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Effects of Two Gait Tasks on Language Complexity in Parkinson's Disease

Betty Ann Marquardt

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

Effects of Two Gait Tasks on Language Complexity in Parkinson's Disease

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Master of Science

The effects of dual tasking in Parkinson's disease (PD) have been studied for a number of years. Previous research has generally focused on changes in gait patterns while another task has been performed concurrently. Very few studies have focused on the impact of a concurrent task on speech or language. Language is key for communication: to express wants and needs, to maintain familial relationships, and for social interaction. Thirty-seven individuals participated in the study: 10 with PD, 14 neurologically healthy older (HO) adults, and 13 healthy younger (HY) adults. The participants were given a list of topics to consider and were invited to select several to talk about during the experiment. Their monologues were recorded as they spoke under three conditions: standing still, walking on a treadmill, and walking over randomly presented obstacles on a treadmill. The monologue recordings were transcribed, marked for processing by Systematic Analysis of Language Transcripts (SALT), and analyzed for subordinate clauses by a language expert. The language variables measured were the mean length of utterance in morphemes (MLUm), relative clauses per utterance, adverbial clauses per utterance, noun clauses per utterance, total clauses per utterance, words per minute, different words per minute, relative clauses per minute, adverbial clauses per minute, noun clauses per minute, total clauses per minutes, and utterances per minute. There were significant changes across the conditions of standing, walking, and obstacle in the language variables of words per minute, different words per minute, noun clauses per minute, total clauses per minute, and utterances per minute. A downward trend was noted for adverbial clauses per minute as the gait task became more demanding. The PD and HO groups had less complex language than the HY group, as reflected by the following language variables: adverbial clauses per minute, noun clauses per minute, and total clauses per minute. These findings suggest that as attentional resources used for the production of language are directed to increasing levels of motoric activity, language complexity will significantly decrease across conditions.

Keywords: Parkinson's disease, dual tasking, language complexity, gait

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I would like to thank my family for supporting me throughout this process. They inserted joy into my life, encouraged me through difficult times, prodded me to move forward when I was faced with obstacles, and shed light at the end of the tunnel. Their support was invaluable in completing this thesis.

I would also like to acknowledge the support of my cohort. They are a remarkable group of motivating, supportive professionals. I consider myself very blessed to be counted among them.

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DESCRIPTION OF THESIS STRUCTURE

This thesis, *Effects of Two Gait Tasks on Language Complexity in Parkinson's Disease*, is structured after recent peer-reviewed communication disorders journal articles. The preliminary pages of the thesis reflect requirements for submission to the university. An annotated bibliography is included in Appendix A. Appendix B contains information regarding the research consent form.

Introduction

Our brains are highly efficient at using our cognitive resources to accomplish a single task. Whether we are young or old or impaired by disease, giving all our resources or our undivided attention to a single task allows for the best outcome. However, we live in a world that more often than not requires performing two tasks at the same time or dividing our attention among multiple tasks. Multitasking is not the exception, but the rule for most people. We multitask from the time we awake in the morning until the time we go to sleep at night. We check our email while watching the news, talk on the phone while driving to work, listen to music while working out, and talk to our family while cooking dinner. More often than not, we divide our cognitive resources between two or more activities at the same time. If we are dividing our attentional resources between two simple tasks, the interference of one task on the other may be minimal, but what is the cost of dividing our attentional resources between two higher-level tasks that draw on cognitive resources? How does multitasking affect the language complexity in this dual task condition?

Theories of Divided Attention

Divided attention is a topic that cognitive psychologists have been studying for the past fifty years. It occurs when any two tasks are performed simultaneously (dual task condition) causing an individual's attention to be divided between the two tasks. If the tasks are automated and simple, there may be minimal interference in the performance of the dual tasks (Dromey & Shim, 2008). However, there is often interference between tasks that creates a less than optimal performance on one or both tasks. In order to evaluate the impact of divided attention between two tasks, it is first necessary to measure performance on the primary task A and separately on task B in a single-task condition. Next, the performance is measured for tasks A and B in the

dual-task condition. The difference in the performance of the primary task A in the single-task and dual-task condition reveals the interference between tasks A and B. For the purpose of this study, we will examine the impact on language in the dual task condition of walking while talking.

