0.199
Concurrent Speech + Linguistic	Level 1 Difficulty	1.072	0.262
	Level 2 Difficulty	1.642	0.292
	Level 3 Difficulty	1.281	0.242

Chapter 4

4 Discussion

The main goal of this study was to determine the effect of various concurrent tasks on speech intensity in individuals with hypophonia and idiopathic Parkinson's disease. To assess the potential concurrent task effects, each participant performed four tasks in isolation (speech, cognitive, linguistic and motor), and three tasks concurrently with a speech task. Data was collected for speech intensity, task performance, and speech durations in order to obtain a detailed evaluation of the relationship between concurrent task performance and speech intensity in individuals with Parkinson's disease and controls.

Several hypotheses were examined in relation to the effect of performing different types of concurrent tasks on speech intensity and task performance. It was predicted that both Parkinson's disease and control participants would experience an increase in speech intensity when performing the cognitive, linguistic or motor task concurrent with the speech task. This prediction was based on the energizing hypothesis. This hypothesis suggests that there is an energizing effect on speech intensity when speech is performed concurrently with other tasks. In addition, it was hypothesized that the individuals with Parkinson's disease would show a relatively greater energizing effect than controls and that this would be reflected in a relatively greater increase in concurrent speech intensity. As well, it was predicted that increases in the difficulty of the concurrent task would be associated with increases in the energizing effect and corresponding increases in speech intensity. With respect to the concurrent task performance, it was hypothesized that there would be an energizing effect on task performance and that task performance scores would improve when a task was performed as a concurrent task compared to when a task was performed in isolation. This hypothesis was also based on the energizing effect, and the notion that performing two tasks concurrently will cause an increase in effort, which in turn will improve performance on both tasks. A final prediction was that there would be differences in concurrent task performance across the three different task types (cognitive, linguistic, and motor). These task type differences were expected to follow the predictions of the functional distance hypothesis. Because the cognitive and linguistic tasks are believed to have a greater overlap of activated processes with the processes involved in the speech task, these tasks were predicted to have greater interference, and subsequently less improvement when performed concurrently as compared to the motor task. This is because the visuospatial and manual motor processes that are used for the motor task are thought to be more distant from the auditory motor processes that are used in the speech task.

The results of the study will be discussed in the following three sections: intensity, performance, and durational measures. Each measured variable and the significance of the results will be discussed, followed by an interpretation of the result in terms of hypotheses about the relationship between concurrent task performance and speech intensity. In addition, strengths and limitations of the current study, directions for future research and potential clinical implications will be presented. The final section will consist of the summary and conclusion of this study.

4.1 Intensity

The average intensity of the carrier phrase, target word and overall utterance was found to be lower in the participants with Parkinson's disease than the controls. A 2.5 – 3 decibel difference between the Parkinson and control participants was found for each of these speech segments. This result is consistent with previous research involving individuals with hypophonia due to Parkinson's disease (Adams & Dykstra, 2009; Fox & Ramig, 1997). As a lower average intensity was found in carrier phrase, target word and overall utterance, this result provides confirmation of hypophonia or reduced speech intensity in the participants with Parkinson's disease that were examined in this study.

In contrast to the group differences, the results related to the effect of a concurrent task on speech intensity were not consistent with previous studies of Parkinson's disease (Adams et al., 2010). The present study found that the speech intensity of the carrier phrase, target word and overall utterance was lower during each of the concurrent speech + linguistic, speech + cognitive and speech + motor tasks than it was during the isolated speech task. This result is not consistent with a previous study by Adams et al. (2010)

that found an increase in speech intensity during a concurrent visuomotor tracking task in participants with Parkinson's disease. In addition, the present results are not consistent with the Dromey and Bates (2005) study, and the Dromey and Shim (2008) study that found an increase in speech intensity during a concurrent tracking task in young healthy participants. Thus, the present results do not appear to provide support for an energizing effect of concurrent tasks on any of the measures of speech. On the other hand, the present results appear to be consistent with a study by Ho et al. (2002) that found a reduction of speech intensity with the introduction of a concurrent manual task. These authors suggested that the effect of a concurrent task on speech intensity was related to the sharing and distribution of attentional resources across the concurrent tasks. For the allocation of attentional resources theory, it was suggested that the introduction of a concurrent task caused some attentional resources to be taken away from the original isolated speech task and that this reduction in resources had the effect of lowering speech intensity, particularly in individuals with hypophonia due to Parkinson's disease. The inconsistent results across these studies may be related to the participant characteristics and task designs. In the studies by Dromey and Bates (2005) and Dromey and Shim (2008), speech intensity data was collected from young healthy adults. The group difference in age could account for the contrasting results. Younger adults may be able to better manage the demands of two concurrent tasks, yielding higher average intensities for the speech tasks. The energizing effect observed in Adams et al. (2010) may be attributed to the nature of the speech task. The Adams et al. (2010) study used a conversational speech task while the current study used a sentence (carrier phrase and target word) repetition speech task. The greater cognitive demands involved in conversation relative to sentence repetition may have caused the increase in speech intensity levels for the individuals with Parkinson's disease in the previous Adams et al. (2010) study. Interestingly, the controls did not experience a rise in speech intensity during conversation. The authors suggested that the lack of energizing effect in the control participants may have been related to the difficulty level of the concurrent manual task. The control participants may have found the concurrent manual tracking task only mildly challenging while the participants with Parkinson's disease may have been challenged to a much greater degree. Future research should consider using tasks that simulate everyday activities for an accurate description of how concurrent task performance affects speech intensity. In addition, future studies should compare the effects of different types of speech tasks to determine if the previously observed energizing effect on speech intensity in Parkinson's disease is limited to conversational speech tasks.

The present study found several interesting results related to the effect of the type of concurrent task (cognitive, linguistic, or motor) on the speech intensity of the carrier phrase, target word and overall utterance. As previously discussed, the isolation speech task was associated with the highest speech intensity when compared to the three concurrent tasks. In addition, significant differences were found for the comparisons involving the three concurrent tasks. The pattern for these task type differences was fairly similar across the carrier phrase, target word and overall utterance measures of speech intensity. Two general results were found. First, the concurrent speech + cognitive task and the concurrent speech + linguistic task were associated with significantly higher speech intensity than the concurrent speech + motor task. Second, the concurrent speech + cognitive task and concurrent speech + linguistic task showed fairly equivalent levels of speech intensity with some minor differences across the carrier phrase, target word, and overall utterance measures of speech intensity. With regard to the first general finding, this finding could be explained by cognitive overload on the motor processes. The concurrent speech + motor task may have a lower carrier phrase intensity than the concurrent speech + cognitive task and concurrent speech + linguistic task, because the concurrent speech + motor task utilizes similar motor processes as those used in speech production, causing greater interference when performing the speech task and the visuomotor tracking task simultaneously. Monitoring speech intensity is primarily a function of motor speech production and regulated within the motor cortex (Simonyan & Horwitz, 2011). The visuomotor tracking task requires the same processes for task completion. Previous research conducted by Dittrich and Stahl (2011) has found that performing similar tasks can cause a cognitive overload, distracting from the task at hand as the individual tries to cope with the demands of two tasks. Chong, Mills, Dailey, Lane, Smith and Lee (2010) suggest that this may be a result of a greater competition for similar visuo-spatial processes. Thus, when the tasks are performed concurrently, it “overloads” the motor processes causing interference in performance for the tasks. This would explain the greatest decrease in speech intensity occurring during the concurrent speech + motor task. Following this, the concurrent speech + cognitive task and the concurrent speech + linguistic task did not experience as large of a drop in intensity as the cognitive processes utilized in the performance of these tasks are more distantly related from the motor speech production processes in the motor cortex which allows the individual to maintain a higher intensity during concurrent task performance.

The present study found some inconsistent results related to the effect of task difficulty level on speech intensity. The results for the analysis of the carrier phrase and target word intensity did not show a significant difference in speech intensity across the three levels of task difficulty. On the other hand, the results for the overall utterance intensity did show a significant effect of task difficulty on speech intensity. In particular, the highest overall utterance intensity was produced during the first level of difficulty, followed by the third level of difficulty, and the lowest average overall utterance intensity produced during the second level of difficulty. Although no direct conclusions can be drawn as to why this relationship between difficulty level and overall utterance intensity exists, it is proposed that it may be related to changes in the utterance duration. As shown in the results section (see Figure 27, section 3.3.1.3), overall utterance duration increased as difficulty level increased. The measurement of overall utterance intensity is based on an average intensity that is calculated across the overall utterance and therefore includes intensity values during hesitations or pauses. Because the intensity values during these pauses are very low, they have the effect of lowering the average overall utterance intensity. If a participant pauses after the carrier phrase in order to continue processing the cognitive or linguistic stimuli, an intensity reading of 0 dB will be incorporated into the average intensity calculation, causing a lowering of the overall utterance intensity. If the pause is short enough, of less than 250 ms, it is typically considered a result of speaking style or grammaticality (Holmes, 1988; Nishio & Niimi, 2001; O’Connell & Kowal, 2005; Skodda, 2011). In this study, a pause after the carrier phrase is called the sentence-response latency. The duration of this pause, if over 250 ms, may actually cause the participant to produce the target word intensity as if it were a separate phrase in itself, therefore increasing its target word intensity. Thus, it is proposed that the sentence-response latency was small enough for the first and second difficulty levels for the overall utterance to be spoken as one phrase, but may have been long enough in duration to initiate this phenomenon, resulting in a target word intensity greater than was reported in the first two difficulty levels, increasing the average overall utterance intensity. Although intensity levels for target word did not significantly differ by difficulty level, the same trend can be observed; target word intensity decreased from the first to second level of difficulty, and then increased from the second to third level of difficulty.

A final intensity result that deserves consideration is the significant interaction between participant group and task type. This was only observed for the overall utterance duration but may reflect an important difference in how the type of concurrent task affected the Parkinson's disease and control participants. The control participants had the highest overall utterance intensity for the concurrent speech + linguistic task, followed by a slightly lower intensity for the concurrent speech + cognitive task, and finally the lowest intensity for the concurrent speech + motor task. The participants with Parkinson's disease showed a different pattern that included the highest intensity for the concurrent speech + cognitive task, followed by the concurrent speech + motor task and, finally, the concurrent speech + linguistic task. This difference in pattern may be a result of the need for extra processing time during the concurrent linguistic task in the Parkinson participants. A study conducted by Crescentini, Mondolo, Biasutti, and Shallice (2008) described the impaired performance on verb generation tasks by individuals with Parkinson's disease as compared to healthy older adults. Along with fewer accurate responses to the noun stimuli, the participants with Parkinson's disease were found to take longer to respond than the control subjects. Péran, Rascol, Démonet, Celsis, Nespoulous, Dubois and Cardebat (2003) found verb generation to be impaired in individuals with Parkinson's disease, even when time pressures were removed from the situation. These authors presented their results as a verb-learning deficit caused by impairment in the frontal region functions. This verb generation impairment in Parkinson's disease could be responsible for a greater sentence-response latency which in turn would lower the average overall utterance intensity for the concurrent speech + linguistic task.

4.2 Task Performance

Task performance was scored for the three secondary tasks; mathematical addition (cognitive), verb generation (linguistic), and visuomotor tracking (motor). The results from these tasks will be discussed in two sections. Because the motor task (average tracking error) used a different scoring scale than the cognitive and linguistic tasks (score out of 15), the results could not be compared across these three tasks. The first section will compare and interpret the results of the cognitive and linguistic tasks, and the second section will discuss the results of the motor task.

4.2.1 Cognitive and Linguistic Task Performance

Performance scores for the cognitive and linguistic tasks were scored out of 15, with 0 being the lowest score possible, and a score of 15 being the highest score obtainable. Performance scores for these two tasks were collected and compared across groups, task condition, task type and difficulty level.

The cognitive and linguistic task performance was associated with a significant difference between the participant groups. The control participants had significantly higher cognitive and linguistic performance scores than the participants with Parkinson's disease. The difference in task performance between these groups could be attributed to cognitive decline in executive functioning for those with Parkinson's disease. Individuals with Parkinson's disease have displayed working memory impairments and language problems (Bastiaanse & Leenders, 2009; Pagonabarraga & Kuliesevsky, 2012). Deficits in these areas would inhibit an individual's ability to manipulate the presented stimuli to accurately answer the question (Theodoros & Ramig, 2011), which could explain the difference in scores between the control group and the participants with Parkinson's disease. In this study, scores for the cognitive task were comparable between both groups, with each group scoring 4.80 (control) and 4.78 (Parkinson's disease) out of 5 for each difficulty level. A greater difference in task score was observed for the linguistic task, with the controls scoring 4.08 out of a possible 5, and the participants with Parkinson's disease scoring 2.62 out of 5. Greater impairment was found for the linguistic task, a result that has been observed in previous studies. Bastiaanse and

Leenders (2009), Crescentini et al. (2008) and Péran et al. (2003) found significant differences in verb production between healthy older adults and individuals with Parkinson's disease. The poor performance given by the Parkinson's disease participants was explained through deficits in non-linguistic cognitive functions, namely verbal working memory.

Interestingly, task condition was not found to be significant for task performance for the cognitive and linguistic tasks. It could be suggested, from this data set, that performance was not enhanced or degraded by concurrent task performance but that instead, the participants in both groups were able to meet the demands on concurrent task performance and performed equally as well under these conditions. This result was surprising given that previous research by McKinlay, Grace, Dalrymple-Alford and Roger (2010) and Pagonabarraga & Kuliesevsky (2012) found that individuals with Parkinson's disease often struggle to perform tasks concurrently. A trade-off theory of cognitive resources across tasks may be responsible for the result found in this study. Participants may have tried to focus more efforts on maximizing their performance on the secondary task, drawing attentional resources away from the speech task. This trade-off of cognitive resources had been previously observed by Holmes, Jenkins, Johnson, Adams and Spaulding (2010) in their study of postural stability and speech for those with Parkinson's disease. In this study, individuals with Parkinson's disease were found to over-constrain their posture prior to performing the speech task and postural task concurrently. By doing this, it is proposed that an individual would be able to allocate more attention and effort to performing the second task. However, this "posture-first" principle diminished the individual's ability to adapt and maintain stability as the tasks progressed. Similar results were found by Li, Abbud, Fraser and DeMont (2012) in a study assessing the effect of a concurrent cognitive task on gait. The participants were able to maintain their performance on a secondary task by prioritizing performance for the cognitive task over gait. The cognitive task did not experience any dual-task costs, however, stride length and duration increased to compensate. This same principle of task prioritization may have been at work in this study, as individuals focused more attention on trying to complete the cognitive and linguistic task, and in turn, reduced their ability to regulate their speech production.

Scores for both groups were found to be significantly higher for the cognitive task than for the linguistic task. It can be interpreted that both the healthy older adults and the participants with Parkinson's disease found the linguistic task to be more challenging than the cognitive task. Dromey and Benson (2003) found a similar result. In looking at lip kinematics, Dromey and Benson (2003) discovered that greater kinematic errors were made, as well as an increase in the spatiotemporal index, suggesting that the verb generation linguistic task affected the speech production process more than the cognitive or motor task. Dromey and Bates (2005) also found higher scores for their cognitive task (two-digit math subtraction problems) in both the isolation and concurrent speech conditions, than the linguistic task (sentence generation) in either condition. These results indicate that participants may find the linguistic task more difficult than the cognitive task due to overlapping processes with speech production (Dromey & Benson, 2003).

Performance for both groups decreased within each difficulty level as the task increased in difficulty. This result is contrary to the hypothesis based on the energizing effect. Increasing the difficulty for the task did not result in improved performance based on the energizing effect theory, but instead showed a decrease in performance. Fraser, Li and Penhune (2010) found that task performance for a semantic judgment task decreased as difficulty level increased in both young adults and healthy older adults. This decrease in performance could be attributed to the increased cognitive demands placed on the individual and his/her inability to meet the demands of the task as required. As the task difficulty increased, more cognitive resources were required for accurate performance. In using a limited capacity system, such as the episodic buffer in working memory, the system may become overloaded by the increase in cognitive effort, resulting in an increase in performance errors (Baddeley, 2000). The increase in task demands as difficulty level increased may have challenged the participants' working memory capacity, which in turn presented itself as a difficulty level effect.

The control participants and participants with Parkinson's disease performed similarly on the cognitive task, however, the individuals with Parkinson's disease performed significantly poorer on the linguistic task. Conclusions about task difficulty can be derived from this result. Both groups performed similarly for the cognitive task. From this, it is suggested that the processes required for mathematical addition may be less affected in Parkinson's disease than the verb-related language processes required for the linguistic task. Verb production deficits have been found to be associated with Parkinson's disease (Bastiaanse & Leenders, 2009; Crescentini et al., 2008). This could account for the degraded performance by the group with Parkinson's disease for the linguistic task when compared to the healthy controls.

It should be noted that the healthy controls also had lower performance on the linguistic task relative to the cognitive task and there was a significant task type by difficulty level interaction. This interaction was related to the finding that both groups performed significantly worse on the linguistic task as the difficulty level of the task increased, whereas performance remained fairly stable for the cognitive task as difficulty increased. Evidence from this analysis suggests that the participants in both groups found the linguistic task more difficult than the cognitive task.

4.2.2 Motor Task Performance

Motor task performance was assessed through the participants' average tracking error. The closer the average tracking error was to 0, the more accurately the participants were tracking the moving horizontal target.

The control participants were observed to perform significantly better on the visuomotor tracking task than the participants with Parkinson's disease. This result contrasts with prior research conducted by Ho et al. (2002), which found that the participants with Parkinson's disease were able to perform the visuomotor tracking task with a performance error that was equivalent to healthy older adults. The findings of this study, however, are similar to those found in Adams et al. (2010). In the previous study, participants were required to perform the manual tracking task concurrent with a conversational speech task. Performance for the tracking task was more accurate for the healthy older adults than individuals with Parkinson's disease. These authors explain this result by stating that the tracking task may have been more challenging for the participants with Parkinson's disease than the healthy controls. This may be a residual effect of the motor control impairments associated with Parkinson's disease, including fine motor control **(**Bronnick, 2010; Zesiewicz et al., 2006**)**, which could have inhibited their ability to manipulate the hand pressure bulb and accurately track the oscillating horizontal target.

Task condition was not found to be significant, and may be a result of more attention and cognitive resources being allocated to the motor task during concurrent task performance in order to maximize manual motor performance. As participants were not encouraged to focus on one task more than the other, this decision was left up to their discretion and momentary intentions. This result is similar to that found in the cognitive and linguistic tasks, in which task performance was not greatly affected by a concurrent speech task (refer to 4.2.1). The lack of concurrent task effect on motor task performance could be a result of "manual motor task first" prioritization by the participant. This decision would allow the individual to focus more resources on performing the motor task, maximizing their performance even in the concurrent task conditions (Holmes et al., 2010; Li, et al., 2012). Dromey and Shim (2008) also found that manual motor task performance was not affected when performed concurrent with a speech task. In Dromey and Shim's study (2008), participants were asked to use their hands to place metal pegs and washers on a pegboard in their proper holes. No significant difference in performance was found when this manual task was performed in isolation or concurrent with the speech task. A trade-off in cognitive load or motor resources may have been observed as participants chose to place more priority on maximizing their performance on the manual motor task than the speech (motor) task, allowing them to perform just as well in the concurrent speech + motor task condition as in the isolated manual motor task condition.

Performance for the motor tracking task was found to decrease as the difficulty level of the task increased. This reflects a need for increased cognitive or motor demands to maximize performance that was not met by the allocated cognitive or motor resources provided by each participant. The decrease in performance as difficulty level increased suggests that the motor system was unable to handle a more complex and demanding motor task at the same level of performance. The demands imposed upon the motor system as the participant tries to manipulate the pressure bulb and track an oscillating target at increasing speeds may be too great, causing a decline in performance as the task becomes more difficulty. A significant interaction was found for the group by task condition by difficulty interaction. The control participants' performance in the isolation task decreased as the task became more difficult. For the concurrent task condition, the control participants' performance improved from the first to second level of difficulty and then decreased in accuracy from the second to third level of difficulty. The motor task performance for the participants with Parkinson's disease decreased as difficulty level increased in both the isolation and concurrent task conditions. The relationship between group, task condition and difficulty level requires further investigation as there is evidence that control participants and participants with Parkinson's disease perform and regulate performance on these tasks differently.

4.3 Durational Measures

4.3.1 Overall Utterance Duration

Rapid speech and short rushes of speech are symptoms that can be present in about 15-50% of individuals with hypokinetic dysarthria due to Parkinson's disease (Adams & Dykstra, 2009). This speech characteristic would imply that the average utterance duration spoken by an individual with Parkinson's disease could be shorter than that of the control subjects. However, this result was not found, and instead, the controls recorded a shorter utterance duration on average as compared to the participants with Parkinson's disease. This result can be attributed to the longer sentence-response latencies reported for the individuals with Parkinson's disease; a pause or hesitation to provide more time for cognitive processing. To determine whether or not the subjects with Parkinson's disease were speaking faster, data was collected for carrier phrase duration (refer to Figure 31 and section 3.3.2.2). Performing the motor task concurrently with the speech task increased utterance duration. This finding appears to provide support for the allocation theory of attention (Kahneman, 1973). In the isolation task, participants were asked to solely read the sentence aloud 15 times, giving full attention to the one task at hand. For the concurrent speech + motor task, the participant had to divide their attention between reading the sentence aloud and performing a manual, visual motor tracking task. Because their cognitive resources are now divided amongst competing tasks, speech rate decreased, with a corresponding increase in utterance duration. Utterance duration also varied by task type, with the concurrent speech + linguistic task presenting the longest utterance duration, followed by concurrent speech + cognitive task and finally the concurrent speech + motor task had the shortest duration. Utterance duration, as previously mentioned, includes sentence-response latency within its span. In the case of the concurrent speech + linguistic task and the concurrent speech + cognitive task, an increase of sentence-response latency would increase the utterance duration. The carrier phrase and target word were provided for the isolation speech task and the concurrent speech + motor tasks, therefore the sentence-response latencies were at a minimum. As difficulty level increased, utterance duration increased. This result can be attributed to the increase in cognitive processing needed for the more difficult levels of the task. The increase in cognitive processing would often cause an increase in sentence-response latency for the utterance. This, in turn, increases the overall utterance duration. A significant interaction was found for the relationship between group and task type. Both groups reported the shortest average utterance duration for the concurrent speech + motor task. Implications for this may lie within the repetitive nature of this task, in that the participant was asked to repeat the carrier phrase and target word 15 times, five times at each of the concurrent tracking speeds. The action of repeating this phrase becomes automatic, and may require progressively less attentional resources as the task continues and also may require less attentional resources than a novel task. When the task becomes more automatic, as may have occurred in this study from numerous repetitions of the same sentence, speech can become accelerated. The effect of accelerated speech has been studied in both healthy older adults and individuals with Parkinson's disease, and a similar trend of acceleration was observed in both, although the subjects with Parkinson's disease did show an increase of acceleration across the task (Nishio & Nimi, 2001; Skodda & Schlegel, 2008; Skodda, 2011). For the control participants, they reported non-significant and almost equal average utterance durations for the concurrent speech + cognitive and concurrent speech + linguistic task, with only a 0.02 second difference, a result also found by Dromey and Bates (2005).