Multiple theories of divided attention have been used to explain interference in the dual-task condition. The cognitive bottleneck theories of divided attention suggest that there is a single channel processor or anatomical structural point or bottleneck in cognitive processing. This bottleneck does not allow simultaneous processing during the performance of dual tasks, but proponents of this theory suggest the sequential processing of tasks, allowing only one task to be processed at a time. Pashler (1990) found “strong evidence for a ‘single-channel bottleneck’ in response selection as the basic source of dual-task interference in simple overlapping tasks” (p. 827). When the tasks were not similar or overlapping, interference was not as great.

Like bottleneck theories, switching theories suggest that dual tasking does not happen simultaneously but occurs through cognitive selection of priority. These theories suggest a synchronization of tasks that require the use of executive function. Decision-making is used to coordinate the interchange between tasks. This interchange results in the tasks being broken into smaller workable parts in a process known as *chunking*.

The capacity theories suggest that there are specialized processors in the brain and each individual has a finite capacity to process information. If the dual tasks are simple, and do not require more capacity than what is available, or the tasks use separate processors, then the dual task will be successful. However, limitation of capacity would force an individual to prioritize more complex tasks, otherwise the processing of information could become slowed and less

precise. Completing dual tasks that require the use of the same limited capacity processor could result in interference. In the dual-task condition of talking while walking, Ferreira and Pashler, (2002) explain, “it also may be that linguistic abilities are based on mechanisms that are shared with the processes that underlie the performance of other, nonlinguistic tasks” (p. 1). Motor and language production share cognitive processes that could overwhelm limited capacity processors, resulting in slowing of the system (LaPointe, Stierwalt, & Maitland, 2010).

The multi-processor model allows for simultaneous processing of dual tasks. Ferreira and Pashler (2002) state that “when different kinds of responses are called for, quite independent cognitive systems are involved in performing the tasks: multiple processors. This allows independence between the performance of the two tasks” (p. 827). Although the model allows for independent performance, because of a lack of the bottleneck effect, the multi-processor model does not insure that the outcome of dual tasking will be as good as the bottleneck performance (Ferreira & Pashler).

The functional distance hypothesis developed by Kinsbourne and Hicks (1978) supports the premise that simultaneous tasks regulated by cortical areas separated by a greater anatomical distance will have less interference than dual tasks regulated by cortical areas with closer proximity. However, the functional distance hypothesis is limited in that the brain has integrated neural pathways, and many functions are not controlled by one isolated region of the brain. The results from Dromey and Shim, (2008) suggest that the functional distance hypothesis may not be the best explanation of dual-task interference.

Parkinson’s Disease

Idiopathic Parkinson’s disease (PD) is a progressive, degenerative neurological disorder that affects upwards of 1.5 million people in the United States. Parkinson’s disease has no known

cure. The average onset is after age 50, the incidence of PD increases with age, and both men and women are equally affected. Diagnosis of PD is made clinically through the identification of four symptoms: resting tremor, rigidity, akinesia, and postural instability. All four of these motor symptoms are neurologically based and are caused by a dopamine insufficiency due to Lewy body lesions in the basal ganglia, specifically the substantia nigra. Those same Lewy body lesions can interfere with communication between neurons causing a cognitive loss that can lead to dementia. “Declines in cognitive performance are associated with the risk of mortality, declines in social interaction, and limited performance of instrumental activities of daily living” (Stegemöller et al., 2014, p. 758).

Individuals with PD can have changes in gait due to motor system difficulties. These changes can lead to increased fall risk, thereby increasing the possibility of injuries. Stegemöller et al. (2014) concluded that “associations between cognitive and gait performance are dissociable and may be differentially affected by dual-task walking due to the pathology of PD” (p. 765). Language is a cognitive process and if gait performance is dissociable from cognition, dual tasking that involves speaking and walking could be very difficult for those with PD. Stierwalt, LaPointe, Maitland, and Toole (2008) found that “analyses on gait measures revealed that manipulating the complexity of cognitive-linguistic tasks affected parameters of gait during simultaneous walking and talking” (p. 264).

Hypokinetic dysarthria, a motor speech disorder, occurs as a result of the lack of dopamine production in the basal ganglia and substantia nigra. The loss of dopamine, which regulates movement, makes it difficult to achieve articulatory targets. Many muscles, including those in the lips, tongue, vocal folds, and diaphragm, are involved in the speech process. When the control of speech muscles becomes impaired, speech becomes slowed, imprecise, and

difficult to understand. This impairment affects the ability to communicate effectively (Holmes, Oates, Phyland, & Hughes, 2000).

Parkinson's disease can affect all the physiological subsystems of speech, leading to changes in respiration, phonation, articulation, and prosody. Difficulties with these subsystems affect intelligibility, breath support, resonance, voice and loudness. These problems can be progressive. Intelligibility can be affected by disfluencies and spiratization (frication of stops that cause distortion). In connected speech, a lack of breath support may cause weak, breathy speech with short rushes, inappropriate pauses, and reduced phrase length. Voice can become monopitch and hypernasal while loudness is decreased and monoloud. These characteristics increase in severity as PD progresses (Holmes et al., 2000).

Even though it is defined as a movement disorder, PD is not purely a motor condition. "Difficulties inherent in idiopathic PD go well beyond the motoric sphere that affect ambulation and motor speech production" (Lewis, LaPointe, Murdoch, & Chenery, 1998, p. 204). Non-motor symptoms are often present before diagnosis, and include loss of smell, autonomic disorders, depression, cognitive impairment, sexual dysfunction, constipation, low blood pressure upon standing, pain, psychosis, and sleep disorders. As the disease progresses, these non-motor symptoms of PD can greatly reduce the quality of life for an individual (Chaudhuri, Healy, & Schapira, 2006).

Multitasking is a cognitive process. The non-motor symptoms of "cognitive impairments in PD manifest as deficits in speed of processing, working memory, and executive function and attention abilities" (Stegemöller et al., 2014, p. 757). In another study (LaPointe et al., 2010), it was observed that in a dual-task condition of walking while talking, the group with PD failed to use the compensatory strategy of increasing double support time (spending more time with both

feet on the ground) while walking in order to reduce the risk of falling. Stegemöller et al. (2014) found that “temporal and postural aspects of gait may be related to different cognitive domains, which can be differentially impaired by dual-task walking due to the pathology of PD” (p. 763). Conversely, this current study will examine whether language is affected in a dual-task condition of walking while speaking.

Parkinson’s disease can affect both language and cognition (Lewis et al., 1998). Lewis et al. found 40% of the participants with PD to have below normal cognitive functioning on the Mattis Dementia Rating Scale (MDRS). Those individuals scored significantly lower in 9 of 13 language measures than did their PD counterparts without loss of cognitive functioning. Whether or not an individual with PD experienced cognitive loss, “a high level of language deficit in a sample of PD participants with normal and below normal cognitive functioning was found” (Lewis et al., p. 204). “Documenting language, as well as speech difficulties is the first step toward developing intervention procedures” (Berg, Björnram, Hartelius, Laakso, & Johnels, 2003, p. 78).

The current study will consider the effects of a dual-task condition on the complexity of spontaneous language in individuals with PD and control speakers. Therefore, it is necessary to consider how language is affected by normal aging. A study of spontaneous language in the older normal population found that aging did not show “consistent trends for expressive language parameters to decline with increasing age” (Shewan & Henderson, 1988, p. 148). Kemper, Kynette, Rash, and O'Brien (1989) found that “young adults with greater memory capacity produce more complex sentences containing more clauses” (p. 63) than older adults.

Language Measures

Language complexity can be analyzed in various ways. Mean length of utterance (MLU), T-units, and mean number of clauses per utterance (MCU), are examples of measures of language complexity. Nippold (2007) states, “the use of subordinate clauses is an important syntactic attainment” (p. 260) and that growth in sentence length gradually continues into adulthood. This statement supports the use of MLU and MCU in determining language complexity. Some researchers have developed proprietary software to measure language complexity (Shewan & Henderson, 1988). Systematic Analysis of Language Transcripts (SALT) is a commonly used software application to analyze language complexity. This current study will use SALT software to evaluate the MLU in morphemes (MLUm). Noun clauses, relative clauses, and adverbial clauses will be evaluated to determine the syntactic complexity of utterances.