Carrier phrase duration was reported as shorter in length for the individuals with Parkinson's disease than the control subjects (see Figure 31, section 3.3.2.2). In addition, carrier phrase duration remained fairly equal across the four tasks (speech, cognitive, linguistic and motor). This finding suggests that the control participants did not find one task more challenging than the other, and therefore did not require more time for cognitive processing, or experience greater interference due to the demands of the task difficulty. In contrast, the participants with Parkinson's disease produced a significantly longer utterance duration for the concurrent speech + linguistic task than the concurrent speech + cognitive task. Although carrier phrase duration was comparable between these two tasks (please refer to section 4.3.2), sentence-response latency was much greater for the concurrent speech + linguistic task (please refer to section 4.3.5). This difference, indicating a need for more cognitive processing time, implies that the individuals with Parkinson's disease found the concurrent speech + linguistic task more challenging than the concurrent speech + cognitive task. Utterance duration varied across difficulty levels for each task type. For the concurrent speech + cognitive task, utterance duration increased as the difficulty of the task increased. The implication of this finding is that the participants required more time for cognitive processing, increasing the sentence-response latency as the difficulty increased. Therefore, there was interference by the concurrent task demands inhibiting the participant's speech production and cognitive processing. In contrast, utterance duration decreased as task difficulty increased for the concurrent speech + motor task. This phenomenon may be accounted for by the acceleration of speech experienced by participants as they read throughout a task (Nishio & Nimi, 2001; Skodda & Schlegel, 2008; Skodda, 2011), a result also found in Dromey and Bates (2005). As the speech task progressed, it became more automatic and the participant began to recite the phrase faster, shortening the utterance duration. Another possible explanation for the shorter utterance duration reported for the concurrent speech + motor task may relate to some type of motor cross-over effect in the speech and manual motor movements. For example, research conducted by Cummins (2009) and Inui (2007) proposes an entrainment relationship between speech production and hand movements. Speech production has been found to entrain hand movement by influencing the amplitude of finger movements. Although previous research by Smith, McFarland and

Weber (1986) has indicated that muscle movement does not entrain speech, the results of the present study provide evidence for a possible entrainment relationship between manual movement speed and speech rate. The increased speed of the oscillating target as the difficulty of the task progressed required an increase in the speed of squeezing and releasing the handheld pressure bulb. This increase in manipulation of the bulb may have entrained the speed of speech production for the carrier phrase and target word, increasing rate of speech and shortening utterance duration. The difference in results provided by this study and Smith and colleagues' work (1986) might be attributed to the type of motor task used. In the current study, a visuomotor tracking task was used, whereas Smith et al. (1986) used a finger-tapping task. For the concurrent speech + linguistic task, utterance duration increased from the first to second level of difficulty, and then decreased from the second to third level of difficulty. The increase in utterance duration from the first to second level of difficulty can be attributed to greater task demands necessitating more cognitive processing with the limited cognitive resources available, increasing the sentence-response latency during the second level of difficulty. However, this was not replicated for the third level of difficulty, as would be assumed. Instead, utterance duration and sentence-response latency decreased. A proposed explanation for this takes into account subject responses. In many cases, if participants were unsure of an answer for the concurrent speech + linguistic task, they would ask to skip the question and continue to the next one. This occurred most often during the third level of difficulty. If a question was skipped, it was removed from the data set. Therefore, the results for the third level of difficulty for this task may be biased towards answers to items for which the participants were confident to answer.

4.3.2 Carrier Phrase Duration

Carrier phrase duration was collected as a means of determining the effect of concurrent tasks on cognitive processing and its relationship to speech production. Task condition affected carrier phrase duration; carrier phrase duration was shorter when spoken during the concurrent speech + motor task as compared to when spoken during the isolation speech task. This may be the result of increased cognitive demands that were introduced by the secondary motor task. Participants could have tried to accelerate their speech in an effort to spend more time focusing on the visuomotor task; thus trying to minimize dividing their attentional resources and instead be able to sequentially process the two tasks (Nishio & Nimi, 2001; Skodda, 2011; Skodda & Schlegel, 2008). Shorter carrier phrase duration for the individuals with Parkinson's disease is consistent with the rapid speech characteristics of hypokinetic dysarthria (Adams & Dykstra, 2009). However, this result may also be attributed to the individual shortening the duration of speech, and consequently the duration of concurrent performance, in order to increase the time they can spend sequentially processing the secondary task demands. Carrier phrase duration varied per task type based on the effect of cognitive load on concurrent task performance. In order of increasing carrier phrase duration, the tasks are as follows: concurrent speech + motor task, concurrent speech + cognitive task, isolation speech task, and concurrent speech + linguistic task. The concurrent speech + motor task, as mentioned earlier, may have produced the shortest carrier phrase duration as participants attempted to minimize the duration of time in which cognitive resources had to be divided to perform both tasks optimally. The carrier phrase duration for the isolation speech task was not found to be significantly different from that of either the concurrent speech + cognitive task or the concurrent speech + linguistic, as determined by Bonferroni post hoc comparisons, indicating that participants were most likely not dividing attentional resources to perform two tasks concurrently during the repetition of the carrier phrase, but instead choosing to perform the tasks sequentially. Carrier phrase duration produced an interesting pattern in relation to difficulty level. Overall, it can be observed that there was a tendency for carrier phrase duration to increase as difficulty level increased from the first to third difficulty level. This pattern is complex because this trend was not present for all of the task types. This trend is further revealed by the significant task type by difficulty level interaction. A significant relationship exists between task type and difficulty level for carrier phrase duration; carrier phrase duration varied for each task type at the various difficulty levels. For the concurrent speech + cognitive task, carrier phrase duration increased as the difficulty of the task increased. The implication of this finding is that interference increases as the demands of the concurrent task increases, inhibiting an individual's speech production and concurrent cognitive processing, lengthening the duration of the carrier phrase. The concurrent speech + motor task presented a different trend, in that carrier phrase duration decreased as task difficulty increased. As mentioned previously, this trend may be explained by an automaticity of the speech task causing an acceleration of speech (Skodda, 2011; Skodda & Schlegel, 2008) or speech-motor entrainment (Cummins, 2009; Inui, 2007). For the concurrent speech + linguistic task, carrier phrase duration decreased from the first to the second level of difficulty, and then increased from the second to third level of difficulty. It is not clear why this trend emerged for carrier phrase duration for the concurrent speech + linguistic task. This raises questions as to whether or not the noun stimuli used accurately reflected the difficulty levels for the population in this study. The noun stimuli were chosen based on the data collected from the pilot study, which had been completed by young adults, whereas it was used in the current study with older adults. The different populations may respond to the noun stimuli in varying ways; a strong association-low selection noun for the young adults may fall under another classification for the older adults. Future studies should consider examining the relationship between age and noun-verb associations, as well as using noun stimuli that have been piloted and classified by the responses given by an older population.

4.3.3 Response Time

Response time, the time elapsed between the presentation of the stimuli and the speech onset of the participant's response, was collected for the isolation cognitive and isolation linguistic tasks. It was found that the individuals with Parkinson's disease took longer to respond to the presented question than the control subjects. The increase in response time for those with Parkinson's disease could be a result of different factors. First, the participants with Parkinson's disease may find the tasks more difficult than the healthy older adults, as is suggested by the increased response time; they required more time to determine an appropriate response for the question. Second, difficulty in initiating speech is a motor speech issue associated with Parkinson's disease (Walsh & Smith, 2011). This difficulty may have resulted in the increase in response time for the individuals with Parkinson's disease as they were unable to begin the speech process as soon as they determined an appropriate answer for response, but instead were delayed as they were unable to engage the correct processes for speech. In addition, significance was found for the relationship between task type and response time; response times were shorter for the cognitive task than the linguistic task. This result suggests that the participants in both groups found it easier to calculate an answer for the cognitive task than generating an appropriate verb response for the noun stimuli. In turn, this could indicate that the subjects found the linguistic task, in general, more difficult than the cognitive task. A significant increase in response time was also observed for each difficulty level; as the task became more difficult, participants took longer to respond as they found the questions more challenging. Two significant interactions, with respect to response time, were found; group by task type, and group by difficulty level. For these interactions, it was observed that both groups followed the same trend, in that the linguistic task was associated with longer response times than the cognitive task, and that the response time increased as difficulty level increased. The most notable aspect of these two interactions, however, was that the group with Parkinson's disease, in both interactions, experienced a greater effect on response time. The individuals with Parkinson's disease had a much longer response time for the linguistic task as compared to the cognitive task, and there was a much greater increase in response time as the difficulty levels increased as compared to the controls. This result indicates that the participants with Parkinson's disease may have found the tasks more challenging. This is suggested by the finding that not only did they take longer to respond, but the change in difficulty level also exacerbated the change in response time.

4.3.4 Response Latency.

Response latency, the time elapsed between the presentation of the stimuli and the speech onset of the carrier phrase, was collected for the concurrent speech + cognitive task, concurrent speech + linguistic task, and concurrent speech + motor task. A significant group difference was found for the response latencies obtained during the three concurrent tasks. Individuals with Parkinson's disease reported a longer response latency, of approximately 1.49 seconds, than the control participants (0.57 seconds). This longer response latency for the Parkinson participants could be attributed to a movement initiation difficulty related to the basic motor deficits associated with Parkinson's disease. Previous research has suggested that movement initiation deficits in Parkinson's disease may result from impaired integration of sensory information in the basal ganglia. This causes abnormal programming and planning for movement, observed as initiation difficulties in Parkinson's disease (Connor & Abbs, 1991; Montgomery, Baker, Lyons & Koller, 2000; Pendt, Reuter, & Müller, 2011; Platz, Brown & Marsden, 1998; Rosin, Topka & Dichgans, 1997; Walsh & Smith, 2011).

4.3.5 Sentence-Response Latency.

Sentence-response latency refers to the pause in speech that occurred after the speech offset of the carrier phrase and the speech onset of the target word. Sentence response latency was associated with significant effects for group, task type and difficulty level. For this variable, data was collected only from the concurrent speech + cognitive task and concurrent speech + linguistic task. With regard to the group differences, it was found that the control subjects had a shorter sentence-response latency, than the individuals with Parkinson's disease. This indicates that the individuals with Parkinson's disease required more processing time to provide their best approximation of the correct answer. Previous research has used 250 ms as the cut-off of a speech pause associated with speaking style, syntax, punctuation or emphasis (Nishio & Niimi, 2001; Hieke, Kowal, & O'Connell, 1983). In both tasks, the sentence-response latency recorded for the subjects with Parkinson's disease exceeded the accepted standard of speech-related pause and is instead classified as a delay for cognitive processing (Hieke et al., 1983; Holmes, 1988; O'Connell & Kowal, 2005). This pattern suggests that the Parkinson group found the tasks more difficult than the controls. Sentence-response latency also differed by task; responses were provided in much less time after the carrier phrase for the concurrent speech + cognitive task than the concurrent speech + linguistic task. Similar to the results reported for response time, the increased sentence-response latency for the concurrent speech + linguistic task appears to provide evidence that the participants found this task more challenging, and therefore required more processing time in order to provide an appropriate response. The sentence-response latency was also found to significantly increase as the difficulty level of the task increased. From these results, it appears that a challenging task will generate a greater duration for sentence-response latency. In addition, the length of the sentence-response latency will increase as the task becomes more difficult. A significant interaction was found for group by task type, indicating that although both groups experienced a longer sentence-response latency for the concurrent speech + linguistic task as compared to the concurrent speech + cognitive task, the individuals with Parkinson's disease experienced a much greater effect of the concurrent speech + linguistic task on the sentence-response latency than the controls. The sentence-response latency for individuals with Parkinson's disease was about 0.5 ms longer than the controls for the concurrent speech + cognitive task but this difference increased to 1.71 seconds for the concurrent speech + linguistic task. The results of this analysis suggests that the Parkinson participants found both tasks to be more difficult than the healthy subjects, and within that, found the concurrent speech + linguistic task to be harder than the concurrent speech + cognitive task. This may be related to the verb generation deficits that have been found to be associated with Parkinson's disease (Crescentini et al., 2008; Theordoros & Ramig, 2011). Significance was achieved for the task type by difficulty level interaction for sentence-response latency. For the concurrent speech + cognitive task, sentence-response latency for both groups increased as the difficulty level of the task increased. However, this pattern changed for the concurrent speech + linguistic task. For this task, sentence-response latency increased from the first level of difficulty to the second, however it then decreased from the second level of difficulty to the third. It is unclear as to why this pattern emerged for the concurrent speech + linguistic task, however, it could have occurred as a result of the conceptual complexity of the presented nouns. Both groups recorded the lowest scores for the third difficulty level. In these cases, participants who could not immediately generate a verb associated with the noun may have provided the first incorrect response they could produce as a means of bypassing the question and continuing on in hopes that they could answer the following question correctly. This method, or a response of "pass", had been observed during both the isolation linguistic and concurrent speech + linguistic tasks when participants struggled to find an answer. It was never observed during the cognitive task, either in isolation or concurrent, as the task is less abstract in nature and participants still attempted to provide their best approximation of the answer if they felt they could not complete the addition. This explanation could account for the short sentence-response latency occurring during the hardest difficulty level of the concurrent speech + linguistic task.

4.4 Strengths and Limitations

This study was designed to provide a more detailed understanding of how various concurrent tasks would affect speech intensity levels in individuals with Parkinson's disease. In doing so, novel tasks were created with varying levels of difficulty. The experimental design of the study is one of its strengths, as previous research had not taken into account how task novelty and task difficulty would affect concurrent task performance and instead utilized familiar tasks that were relatively easy to perform, such as counting (Ho et al., 2002). In using novel tasks, this study was able to examine how an individual's speech intensity may change as they adjust to the demands of the task at hand.

Although this study did reveal a substantial amount of new information about the relationship between concurrent task performance and speech intensity, there are certain methodological limitations that need to be considered. The main limitations of this study can be grouped into two categories; sample and participant characteristics, and task – related limitations.

4.4.1 Sample and Participant Characteristics

The first limitation of this study is related to sample size. Data were collected from twenty-two healthy older adults and thirteen individuals with idiopathic Parkinson's disease. Subtle differences between tasks may have been too small to be detected with the current sample size for the experimental group, which may explain why certain main effects and interactions did not reach significance. Another possible limitation related to participant characteristics is the participants' cognitive ability. Each participant with Parkinson's disease was given the MoCA. The control participants did not complete a cognitive screening tool such as the MoCA. This is a limitation of the study because some of the normal participants may have had an undetected mild cognitive impairment that influenced the results.

4.4.2 Task-Related

Additional limitations of the study may be related to the type of tasks that were used. First and foremost, it was difficult to design tasks that did not require the use of multiple modalities at once. For example, in the case of the cognitive task, the participant was required to solve the math question, and then verbally report it. This does require the engagement of various mental processes that would be likely to overlap with processes that would be used in the linguistic task and the motor task. The overlapping of activated processes across tasks prevents direct conclusions about which processes may be more inhibitory or affected during concurrent task performance. In addition to this, it cannot be explicitly stated as to whether the participants were performing the tasks concurrently or serially. The tasks were created in order to promote concurrent processing but it is not possible to be absolutely certain that concurrent processing of the tasks occurred. Due to the methodology of this study, the subjects' performance on the concurrent tasks could have been influenced by practice effects. No difference was found between the concurrent and non-concurrent (isolated) tasks. But the study design required the isolation task to always be performed before the corresponding concurrent task. Therefore, each time the isolation task was completed, the participant was learning how to perform the task, whereas when they performed the concurrent task, they already knew what to expect and how to complete the task.

An additional concern is that performance on the concurrent tasks could have been confounded by fatigue, as they were always performed second to the isolation tasks, therefore later in the testing session. Depending on the subject's performance, this could have ranged in time from 15 minutes into the session to an hour after the session began. Ideally, to solve these issues, practice trials for each task would have been performed, and then the isolation and concurrent task conditions counterbalanced across participants to eliminate the potential for practice and fatigue effects. Another limitation of this study relates to the creation of the verb generation task. The initial noun list used in the pilot study was taken from Del Missiers and Crescentini (2011) study of Italian noun-verb associations and was translated into English. The generated list of nouns was then given to 50 undergraduate students to complete. The association and selection strength for each noun-verb pair was based on the responses provided by the undergraduate students. It was assumed that the noun-verb association results obtained from this preliminary study of young individuals would predict the performance of the older participants but there may have been age-related factors that influenced the results related to the differences across difficulty levels in the linguistic (noun-verb generation) task. The verb generation task was developed via the preliminary study of younger adults primarily because of time constraints and the availability of young volunteers; however, for future studies involving older Parkinson participants, a verb generation task should be piloted and designed on a healthy older adult population.

A concern for the linguistic task and cognitive task is the possible effect of the syllable length of the target response on the intensity values. For example, as the difficulty level of math task increased the syllable length of the target responses by the participants also increased (i.e. the number six was an answer for the low difficulty level whereas twenty-three was an answer for a higher difficulty level).

4.5 Directions for Future Research

The current study provided a novel perspective as to how the performance of various secondary tasks can affect speech intensity for those with hypophonia and Parkinson's disease. Interesting results were obtained with regard to task conditions, type of tasks used, and difficulty levels. Further research in each of these task-related effects is required to build a more complete explanation of the relationship between multiple task performance and speech intensity. Future work using concurrent tasks that involve more typical activities of daily living and conversational speech tasks may help to provide a more ecologically valid examination of the effects of concurrent tasks on speech production.

This study focused on the cognitive aspect of resource allocation and the functional distance hypothesis to help further define this relationship. To provide a more complete profile, information on the physical correlates of this relationship could help better explain the decrease in speech intensity associated with concurrent task performance. As cognitive resources are re-allocated to allow for multiple task performance, determining how this would affect the motor speech production process, as described by lip and jaw kinematics, could help explain why a decrease in speech intensity occurs and why this is affected in such a varying degree dependent on the type of secondary task performed.

In addition, future research should continue to assess the effects of concurrent task performance on speech. Particular areas of interest include articulation, prosody and overall intelligibility. Articulatory issues have been found to be associated with Parkinson's disease; a possible result of a reduced amplitude of movement in the orofacial region (Duffy, 2005). This, in turn, may be responsible for slurred speech and imprecise consonant formation. In addition, speech effects on prosody, such as monopitch, increased rate, and speech rate abnormalities (short bursts of speech followed by inappropriate prolonged silent pauses) have also been attributed to hypokinetic dysarthria in Parkinson's disease (Adams & Dykstra, 2009). Both articulation and prosody play key roles in overall speech intelligibility. Future studies are required to determine the effects of concurrent tasks on these additional speech parameters. Continuing research in these areas would help define the relationship between concurrent task performance and speech.

4.6 Implications for Clinical Application

Several potential clinical implications can be drawn from the results of this study. As reported by a number of previous studies, and supported by the results of the present study, individuals with hypophonia related to Parkinson’s disease produce speech at a lower average intensity than healthy older adults (Adams & Dykstra, 2009; Fox and Ramig, 1997; Darley et al, 1975). The problem of low speech intensity, as evidenced in this study, became exacerbated when individuals with Parkinson’s disease were required to perform more than one task at a time. As many activities of daily living are often performed concurrently, such as walking and talking, the challenge of performing multiple tasks at once can limit an individual’s daily functioning. The present study focused on the relationship between concurrent task performance and speech intensity by examining attention allocation and how the type of task being performed would affect the distribution of cognitive resources to maximize performance. Future research should investigate how this relationship is demonstrated through physical correlates by measuring lip kinematics during speech production. With this knowledge, future therapies could be further developed that focus on helping individuals compensate for these deficits. One of the most frequently used treatments for hypophonia, the Lee Silverman Voice Treatment, focuses predominantly on training individuals to increase their speech intensity during isolated speech tasks (Fox, Morrison, Ramig & Sapir, 2002). However, the benefits from this speech-focused therapy may become diluted when the individual is placed in a concurrent task setting. Conclusions from this study indicate that when an individual is performing a speech task concurrent with a secondary task, they may shift a greater proportion of their attention and effort to the secondary task which may negatively affect their speech performance. In order to avoid an imbalance in the re-allocation of effort and cognitive resources during dual speech-related activities, new therapeutic procedures may need to be developed. Such procedures may incorporate systematic practice in speech-related dual task activities that help the individual to develop new strategies for maintaining an appropriate balance of attention and effort across the dual activities. Such dual-task treatment procedures could involve a wide range of activities including those that would closely simulate or actually involve speech-related dual activities that typically occur during an individual's social interactions. It is anticipated that the extensive use of these dual task therapy procedures may lead to enhanced transfer and generalization of effective speech intensity strategies to many of the communicative interactions that frequently involve dual activities.

4.7 Summary and Conclusions

This study investigated the effect of concurrent tasks on speech intensity in Parkinson's disease. Thirteen participants with Parkinson's disease and twenty-two controls performed three tasks concurrent with a speech task. The speech task involved a repeated carrier phrase and a target word. The concurrent tasks involved math addition (cognitive), verb generation (linguistic), and manual visuomotor tracking (motor) at three levels of difficulty. The average intensity of the carrier phrase, target word and overall utterance was found to be approximately 3 decibels lower in the participants with Parkinson's disease than the controls. This result provided confirmation of hypophonia or reduced speech intensity in the participants with Parkinson's disease that were examined in this study.

All three concurrent tasks were associated with reduced speech intensity relative to the isolated speech task. The concurrent speech + manual motor task was generally associated with the greatest reduction in speech intensity. The concurrent speech + cognitive task and concurrent speech + linguistic task showed fairly equivalent levels of speech intensity.

The present study found some inconsistent results related to the effect of task difficulty level on speech intensity. For example, the highest overall utterance intensity was produced during the first level of difficulty, followed by the third level of difficulty, and the lowest average overall utterance intensity produced during the second level of difficulty.

The control participants had significantly higher cognitive, linguistic and motor performance scores than the participants with Parkinson's disease. Task performance measures were not significantly different for the concurrent and isolated tasks. This result may reflect the operation of a task prioritization process that involved giving higher priority to the concurrent cognitive, linguistic and motor tasks instead of the concurrent speech task. Across the three types of concurrent tasks, the participants with Parkinson's disease were found to demonstrate relatively worse performance on the linguistic and motor tasks than the cognitive task. In addition, task performance for both groups generally decreased as the task difficulty level increased.

The results of this study failed to support the energizing hypothesis. Instead, the results appear to support a cognitive/attention resource allocation hypothesis with regard to the effect of concurrent tasks on speech intensity regulation in Parkinson's disease.

Further research in each of these task-related effects is required to build a more complete explanation of the relationship between multiple task performance and speech intensity. Future work using concurrent tasks that involve more typical activities of daily living and conversational speech tasks may help to provide a more ecologically valid examination of the effects of concurrent tasks on speech production in Parkinson's disease.

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Appendices

Appendix A

Research Western

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Scott Adams
Review Number: 18212E
Review Level: Delegated
Approved Local Adult Participants: 40
Approved Local Minor Participants: 0
Protocol Title: The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's Disease
Department & Institution: Communication Sciences & Disorders, University of Western Ontario
Sponsor:
Ethics Approval Date: July 19, 2011 **Expiry Date:** August 31, 2012
Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
UWO Protocol		
Letter of Information & Consent	Parkinson's Patient	2011/07/28
Letter of Information & Consent	Control	2011/07/28

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	✓___ **Grace Kelly**	___ **Shantel Walcott**

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

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

Appendix B

LAWSON HEALTH RESEARCH INSTITUTE
FINAL APPROVAL NOTICE

RESEARCH OFFICE REVIEW NO.: R-11-263

PROJECT TITLE: The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's disease.

PRINCIPAL INVESTIGATOR: Dr. Scott Adams

DATE OF REVIEW BY CRIC: August 3, 2011

Health Sciences REB#: 18212E

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

Was Approved

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

Dr. David Hill

V.P. Research

Lawson Health Research Institute

All future correspondence concerning this study should include the Research Office Review Number and should be directed to Sherry Paiva.

cc: Administration

Appendix C

Isolation Cognitive Task

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of single digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer. Once you have an answer, verbally report it by saying it out loud.

5 + 3
8 + 6
3 + 2
9 + 4
7 + 5

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of double digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer. Once you have an answer, verbally report it by saying it out loud.

45 + 7
78 + 5
24 + 7
56 + 6
32 + 8

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of double digit – single digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer. Once you have an answer, verbally report it by saying it out loud.

50 + 8 + 6
34 + 4 + 1
52 + 5 + 3
91 + 2 + 9
55 + 9 + 7

Appendix D

Concurrent Speech + Cognitive Task

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of single digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer while stating the carrier phrase "The next word I am going to say is..." and finishing the sentence by verbally reporting your answer.

3 + 3
9 + 5
4 + 7
1 + 8
6 + 4

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of double digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer while stating the carrier phrase "The next word I am going to say is..." and finishing the sentence by verbally reporting your answer.

18 + 9
43 + 2
57 + 9
22 + 1
88 + 6

Cognitive Task.

In the following task, you will be presented with 5 math questions consisting of double digit – single digit – single digit addition.

As soon as the question has been presented, do your best to determine the answer while stating the carrier phrase "The next word I am going to say is..." and finishing the sentence by verbally reporting your answer.

91 + 5 + 3
48 + 3 + 1
18 + 7 + 4
36 + 4 + 8
68 + 3 + 7

Appendix E

Linguistic Task Questionnaire – Pilot Study

Age: ______

Gender: ________

Is English your first language? Yes N

If No, please indicate your first language: ________________________

Instructions:

For each noun, write down an associated action verb.