Purpose of the Present Study

Multitasking for individuals with PD, specifically walking and talking, is a difficult endeavor (Galletly & Brauer, 2005). People with PD have documented motor deficits and possible cognitive deficits. In a dual-task condition of producing spontaneous language while walking in different conditions, attention is divided. This endeavor can lead to falls, even injurious falls. When attention is directed to walking, will language complexity be compromised? This current study will examine the complexity of language produced in three conditions: standing, walking, and walking over obstacles. Mean length of utterance in morphemes (MLUm) and the use of noun, adverbial, and relative clauses will be evaluated to determine language complexity in each condition. It is hypothesized that language complexity will decrease as motoric difficulty increases in the dual task condition.

Method

The current work is part of a larger study conducted at the University of Utah in the Motion Capture Core Facility (MOCAP). The larger study is primarily concerned with the collection of gait and stride data. Lorinda Smith, a doctoral candidate at the University of Utah, collected the speech samples. They were released with University of Utah Institutional Review Board (IRB) approval to Brigham Young University for the study of spontaneous language structure.

Participants

Thirty-seven individuals in three groups participated in the study: individuals with PD (10), neurologically Healthy Older (14), and neurologically Healthy Younger (13). Inclusion criteria for the patients with PD included: medically confirmed diagnosis of mild to moderate idiopathic PD, ≥ 40 years old, and the ability to participate. Individuals using dopamine replacement drugs were tested 1 to 1.5 hours after taking medication. Healthy Older (HO) participants were age- and gender-matched to the participants with PD. Because of minimal fall risk during balance testing, all participants were medically cleared for participation. Exclusion criteria included: orthopedic, cardiovascular, or other health concerns that may make participation difficult or unsafe; lower limb neuropathy; surgical treatment of PD; cognitive impairment that limits participation; uncorrected vision/hearing loss that limits participation; and significant or frequent freezing episodes when on medication. The primary recruitment source for participation was the Parkinsonism Exercise Program at the University of Utah Rehabilitation and Wellness Clinic.

Instruments

A Bertec side-by-side dual-belt treadmill (Columbus, Ohio) with removable safety rails

on the sides and front was used for the conditions involving walking. A head-mounted USB microphone was used to record the spoken language samples into a lab computer with Audacity software (<http://audacity.sourceforge.net/>). A VICON Motion Analysis System (Oxford, United Kingdom) was used to collect marker-based gait data for the larger study and does not pertain to the current report.

Procedure

Each participant signed a consent form prior to testing and provided relevant demographic information. Each participant was given a list of possible conversational topics to choose from during testing. The participant would say next when he/she had exhausted a topic and the test administrator would present the next topic. Each participant was secured by a tether release system during testing to prevent any injury in case of a fall.

Each participant produced spontaneous monologues under three conditions: standing while talking, walking on a treadmill while talking, and talking while walking on a treadmill as random obstacles were intermittently placed on the treadmill. The speech of each participant was recorded in each condition.

Data Analysis

Three undergraduate students from the Communication Disorders department at BYU were employed to transcribe the recordings using the SALT transcription conventions. SALT software was used to analyze the language samples to compute the mean length of utterance in morphemes (MLUm), the number of words used, and different number of words used.

The frequencies of noun, adverbial, and relative clauses used in each sample were tabulated as indicators of syntactic complexity. The frequencies of these three embedded clause types were also summed to yield a total number of embedded clauses. These totals as well as the three type

frequencies were each divided by the number of utterances in the sample to allow comparison of syntactic complexity for samples of different lengths.

Results

Changes in the dependent measures across the conditions of standing, walking, and obstacle walking were tested with SPSS software using a repeated measures analysis of variance (RM-ANOVA). Concurrent contrasts were run to reveal which conditions differed from the baseline (standing) condition. Group and gender were included as between-subject factors, and significant differences were examined in greater detail with post hoc testing (Tukey HSD). Descriptive statistics were computed for each group by condition and are reported in Table 1. While gender was included as a factor in the ANOVA testing, there were no significant gender effects; therefore, all results presented below are combined for men and women.