Example: Apple (noun) → Eat (action verb)

1. File → ______________________
2. Thief → ______________________
3. Hymn → ______________________
4. Pizza → ______________________
5. Pool → ______________________
6. Staircase → ______________________
7. Blade → ______________________
8. Doll → ______________________
9. Can → ______________________
10. Installment → ______________________
11. Radio → ______________________
12. Music → ______________________
13. Pen → ______________________
14. Table → ______________________
15. Brick → ______________________
16. Scissors → ______________________
17. Sheet → ______________________
18. Stamp → ______________________
19. Cigarette → ______________________
20. Cup → ______________________

21. Necklace → ______________________
22. Rifle → ______________________
23. Pipe → ______________________
24. Wool → ______________________
25. Elbow → ______________________
26. Animal → ______________________
27. Reactor → ______________________
28. Bag → ______________________
29. Island → ______________________
30. Lesion → ______________________
31. Gem → ______________________
32. Ice → ______________________
33. Wave → ______________________
34. Comet → ______________________
35. Folder → ______________________
36. Cotton → ______________________
37. Dome → ______________________
38. Map → ______________________
39. Skin → ______________________
40. Curtain → ______________________
41. Tower → ______________________
42. Card → ______________________
43. Troop → ______________________
44. Beach → ______________________
45. Sword → ______________________
46. Dress → ______________________
47. Shield → ______________________
48. Lottery Ticket → ______________________
49. Coach → ______________________
50. Lamp → ______________________
51. Salt → ______________________

52. Boat → ______________________
53. Light → ______________________
54. Button → ______________________
55. Ice Cream → ______________________
56. Pear → ______________________
57. Ball → ______________________
58. Missile → ______________________
59. Cradle → ______________________
60. Cinema → ______________________
61. Pencil → ______________________
62. Blanket → ______________________
63. Gospel → ______________________
64. Video → ______________________
65. Olive → ______________________
66. Candle → ______________________
67. Rubber → ______________________

For further information, questions or comments, please contact Teresa Valenzano.

Appendix F

Isolation Linguistic Task

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Once you have determined a possible verb, report it verbally by saying it out loud.

Cup
Pen
Necklace
Olive
Rifle

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Once you have determined a possible verb, report it verbally by saying it out loud.

Blanket
Ice Cream
Boat
Comet
Ball

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Once you have determined a possible verb, report it verbally by saying it out loud.

Button
Skin
Reactor
Coach
File

Appendix G

Concurrent Speech + Linguistic Task

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Do your best to determine the answer while stating the carrier phrase "The next word I am going to say is..." and finishing the sentence by verbally reporting your answer.

Thief
Pizza
Hymn
Pool
Cigarette

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Do your best to determine the answer while stating the carrier phrase "The next word I am going to say is..." and finishing the sentence by verbally reporting your answer.

Salt
Stamp
Missile
Wave
Music

Linguistic Task.

In the following task, you will be presented with 15 nouns.

As soon as the question has been presented, think of a verb that can be associated with that noun. For example:

Scissors – cut

Do your best to determine the answer while stating the carrier phrase “The next word I am going to say is...” and finishing the sentence by verbally reporting your answer.

Animal
Gem
Dome
Map
Curtain

Appendix H

LETTER OF INFORMATION
Participants with Parkinson's disease

STUDY TITLE

The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's disease

PRINCIPAL INVESTIGATOR
Scott Adams, Ph.D.
Professor
School of Communication Sciences and Disorders; Clinical Neurological Sciences
University of Western Ontario

CO-INVESTIGATORS
Dr. Allyson Dykstra, Ph.D.
Assistant Professor
School of Communication Sciences and Disorders
University of Western Ontario

Dr. Mandar Jog, MD, FRCPC
Director, Movement Disorders Program,
London Health Sciences Centre, University Campus and
University of Western Ontario

Teresa Valenzano
MSc. Candidate,
Health and Rehabilitation Sciences
University of Western Ontario

INTRODUCTION

This letter of information describes a research study and what you may expect if you decide to participate. You should read the letter carefully and ask the person discussing this with you any questions that you may have before making a decision whether or not to participate. This form contains important information and telephone numbers, so you should keep this copy for future reference. If you decide not to participate in this study, the decision will not be held against you and will not affect your treatment in any way.

You are being asked to participate in this research study because you are an individual with reduced speech intensity and Parkinson's disease. The purpose of this study is to investigate the effects of various concurrent tasks on speech intensity in Parkinson's disease. An example of tasks being performed concurrently is speaking while making a sandwich.

This study will involve 40 participants. Twenty of the participants will have reduced speech intensity and Parkinson's disease. The other twenty participants will not have any neurological conditions. Dr. Jog will identify eligible PD participants from his existing active patient files and discuss the study with the eligible participants at the end of their regular clinic appointments. Dr. Jog is a member of these patients' existing health care team. Once an eligible participant is identified, Dr. Jog will briefly describe the study and invite the patients to participate. Dr. Scott Adams will recruit control participants for the study from the Retirement Research Association (RRA) at the University of Western Ontario. Dr. Scott Adams will submit a letter to the Director of the RRA explaining the study and requesting permission to meet with members of the RRA to describe the nature of the study and invite members to participate.

Information about participants will be collected from patient charts and person-to-person interviews by the principal experimenter or another designated member of the research team. This will include information about the participant's date of birth, general medical history, neurological history, and speech and hearing history.

This study will involve evaluating your speech intensity in isolation and during the performance of three different concurrent tasks. For the isolated speech task, you will be asked to repeat a phrase 15 times in succession. The three other tasks include a verb generation task, a math addition task, and a visually-guided hand movement task. The verb generation task and the math addition task, will require you to provide a spoken answer in response to simple word problems and simple math problems. In the visually-guided hand movement task, you will be asked to use a hand bulb to control a display on a computer screen. The hand bulb is similar to the ones that are used by doctors to inflate a blood pressure cuff. After these 3 tasks have been completed, you will be asked to do each task again while simultaneously performing another speech task involving longer sentences. During all of the conditions, you will wear a head-set microphone that will record your speech on a laptop computer. After you complete the experimental trials, we will conduct a standard hearing assessment. During the standard hearing assessment, you will hear a variety of sounds at different intensities and frequencies. If you agree to participate you will be asked to come one time to Elborn College at the University of Western Ontario for testing. It is anticipated that the total time for this experiment and the hearing test will be no more than 90 minutes.

The experimental procedures will require very little physical effort, and there is no known discomfort or risk involved in performing them. You will be seated in a comfortable chair throughout the procedures and you will be given rest breaks approximately every five minutes or more frequently if required.

The procedures that will be used during this study are experimental in nature and will not provide any direct benefit to the participant's medical condition, however, it is anticipated that results from this study may provide important information about the effect of divided attention and domain-specific cognitive processing on the speech volume of individuals with Parkinson's disease. Financial compensation will not be provided upon completion of this study. Free parking will be provided while you are visiting the lab at Elborn College.

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions, or withdraw from the study at any time with no effect on your future care.

All of the information obtained in this study will be held in strict confidence. Your name and any identifying information will be removed from the data. If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published.

Throughout the study, all confidential information will be preserved in a locked filing cabinet in the Principal Investigator's laboratory at Elborn College, University of Western Ontario.

If requested, you will be provided with a copy of any publication related to the results of this study when it becomes available.

If you have any questions or would like additional information about this study, please contact Professor Scott Adams at the School of Communication Sciences and Disorders, Elborn College, University of Western Ontario, London, Ontario, N6G 1H1.

If you have any questions about the conduct of this study or your rights as a research subject you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute.

If you agree to participate in this study, please sign the consent form on the next page.

Sincerely,

Scott Adams, Ph.D.
Professor

Appendix I

CONSENT FORM

STUDY TITLE

The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's disease

PRINCIPAL INVESTIGATOR
Scott Adams, Ph.D.
Professor
School of Communication Sciences and Disorders; Clinical Neurological Sciences
University of Western Ontario

CO-INVESTIGATORS
Dr. Allyson Dykstra, Ph.D.
Assistant Professor
School of Communication Sciences and Disorders
University of Western Ontario

Dr. Mandar Jog, MD, FRCPC
Director, Movement Disorders Program,
London Health Sciences Centre, University Campus and
University of Western Ontario

Teresa Valenzano
MSc. Candidate,
Health and Rehabilitation Sciences
University of Western Ontario

I have read the Letter of Information (have had the nature of the study explained to me), and I agree to participate. All questions have been answered to my satisfaction.

____

Signature of Research Subject   Printed Name   Date

____

Signature of Person Obtaining Consent   Printed Name   Date

Appendix J

LETTER OF INFORMATION
Participants without Parkinson's disease (Control participant)

STUDY TITLE

The effect of concurrent cognitive, linguistic and motor tasks on speech intensity in Parkinson's disease

PRINCIPAL INVESTIGATOR

Scott Adams, Ph.D.
Professor
School of Communication Sciences and Disorders; Clinical Neurological Sciences
University of Western Ontario

CO-INVESTIGATORS

Dr. Allyson Dykstra, Ph.D.
Assistant Professor
School of Communication Sciences and Disorders
University of Western Ontario

Dr. Mandar Jog, MD, FRCPC
Director, Movement Disorders Program,
London Health Sciences Centre, University Campus and
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Teresa Valenzano
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University of Western Ontario

INTRODUCTION

This letter of information describes a research study and what you may expect if you decide to participate. You should read the letter carefully and ask the person discussing this with you any questions that you may have before making a decision whether or not to participate. This form contains important information and telephone numbers, so you should keep this copy for future reference. If you decide not to participate in this study, the decision will not be held against you and will not affect your treatment in any way.

You are being asked to participate in this research study because you are an individual who does not have Parkinson's disease or any other neurological disorder. The purpose of this study is to investigate the effects of various concurrent tasks on speech intensity in Parkinson's disease. An example of tasks being performed concurrently is speaking while making a sandwich.

This study will involve 40 participants. Twenty of the participants will have reduced speech intensity and Parkinson's disease. The other twenty participants will not have any neurological conditions. Dr. Jog will identify eligible PD participants from his existing active patient files and discuss the study with the eligible participants at the end of their regular clinic appointments. Dr. Jog is a member of these patients' existing health care team. Once an eligible participant is identified, Dr. Jog will briefly describe the study and invite the patients to participate. Dr. Scott Adams will recruit control participants for the study from the Retirement Research Association (RRA) at the University of Western Ontario. Dr. Scott Adams will submit a letter to the Director of the RRA explaining the study and requesting permission to meet with members of the RRA to describe the nature of the study and invite members to participate.

Information about participants will be collected from patient charts and person-to-person interviews by the principal experimenter or another designated member of the research team. This will include information about the participant's date of birth, general medical history, neurological history, and speech and hearing history.

This study will involve evaluating your speech intensity in isolation and during the performance of three different concurrent tasks. For the isolated speech task, you will be asked to repeat a phrase 15 times in succession. The three other tasks include a verb generation task, a math addition task, and a visually-guided hand movement task. The verb generation task and the math addition task, will require you to provide a spoken answer in response to simple word problems and simple math problems. In the visually-guided hand movement task, you will be asked to use a hand bulb to control a display on a computer screen. The hand bulb is similar to the ones that are used by doctors to inflate a blood pressure cuff. After these 3 tasks have been completed, you will be asked to do each task again while simultaneously performing another speech task involving longer sentences. During all of the conditions, you will wear a head-set microphone that will record your speech on a laptop computer. After you complete the experimental trials, we will conduct a standard hearing assessment. During the standard hearing assessment, you will hear a variety of sounds at different intensities and frequencies. If you agree to participate you will be asked to come one time to Elborn College at the University of Western Ontario for testing. It is anticipated that the total time for this experiment and the hearing test will be no more than 90 minutes.

The experimental procedures will require very little physical effort, and there is no known discomfort or risk involved in performing them. You will be seated in a comfortable chair throughout the procedures and you will be given rest breaks approximately every five minutes or more frequently if required.

The procedures that will be used during this study are experimental in nature and will not provide any direct benefit to the participant's medical condition, however, it is anticipated that results from this study may provide important information about the effect of divided attention and domain-specific cognitive processing on the speech volume of individuals with Parkinson's disease. Financial compensation will not be provided upon completion of this study. Free parking will be provided while you are visiting the lab at Elborn College.

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions, or withdraw from the study at any time with no effect on your future care.

All of the information obtained in this study will be held in strict confidence. Your name and any identifying information will be removed from the data. If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published.

Throughout the study, all confidential information will be preserved in a locked filing cabinet in the Principal Investigator's laboratory at Elborn College, University of Western Ontario.

If requested, you will be provided with a copy of any publication related to the results of this study when it becomes available.

If you have any questions or would like additional information about this study, please contact Professor Scott Adams at the School of Communication Sciences and Disorders, Elborn College, University of Western Ontario, London, Ontario, N6G 1H1.

If you have any questions about the conduct of this study or your rights as a research subject you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute.

If you agree to participate in this study, please sign the consent form on the next page.

Sincerely,

Scott Adams, Ph.D.
Professor

Appendix K

Carrier Phrase Intensity
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpCPIOv	1.00	69.1563	3.49611	21
	2.00	67.0752	1.76096	13
	Total	68.3606	3.09664	34
ConMoCPIOv	1.00	66.9105	3.98289	21
	2.00	64.5608	3.15141	13
	Total	66.0121	3.81693	34

Tests of Within -Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	90.970	1	90.970	.000
Manner * Code	Sphericity Assumed	.290	1	.290	.778
Error(Manner)	Sphericity Assumed	114.299	32	3.572	

Tests of Within -Subjects Effects
Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.000	.443
Manner * Code	Sphericity Assumed	.778	.003

Tests of Between -Subjects Effects
Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	287712.956	1	287712.956	15247.764	.000	.998
Code	78.815	1	78.815	4.177	.049	.115
Error	603.814	32	18.869			

Appendix L

Carrier Phrase Intensity
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpCPIOv	1.00	69.1754	3.58580	20
	2.00	67.0752	1.76096	13
	Total	68.3481	3.14378	33
ConMtCPIOv	1.00	68.5061	3.60036	20
	2.00	65.0850	3.31434	13
	Total	67.1584	3.83372	33
ConVgCPIOv	1.00	68.9704	3.48638	20
	2.00	65.2690	2.06253	13
	Total	67.5123	3.49076	33
ConMoCPIOv	1.00	66.7669	4.03020	20
	2.00	64.5608	3.15141	13
	Total	65.8978	3.81661	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	97.254	3	32.418	15.059
TaskType * Code	Sphericity Assumed	15.975	3	5.325	2.473
Error(TaskType)	Sphericity Assumed	200.209	93	2.153	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.327
TaskType * Code	Sphericity Assumed	.066	.074

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	564638.588	1	564638.588	14970.932	.000	.998
Code	257.274	1	257.274	6.821	.014	.180
Error	1169.185	31	37.716			

Appendix M

Carrier Phrase Intensity
Statistical Analysis Three

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtCPI1	1.00	68.6163	3.60733	20
	2.00	64.8211	4.66935	13
	Total	67.1212	4.41008	33
ConMtCPI2	1.00	68.3806	3.64645	20
	2.00	65.0895	2.98181	13
	Total	67.0841	3.72771	33
ConMtCPI3	1.00	68.5213	3.69027	20
	2.00	65.3445	2.60689	13
	Total	67.2698	3.62202	33
ConVgCPI1	1.00	69.1870	3.54922	20
	2.00	65.5900	1.90153	13
	Total	67.7700	3.46714	33
ConVgCPI2	1.00	68.8538	3.60494	20
	2.00	65.0509	2.36345	13
	Total	67.3557	3.65671	33
ConVgCPI3	1.00	68.9583	3.51519	20
	2.00	65.1662	2.10352	13
	Total	67.4645	3.54069	33
ConMoCPI1	1.00	67.0881	3.92102	20
	2.00	65.0520	2.58910	13
	Total	66.2860	3.55852	33
ConMoCPI2	1.00	66.1876	5.37225	20
	2.00	64.2823	4.16220	13
	Total	65.4370	4.95242	33
ConMoCPI3	1.00	67.0249	3.63042	20
	2.00	64.3482	2.89266	13
	Total	65.9704	3.56756	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	112.131	2	56.066	9.409
TaskType * Code	Sphericity Assumed	30.700	2	15.350	2.576
Error (TaskType)	Sphericity Assumed	369.457	62	5.959	
Difficulty	Sphericity Assumed	8.392	2	4.196	2.277
Difficulty * Code	Sphericity Assumed	.568	2	.284	.154
Error (Difficulty)	Sphericity Assumed	114.261	62	1.843	
TaskType * Difficulty	Sphericity Assumed	6.760	4	1.690	1.034
TaskType * Difficulty * Code	Sphericity Assumed	4.035	4	1.009	.617
Error (TaskType* Difficulty)	Sphericity Assumed	202.571	124	1.634	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.233
TaskType * Code	Sphericity Assumed	.084	.077
Difficulty	Sphericity Assumed	.111	.068
Difficulty * Code	Sphericity Assumed	.857	.005
TaskType * Difficulty	Sphericity Assumed	.392	.032
TaskType * Difficulty * Code	Sphericity Assumed	.651	.020

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1255490.195	1	1255490.195	13484.024	.000	.998
Code	689.925	1	689.925	7.410	.011	.193
Error	2886.393	31	93.109			

Appendix N

Target Word Intensity
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpTWIOv	1.00	64.4128	4.38869	19
	2.00	62.0850	2.99108	13
	Total	63.4671	3.99949	32
IsMtTWIOv	1.00	67.4353	4.35717	19
	2.00	64.1404	4.35010	13
	Total	66.0967	4.58822	32
IsVgTWIOv	1.00	69.4799	3.72899	19
	2.00	65.8128	2.52483	13
	Total	67.9902	3.72694	32
ConMoTWIOv	1.00	62.2655	4.64323	19
	2.00	59.4911	3.60587	13
	Total	61.1384	4.41228	32
ConMtTWIOv	1.00	68.6280	8.95706	19
	2.00	63.5379	4.49862	13
	Total	66.5601	7.80190	32
ConVgTWIOv	1.00	68.2111	3.87566	19
	2.00	64.7684	2.56141	13
	Total	66.8125	3.76993	32

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	53.756	1	53.756	5.312
Manner * Code	Sphericity Assumed	5.236	1	5.236	.517
Error(Manner)	Sphericity Assumed	303.613	30	10.120	
TaskType	Sphericity Assumed	850.484	2	425.242	37.918
TaskType * Code	Sphericity Assumed	21.140	2	10.570	.942
Error (TaskType)	Sphericity Assumed	672.890	60	11.215	
Manner * TaskType	Sphericity Assumed	54.995	2	27.498	2.805
Manner * TaskType * Code	Sphericity Assumed	8.167	2	4.083	.417
Error(Manner* TaskType)	Sphericity Assumed	588.086	60	9.801	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.028	.150
Manner * Code	Sphericity Assumed	.478	.017
TaskType	Sphericity Assumed	.000	.558
TaskType * Code	Sphericity Assumed	.395	.030
Manner * TaskType	Sphericity Assumed	.068	.086
Manner * TaskType * Code	Sphericity Assumed	.661	.014

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	783219.490	1	783219.490	9934.126	.000	.997
Code	545.756	1	545.756	6.922	.013	.187
Error	2365.239	30	78.841			

Appendix O

Target Word Intensity
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtTWI1	1.00	66.8614	4.49291	20
	2.00	63.1197	5.95140	13
	Total	65.3874	5.35862	33
ConMtTWI2	1.00	65.8351	4.27935	20
	2.00	62.2618	5.01301	13
	Total	64.4275	4.84157	33
ConMtTWI3	1.00	73.5898	24.92378	20
	2.00	65.2322	3.10564	13
	Total	70.2974	19.73954	33
ConVgTWI1	1.00	68.2700	4.03416	20
	2.00	65.3226	4.24115	13
	Total	67.1089	4.30664	33
ConVgTWI2	1.00	68.3469	3.75282	20
	2.00	64.1111	2.62125	13
	Total	66.6782	3.91872	33
ConVgTWI3	1.00	68.6856	3.97211	20
	2.00	64.8717	1.84885	13
	Total	67.1832	3.77243	33
ConMoTWI1	1.00	62.2834	4.82030	20
	2.00	60.3859	3.63079	13
	Total	61.5359	4.43011	33
ConMoTWI2	1.00	62.4159	4.89244	20
	2.00	59.0428	4.49809	13
	Total	61.0871	4.95991	33
ConMoTWI3	1.00	62.7527	4.45631	20
	2.00	59.0445	3.21380	13
	Total	61.2919	4.36463	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	1839.515	2	919.757	18.822
TaskType * Code	Sphericity Assumed	61.927	2	30.963	.634
Error (TaskType)	Sphericity Assumed	3029.633	62	48.865	
Difficulty	Sphericity Assumed	200.261	2	100.130	2.123
Difficulty * Code	Sphericity Assumed	71.780	2	35.890	.761
Error (Difficulty)	Sphericity Assumed	2923.851	62	47.159	
TaskType * Difficulty	Sphericity Assumed	329.124	4	82.281	1.800
TaskType * Difficulty * Code	Sphericity Assumed	65.791	4	16.448	.360
Error (TaskType* Difficulty)	Sphericity Assumed	5669.377	124	45.721	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.378
TaskType * Code	Sphericity Assumed	.534	.020
Difficulty	Sphericity Assumed	.128	.064
Difficulty * Code	Sphericity Assumed	.471	.024
TaskType * Difficulty	Sphericity Assumed	.133	.055
TaskType * Difficulty * Code	Sphericity Assumed	.837	.011

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1182912.850	1	1182912.850	7690.828	.000	.996
Code	1112.502	1	1112.502	7.233	.011	.189
Error	4768.056	31	153.808			

Appendix P

Overall Utterance Intensity
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpOIOv	1.00	68.4305	3.55524	21
	2.00	66.2491	1.81474	13
	Total	67.5964	3.16478	34
ConMoOIOv	1.00	66.3100	3.74132	21
	2.00	63.5398	3.11175	13
	Total	65.2508	3.72446	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	93.654	1	93.654	32.053
Manner * Code	Sphericity Assumed	1.392	1	1.392	.476
Error (Manner)	Sphericity Assumed	93.498	32	2.922	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.000	.500
Manner * Code	Sphericity Assumed	.495	.015

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	280932.257	1	280932.257	15109.927	.000	.998
Code	98.432	1	98.432	5.294	.028	.142
Error	594.962	32	18.593			

Appendix Q

Overall Utterance Intensity
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpOIOv	1.00	68.4459	3.64688	20
	2.00	66.2491	1.81474	13
	Total	67.5805	3.21245	33
ConMtOIOv	1.00	67.6647	3.69418	20
	2.00	64.0427	3.37721	13
	Total	66.2378	3.95094	33
ConVgOIOv	1.00	68.2012	3.39420	20
	2.00	63.5005	2.81117	13
	Total	66.3494	3.90439	33
ConMoOIOv	1.00	66.1664	3.77867	20
	2.00	63.5398	3.11175	13
	Total	65.1317	3.71584	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	99.984	3	33.328	15.235
TaskType * Code	Sphericity Assumed	29.432	3	9.811	4.485
Error (TaskType)	Sphericity Assumed	203.442	93	2.188	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.330
TaskType * Code	Sphericity Assumed	.006	.126

Tests of Between -Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	548725.511	1	548725.511	14341.041	.000	.998
Code	340.396	1	340.396	8.896	.006	.223
Error	1186.141	31	38.263			

Appendix R

Overall Utterance Intensity
Statistical Analysis Three

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtOVI1	1.00	68.0502	4.09434	20
	2.00	64.3263	4.89596	13
	Total	66.5832	4.72828	33
ConMtOVI2	1.00	67.5921	3.78672	20
	2.00	63.9229	3.09094	13
	Total	66.1467	3.92573	33
ConMtOI3	1.00	67.3517	3.99900	20
	2.00	63.8789	2.73283	13
	Total	65.9836	3.90707	33
ConVgOI1	1.00	68.9155	3.55669	20
	2.00	64.1725	2.43739	13
	Total	67.0471	3.90865	33
ConVgOI2	1.00	67.7863	3.66514	20
	2.00	62.8592	3.15315	13
	Total	65.8453	4.20493	33
ConVgOI3	1.00	68.5810	3.55904	20
	2.00	63.4698	3.11448	13
	Total	66.5675	4.19409	33
ConMoOI1	1.00	66.2132	3.89488	20
	2.00	64.1146	2.52609	13
	Total	65.3865	3.53334	33
ConMoOI2	1.00	66.0586	3.95026	20
	2.00	63.1526	4.13679	13
	Total	64.9138	4.21447	33
ConMoOI3	1.00	66.2273	3.61665	20
	2.00	63.3522	2.86654	13
	Total	65.0947	3.58930	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	70.837	2	35.418	6.086
TaskType * Code	Sphericity Assumed	62.923	2	31.461	5.406
Error (TaskType)	Sphericity Assumed	360.843	62	5.820	
Difficulty	Sphericity Assumed	26.571	2	13.286	6.956
Difficulty * Code	Sphericity Assumed	1.469	2	.734	.385
Error(Difficulty)	Sphericity Assumed	118.418	62	1.910	
TaskType * Difficulty	Sphericity Assumed	7.820	4	1.955	.824
TaskType * Difficulty * Code	Sphericity Assumed	2.638	4	.660	.278
Error(TaskType *Difficulty)	Sphericity Assumed	294.081	124	2.372	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.004	.164
TaskType * Code	Sphericity Assumed	.007	.148
Difficulty	Sphericity Assumed	.002	.183
Difficulty * Code	Sphericity Assumed	.682	.012
TaskType * Difficulty	Sphericity Assumed	.512	.026
TaskType * Difficulty * Code	Sphericity Assumed	.892	.009