Table 1

Descriptive Statistics all Dependent Variables for the Healthy Young Group

Variable	Stand		Walk		Obstacle	
	Mean	SD	Mean	SD	Mean	SD
MLU	15.05	2.8	13.51	2.56	13.73	3.36
RCA	0.14	0.07	0.12	0.06	0.12	0.05
ACA	0.3	0.15	0.23	0.12	0.29	0.17
NCA	0.59	0.21	0.42	0.13	0.55	0.27
TCA	1.04	0.25	0.78	0.22	0.96	0.36
Words_Min	154.83	25.41	147.33	35.01	122.02	32.13
Diff_Min	66.16	9.34	64.58	9.95	58.06	14.8
RC_Min	1.72	0.73	1.7	0.88	1.3	0.75
AC_Min	3.62	1.65	3.15	1.7	3.06	1.75
NC_Min	7.48	3.62	5.64	2.19	5.56	2.39
TC_Min	12.82	4.42	10.49	3.97	9.92	3.43

Note. SD = standard deviation, MLU_m = mean length of utterance in morphemes, RCA = relative clauses per utterance, ACA = adverbial clauses per utterance, NCA = noun clauses per utterance, TCA = total clauses per utterance, Words_Min = words per minute, Diff_Min = different words per minute, RC_Min = relative clauses per minute, AC_Min = adverbial clauses per minute, NC_Min = noun clauses per minute, TC_Min = total clauses per minute, Nutts_Min = utterances per minute.

Table 2

Descriptive Statistics for all Dependent Variables for the Healthy Older Speakers

Variable	Stand		Walk		Obstacle	
	Mean	SD	Mean	SD	Mean	SD
MLU	14.54	4.28	14.57	3.90	14.09	3.75
RCA	0.16	0.12	0.16	0.13	0.16	0.12
ACA	0.24	0.08	0.18	0.13	0.25	0.12
NCA	0.47	0.23	0.56	0.29	0.51	0.22
TCA	0.87	0.36	0.90	0.32	0.93	0.37
Words_Min	131.08	28.61	114.84	26.16	111.03	32.60
Diff_Min	61.97	12.31	57.33	12.37	49.55	11.56
RC_Min	1.74	0.94	1.52	1.17	1.49	0.92
AC_Min	2.92	1.26	1.88	1.49	2.45	1.12
NC_Min	5.47	2.09	5.22	2.21	4.77	2.09
TC_Min	10.13	3.24	8.62	2.95	8.71	3.26
Nutts_Min	12.03	2.29	10.00	2.64	10.04	2.46

For abbreviations, see Table 1.

Table 3

Descriptive Statistics for all Dependent Variables for the Speakers with Parkinson's Disease

Variable	Stand		Walk		Obstacle	
	Mean	SD	Mean	SD	Mean	SD
MLU	13.48	3.44	14.97	4.59	12.45	2.90
RCA	0.12	0.08	0.16	0.10	0.13	0.08
ACA	0.25	0.13	0.25	0.14	0.19	0.12
NCA	0.45	0.22	0.48	0.25	0.31	0.10
TCA	0.82	0.34	0.89	0.40	0.63	0.21
Words_Min	125.50	27.04	118.72	28.41	107.86	26.42
Diff_Min	58.64	10.16	60.20	12.05	53.15	13.53
RC_Min	1.28	0.69	1.42	0.72	1.36	0.86
AC_Min	2.72	1.58	2.14	0.56	1.79	0.93
NC_Min	4.77	2.63	4.46	1.88	3.39	1.64
TC_Min	8.78	3.98	8.02	2.30	6.55	1.96
Nutts_Min	11.80	3.66	10.35	4.38	11.14	4.37

For abbreviations, see Table 1.

The number of words per minute differed significantly across the conditions of standing, walking, and obstacle, $F(2, 62) = 22.129$; $p < .001$, $\eta_p^2 = .417$. The within-subjects contrast showed a significant difference between the conditions of standing and walking, $F(1, 31) = 7.350$, $p < .011$, $\eta_p^2 = .192$. As seen in Figure 1, the number of words per minute decreased from standing to walking. The decrease of the number of words per minute was even greater between the conditions of standing and obstacle, $F(1,31) = 41.276$, $p < .001$, $\eta_p^2 = .571$. The three groups did not differ significantly from each other at the $p < .05$ level, although the HO and PD groups both produced fewer words per minute than the HY group, $F(2, 31) = 3.131$, $p < .058$.