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1218987.789	1	1218987.789	13164.934	.000	.998
Code	984.010	1	984.010	10.627	.003	.255
Error	2870.400	31	92.594			

Appendix S

Task Performance
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsMtSc1	1.00	4.9500	.22361	20
	2.00	5.0000	.00000	13
	Total	4.9697	.17408	33
IsMtSc2	1.00	4.8500	.36635	20
	2.00	4.8462	.37553	13
	Total	4.8485	.36411	33
IsMtSc3	1.00	4.7500	.44426	20
	2.00	4.6923	.48038	13
	Total	4.7273	.45227	33
IsVgSc1	1.00	4.5000	1.00000	20
	2.00	2.6154	1.55662	13
	Total	3.7576	1.54172	33
IsVgSc2	1.00	4.4000	1.14248	20
	2.00	2.6154	1.98068	13
	Total	3.6970	1.74078	33
IsVgSc3	1.00	3.3500	1.56525	20
	2.00	2.0000	1.15470	13
	Total	2.8182	1.55029	33
ConMtSc1	1.00	4.9000	.30779	20
	2.00	4.9231	.27735	13
	Total	4.9091	.29194	33
ConMtSc2	1.00	4.6500	.81273	20
	2.00	4.6154	.50637	13
	Total	4.6364	.69903	33
ConMtSc3	1.00	4.7000	.57124	20
	2.00	4.6154	.50637	13
	Total	4.6667	.54006	33
ConVgSc1	1.00	4.4500	1.19097	20
	2.00	3.4615	1.76141	13
	Total	4.0606	1.49874	33
ConVgSc2	1.00	4.1500	1.08942	20
	2.00	2.8462	1.90815	13
	Total	3.6364	1.57754	33
ConVgSC3	1.00	3.6500	1.26803	20
	2.00	2.2308	1.42325	13
	Total	3.0909	1.48668	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.255	1	.255	.337	.566	.011
Manner * Code	Sphericity Assumed	.982	1	.982	1.300	.263	.040
Error (Manner)	Sphericity Assumed	23.427	31	.756			
Task Type	Sphericity Assumed	194.760	1	194.760	56.028	.000	.644
Task Type * Code	Sphericity Assumed	48.821	1	48.821	14.044	.001	.312
Error (Task Type)	Sphericity Assumed	107.760	31	3.476			
Difficulty	Sphericity Assumed	23.240	2	11.620	30.621	.000	.497
Difficulty * Code	Sphericity Assumed	.109	2	.054	.143	.867	.005
Error (Difficulty)	Sphericity Assumed	23.528	62	.379			
Manner * Task Type	Sphericity Assumed	2.606	1	2.606	3.200	.083	.094
Manner * Task Type * Code	Sphericity Assumed	1.273	1	1.273	1.563	.221	.048
Error (Manner*TaskType)	Sphericity Assumed	25.247	31	.814			
Manner * Difficulty	Sphericity Assumed	1.347	2	.674	1.258	.291	.039
Manner * Difficulty * Code	Sphericity Assumed	.923	2	.462	.862	.427	.027
Error (Manner*Difficulty)	Sphericity Assumed	33.198	62	.535			

Task Type * Difficulty	Sphericity Assumed	9.464	2	4.732	12.858	.000	.293
Task Type * Difficulty * Code	Sphericity Assumed	.192	2	.096	.260	.772	.008
Error (Task Type* Difficulty)	Sphericity Assumed	22.819	62	.368			
Manner * Task Type * Difficulty	Sphericity Assumed	.258	2	.129	.240	.788	.008
Manner * Task Type * Difficulty * Code	Sphericity Assumed	.924	2	.462	.859	.429	.027
Error (Manner* Task Type* Difficulty)	Sphericity Assumed	33.358	62	.538			

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	6275.007	1	6275.007	1411.793	.000	.979
Code	51.290	1	51.290	11.540	.002	.271
Error	137.786	31	4.445			

Appendix T

Task Performance
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsMoEr1	1.00	5.0548	2.68658	21
	2.00	10.6354	7.65796	13
	Total	7.1885	5.76864	34
IsMoEr2	1.00	6.1121	2.63831	21
	2.00	10.5877	6.83461	13
	Total	7.8234	5.10671	34
IsMoEr3	1.00	7.5129	4.19917	21
	2.00	11.8523	6.15078	13
	Total	9.1721	5.38754	34
ConMoER1	1.00	6.8681	3.33787	21
	2.00	9.6364	6.13858	13
	Total	7.9265	4.72436	34
ConMoER2	1.00	6.0071	2.80308	21
	2.00	10.1379	6.34011	13
	Total	7.5866	4.85086	34
ConMoER3	1.00	6.7595	2.46124	21
	2.00	11.7965	7.85824	13
	Total	8.6854	5.68329	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	.404	1	.404	.038
Manner * Code	Sphericity Assumed	8.095	1	8.095	.756
Error (Manner)	Sphericity Assumed	342.888	32	10.715	
Difficulty	Sphericity Assumed	78.937	2	39.469	5.951
Difficulty * Code	Sphericity Assumed	2.295	2	1.148	.173
Error (Difficulty)	Sphericity Assumed	424.484	64	6.633	
Manner * Difficulty	Sphericity Assumed	6.122	2	3.061	.773
Manner * Difficulty * Code	Sphericity Assumed	26.089	2	13.045	3.293
Error (Manner* Difficulty)	Sphericity Assumed	253.534	64	3.961	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.847	.001
Manner * Code	Sphericity Assumed	.391	.023
Difficulty	Sphericity Assumed	.004	.157
Difficulty * Code	Sphericity Assumed	.841	.005
Manner * Difficulty	Sphericity Assumed	.466	.024
Manner * Difficulty * Code	Sphericity Assumed	.044	.093

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	14186.521	1	14186.521	129.325	.000	.802
Code	927.877	1	927.877	8.459	.007	.209
Error	3510.281	32	109.696			

Appendix U

Utterance Duration
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpUDOv	1.00	2.0319	.32495	21
	2.00	1.9689	.28644	13
	Total	2.0078	.30789	34
ConMoUDOv	1.00	2.4752	.50132	21
	2.00	2.2319	.39005	13
	Total	2.3822	.47121	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	2.003	1	2.003	42.668
Manner * Code	Sphericity Assumed	.130	1	.130	2.779
Error (Manner)	Sphericity Assumed	1.503	32	.047	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.000	.571
Manner * Code	Sphericity Assumed	.105	.080

Tests of Between -Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	304.424	1	304.424	1153.396	.000	.973
Code	.377	1	.377	1.427	.241	.043
Error	8.446	32	.264			

Appendix V

Utterance Duration
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpUDOv	1.00	2.0640	.29724	20
	2.00	1.9689	.28644	13
	Total	2.0265	.29233	33
ConMtUDOv	1.00	2.5686	.65727	20
	2.00	2.7941	.93826	13
	Total	2.6574	.77405	33
ConVgUDOv	1.00	2.6332	.67367	20
	2.00	4.1116	2.07924	13
	Total	3.2156	1.55844	33
ConMoUDOv	1.00	2.5346	.43211	20
	2.00	2.2319	.39005	13
	Total	2.4153	.43643	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	31.201	3	10.400	20.928
TaskType * Code	Sphericity Assumed	15.052	3	5.017	10.096
Error (TaskType)	Sphericity Assumed	46.218	93	.497	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.403
TaskType * Code	Sphericity Assumed	.000	.246

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	860.943	1	860.943	649.501	.000	.954
Code	3.360	1	3.360	2.535	.122	.076
Error	41.092	31	1.326			

Appendix W

Utterance Duration
Statistical Analysis Three

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtUD1	1.00	2.0773	.49144	20
	2.00	2.1748	1.12283	13
	Total	2.1157	.78646	33
ConMtUD2	1.00	2.4529	.64167	20
	2.00	2.5190	.75716	13
	Total	2.4789	.67862	33
ConMtUD3	1.00	3.1755	1.07919	20
	2.00	3.6886	1.54106	13
	Total	3.3777	1.28332	33
ConVgUD1	1.00	2.0297	.38357	20
	2.00	3.9054	2.63336	13
	Total	2.7686	1.88524	33
ConVgUD2	1.00	2.9000	1.02015	20
	2.00	4.5168	2.50147	13
	Total	3.5369	1.89950	33
ConVgUD3	1.00	2.7107	.94740	20
	2.00	3.9124	2.25385	13
	Total	3.1841	1.67135	33
ConMoUD1	1.00	2.0345	.32728	20
	2.00	1.7580	.30267	13
	Total	1.9255	.34173	33
ConMoUD2	1.00	1.8918	.32218	20
	2.00	1.6668	.29550	13
	Total	1.8032	.32687	33
ConMoUD3	1.00	1.8361	.33889	20
	2.00	1.6596	.30556	13
	Total	1.7666	.33298	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	110.218	2	55.109	32.130
TaskType * Code	Sphericity Assumed	41.004	2	20.502	11.953
Error (TaskType)	Sphericity Assumed	106.343	62	1.715	
Difficulty	Sphericity Assumed	12.225	2	6.113	10.623
Difficulty * Code	Sphericity Assumed	.078	2	.039	.067
Error (Difficulty)	Sphericity Assumed	35.675	62	.575	
TaskType * Difficulty	Sphericity Assumed	25.508	4	6.377	10.121
TaskType * Difficulty * Code	Sphericity Assumed	2.765	4	.691	1.097
Error (TaskType* Difficulty)	Sphericity Assumed	78.131	124	.630	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.509
TaskType * Code	Sphericity Assumed	.000	.278
Difficulty	Sphericity Assumed	.000	.255
Difficulty * Code	Sphericity Assumed	.935	.002
TaskType * Difficulty	Sphericity Assumed	.000	.246
TaskType * Difficulty * Code	Sphericity Assumed	.361	.034

Tests of Between -Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1926.392	1	1926.392	448.204	.000	.935
Code	19.280	1	19.280	4.486	.042	.126
Error	133.239	31	4.298			

Appendix X

Carrier Phrase Duration
Statistical Analysis One

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpCPUDOv	1.00	1.5800	.26380	20
	2.00	1.4886	.27058	13
	Total	1.5440	.26614	33
ConMoCPUDOv	1.00	1.3915	.27084	20
	2.00	1.2139	.27221	13
	Total	1.3216	.28126	33

Tests of Within -Subjects Effects
Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Manner	Sphericity Assumed	.845	1	.845	36.029
Manner * Code	Sphericity Assumed	.029	1	.029	1.248
Error(Manner)	Sphericity Assumed	.727	31	.023	

Tests of Within -Subjects Effects
Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
Manner	Sphericity Assumed	.000	.538
Manner * Code	Sphericity Assumed	.273	.039

Tests of Between -Subjects Effects
Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	126.829	1	126.829	1046.635	.000	.971
Code	.285	1	.285	2.353	.135	.071
Error	3.757	31	.121			

Appendix Y

Carrier Phrase Duration
Statistical Analysis Two

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsSpCPUDOv	1.00	1.5800	.26380	20
	2.00	1.4886	.27058	13
	Total	1.5440	.26614	33
ConMtCPUDOv	1.00	1.5783	.30094	20
	2.00	1.3070	.26266	13
	Total	1.4714	.31266	33
ConVgoCPUDOv	1.00	1.7035	.34625	20
	2.00	1.4512	.38677	13
	Total	1.6041	.37810	33
ConMoCPUDOv	1.00	1.3915	.27084	20
	2.00	1.2139	.27221	13
	Total	1.3216	.28126	33

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	1.395	3	.465	14.306
TaskType * Code	Sphericity Assumed	.158	3	.053	1.624
Error (TaskType)	Sphericity Assumed	3.022	93	.032	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.316
TaskType * Code	Sphericity Assumed	.189	.050

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	270.278	1	270.278	1036.525	.000	.971
Code	1.237	1	1.237	4.746	.037	.133
Error	8.083	31	.261			

Appendix Z

Carrier Phrase Duration
Statistical Analysis Three

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtCPUD1	1.00	1.4302	.35607	21
	2.00	1.2644	.25028	13
	Total	1.3668	.32605	34
ConMtCPUD2	1.00	1.4469	.32781	21
	2.00	1.2590	.27610	13
	Total	1.3751	.31849	34
ConMtCPUD3	1.00	1.7474	.49125	21
	2.00	1.3977	.30063	13
	Total	1.6137	.45704	34
ConVgCPUD1	1.00	1.5718	.48938	21
	2.00	1.5105	.40608	13
	Total	1.5483	.45390	34
ConVgCPUD2	1.00	1.6441	.52610	21
	2.00	1.4067	.36312	13
	Total	1.5533	.47896	34
ConVgCPUD3	1.00	1.6512	.52793	21
	2.00	1.4363	.45379	13
	Total	1.5691	.50501	34
ConMoCPUD1	1.00	1.4408	.27888	21
	2.00	1.2595	.26341	13
	Total	1.3715	.28348	34
ConMoCPUD2	1.00	1.3525	.28224	21
	2.00	1.1842	.28710	13
	Total	1.2882	.29179	34
ConMoCPUD3	1.00	1.3087	.32022	21
	2.00	1.1980	.29568	13
	Total	1.2664	.31132	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	2.926	2	1.463	11.532
TaskType * Code	Sphericity Assumed	.087	2	.044	.345
Error (TaskType)	Sphericity Assumed	8.119	64	.127	
Difficulty	Sphericity Assumed	.269	2	.134	4.540
Difficulty * Code	Sphericity Assumed	.100	2	.050	1.691
Error (Difficulty)	Sphericity Assumed	1.895	64	.030	
TaskType * Difficulty	Sphericity Assumed	.972	4	.243	10.636
TaskType * Difficulty * Code	Sphericity Assumed	.232	4	.058	2.539
Error (TaskType* Difficulty)	Sphericity Assumed	2.924	128	.023	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.265
TaskType * Code	Sphericity Assumed	.710	.011
Difficulty	Sphericity Assumed	.014	.124
Difficulty * Code	Sphericity Assumed	.192	.050
TaskType * Difficulty	Sphericity Assumed	.000	.249
TaskType * Difficulty * Code	Sphericity Assumed	.043	.074

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	580.576	1	580.576	633.486	.000	.952
Code	2.510	1	2.510	2.739	.108	.079
Error	29.327	32	.916			

Appendix AA

Response Time
Statistical Analysis

Descriptive Statistics

	Code	Mean	Std. Deviation	N
IsMtRT1	1.00	.9816	.33716	21
	2.00	1.1405	.64132	13
	Total	1.0423	.47393	34
IsMtRT2	1.00	1.7877	.92823	21
	2.00	1.9053	.86432	13
	Total	1.8327	.89286	34
IsMtRT3	1.00	2.8674	1.00924	21
	2.00	4.1342	2.42562	13
	Total	3.3518	1.77405	34
IsVgRT1	1.00	1.8714	2.09827	21
	2.00	3.4646	3.10486	13
	Total	2.4806	2.60604	34
IsVgRT2	1.00	1.7126	.47779	21
	2.00	4.2221	3.95888	13
	Total	2.6721	2.71476	34
IsVgRT3	1.00	2.7713	1.02864	21
	2.00	7.9966	5.95442	13
	Total	4.7692	4.49193	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	113.806	1	113.806	18.246
TaskType * Code	Sphericity Assumed	81.099	1	81.099	13.002
Error (TaskType)	Sphericity Assumed	199.592	32	6.237	
Difficulty	Sphericity Assumed	237.300	2	118.650	40.148
Difficulty * Code	Sphericity Assumed	51.079	2	25.540	8.642
Error (Difficulty)	Sphericity Assumed	189.139	64	2.955	
TaskType * Difficulty	Sphericity Assumed	4.784	2	2.392	.614
TaskType * Difficulty * Code	Sphericity Assumed	13.039	2	6.519	1.673
Error (TaskType* Difficulty)	Sphericity Assumed	249.402	64	3.897	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.363
TaskType * Code	Sphericity Assumed	.001	.289
Difficulty	Sphericity Assumed	.000	.556
Difficulty * Code	Sphericity Assumed	.000	.213
TaskType * Difficulty	Sphericity Assumed	.544	.019
TaskType * Difficulty * Code	Sphericity Assumed	.196	.050

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1625.810	1	1625.810	158.015	.000	.832
Code	158.161	1	158.161	15.372	.000	.324
Error	329.247	32	10.289			

Appendix BB

Response Latency
Statistical Analysis

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtRL1	1.00	.5627	.28424	21
	2.00	.8203	.58378	13
	Total	.6612	.43478	34
ConMtRL2	1.00	.5264	.12865	21
	2.00	2.2139	5.69312	13
	Total	1.1716	3.53398	34
ConMtRL3	1.00	.6397	.18646	21
	2.00	1.1600	.61428	13
	Total	.8387	.47346	34
ConVgRL1	1.00	.4940	.19686	21
	2.00	1.4800	.95501	13
	Total	.8710	.76922	34
ConVgRL2	1.00	.5662	.18609	21
	2.00	1.2649	.81411	13
	Total	.8333	.61707	34
ConVgRL3	1.00	.6576	.44244	21
	2.00	1.9802	2.19929	13
	Total	1.1633	1.51761	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	.362	1	.362	.138
TaskType * Code	Sphericity Assumed	.393	1	.393	.150
Error (TaskType)	Sphericity Assumed	83.872	32	2.621	
Difficulty	Sphericity Assumed	3.560	2	1.780	.729
Difficulty * Code	Sphericity Assumed	2.623	2	1.312	.537
Error (Difficulty)	Sphericity Assumed	156.194	64	2.441	
TaskType * Difficulty	Sphericity Assumed	7.179	2	3.590	1.875
TaskType * Difficulty * Code	Sphericity Assumed	8.248	2	4.124	2.154
Error (TaskType* Difficulty)	Sphericity Assumed	122.518	64	1.914	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.713	.004
TaskType * Code	Sphericity Assumed	.701	.005
Difficulty	Sphericity Assumed	.486	.022
Difficulty * Code	Sphericity Assumed	.587	.017
TaskType * Difficulty	Sphericity Assumed	.162	.055
TaskType * Difficulty * Code	Sphericity Assumed	.124	.063

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	204.638	1	204.638	54.598	.000	.630
Code	40.083	1	40.083	10.694	.003	.250
Error	119.939	32	3.748			

Appendix CC

Sentence-Response Latency
Statistical Analysis

Descriptive Statistics

	Code	Mean	Std. Deviation	N
ConMtSRL1	1.00	.1181	.25579	21
	2.00	.4462	1.01770	13
	Total	.2436	.66519	34
ConMtSRL2	1.00	.2221	.38453	21
	2.00	.3960	.49332	13
	Total	.2886	.43066	34
ConMtSRL3	1.00	.6175	.83499	21
	2.00	1.6129	1.49228	13
	Total	.9981	1.21384	34
ConVgSRL1	1.00	.1891	.44945	21
	2.00	1.9541	2.35191	13
	Total	.8640	1.70055	34
ConVgSRL2	1.00	.6694	.85533	21
	2.00	2.6139	2.46759	13
	Total	1.4129	1.89144	34
ConVgSRL3	1.00	.5255	.69904	21
	2.00	2.0359	2.05471	13
	Total	1.1030	1.54481	34

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
TaskType	Sphericity Assumed	28.012	1	28.012	17.122
TaskType * Code	Sphericity Assumed	18.544	1	18.544	11.335
Error (TaskType)	Sphericity Assumed	52.351	32	1.636	
Difficulty	Sphericity Assumed	8.781	2	4.390	6.412
Difficulty * Code	Sphericity Assumed	.430	2	.215	.314
Error (Difficulty)	Sphericity Assumed	43.818	64	.685	
TaskType * Difficulty	Sphericity Assumed	10.956	2	5.478	5.671
TaskType * Difficulty * Code	Sphericity Assumed	3.396	2	1.698	1.758
Error (TaskType* Difficulty)	Sphericity Assumed	61.823	64	.966	

Tests of Within -Subjects Effects

Measure:MEASURE_1

Source		Sig.	Partial Eta Squared
TaskType	Sphericity Assumed	.000	.349
TaskType * Code	Sphericity Assumed	.002	.262
Difficulty	Sphericity Assumed	.003	.167
Difficulty * Code	Sphericity Assumed	.732	.010
TaskType * Difficulty	Sphericity Assumed	.005	.151
TaskType * Difficulty * Code	Sphericity Assumed	.181	.052

Tests of Between -Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	173.937	1	173.937	46.060	.000	.590
Code	60.384	1	60.384	15.990	.000	.333
Error	120.842	32	3.776			

Curriculum Vitae

Name:	Teresa Valenzano
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	Research Assistant Cognitive Neuropsychology Lab York University 2008-2010

Conferences:

Valenzano, T., Adams, S. G., Dykstra, A. & Jog, M. (May 4th, 2012). Linguistic, Cognitive, Linguistic and motor concurrent task effects on speech intensity and task performance for individuals with Parkinson's disease. Oral presentation given at the 13th Research Colloquium in Rehabilitation. McGill University, Montreal, Quebec. [National]

Valenzano, T., Adams, S. G., Dykstra, A. & Jog, M. (March 27th, 2012). Concurrent task effects on speech intensity and task performance for individuals with Parkinson's disease. Oral presentation given at the 24th Annual Western Research Forum. University of Western Ontario, London, Ontario. [Institutional]

Valenzano, T., Adams, S. G., Dykstra, A. & Jog, M. (February 24th & 25th, 2012). Concurrent task effects on speech intensity for individuals with Parkinson's disease. Oral presentation given at the Southern Ontario Interdisciplinary Health & Aging Symposium. McMaster University, Hamilton, Ontario. [National]

Valenzano, T., Adams, S. G., Dykstra, A. & Jog, M. (February 8th, 2012). The effect of cognitive, linguistic and motor concurrent tasks on speech intensity for individuals with Parkinson's disease. Oral presentation given at the 5th Annual Health & Rehabilitation Sciences Graduate Research Forum; "Brewing Research, Steeped in Ideas". University of Western Ontario, London, Ontario. [Institutional]

Valenzano, T., Adams, S. G., Dykstra, A. & Jog, M. (February 3rd, 2012). The effect of cognitive, linguistic and motor concurrent tasks on speech intensity for individuals with Parkinson's disease. Poster presented at the Aging, Rehabilitation, and Geriatric Care/Faculty of Health Sciences Symposium; "Ideas to Action: Knowledge Translation at the Point of 'Health' Care". Parkwood Hospital, London, Ontario. [Institutional]

Valenzano, T., Clark, J., Leszcz, T., Adams, S. G., & Jog, M. Declination of speech intensity and pitch in Parkinson's disease.

- Oral presentation given at the 13th Rehabilitation Research Colloquium. (May 20th, 2011). Queen's University, Kingston, Ontario. [National]
- Poster presented at the Western Research Forum. (February 26th, 2011). University of Western Ontario, London, Ontario.
- Poster presented at the Aging, Rehabilitation, and Geriatric Care/Faculty of Health Sciences Symposium: "Field of Dreams, Seeds for Tomorrow". (February 4th, 2011). University of Western Ontario, London, Ontario.

Clark, J., Leszcz, T., **Valenzano, T.,** Adams, S. G., & Jog, M. (February 9th, 2011). Declination of speech intensity and pitch in Parkinson's disease. Poster presented at the 4th Annual Health & Rehabilitation Sciences Graduate Research Forum; "Stories Worth Sharing". University of Western Ontario, London, Ontario.

Valenzano, T. (April 6th, 2010). The function of attention in error monitoring behaviour for naturalistic action performance. Poster presented at the York University Cognitive Science Annual Undergraduate Research Showcase. York University, Toronto, Ontario.

Public Presentations:

Valenzano, T. & Adams, S. G. (March 3rd, 2012). Concurrent task effects on speech intensity and task performance for individuals with Parkinson's disease. Chartwell Select Riverside Retirement Residence, London, ON. [Local]

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April 2011 – April 2012
Vice Presdent Academic

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