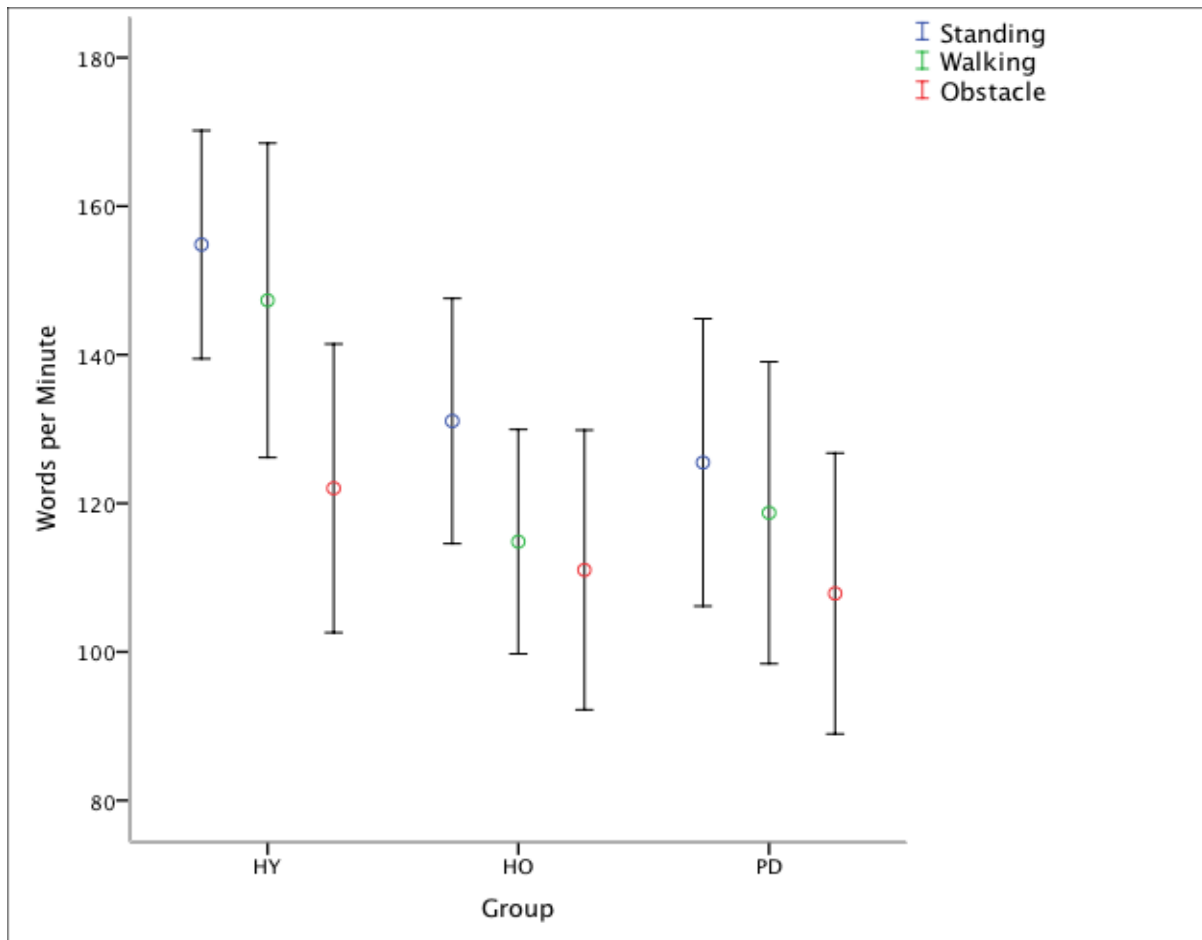


Figure 1. Mean (and 95% confidence interval) for words per minute.

The number of different words per minute differed significantly across the conditions of standing, walking, and obstacle, $F(2, 62) = 14.451$; $p < .001$, $\eta_p^2 = .318$. As seen in Figure 2, the count of different words per minute decreased from standing to obstacle for all three groups. Within-subjects revealed this difference to be significant, $F(1, 31) = 22.751$, $p < .001$, $\eta_p^2 = .423$. There were no differences between the three groups.

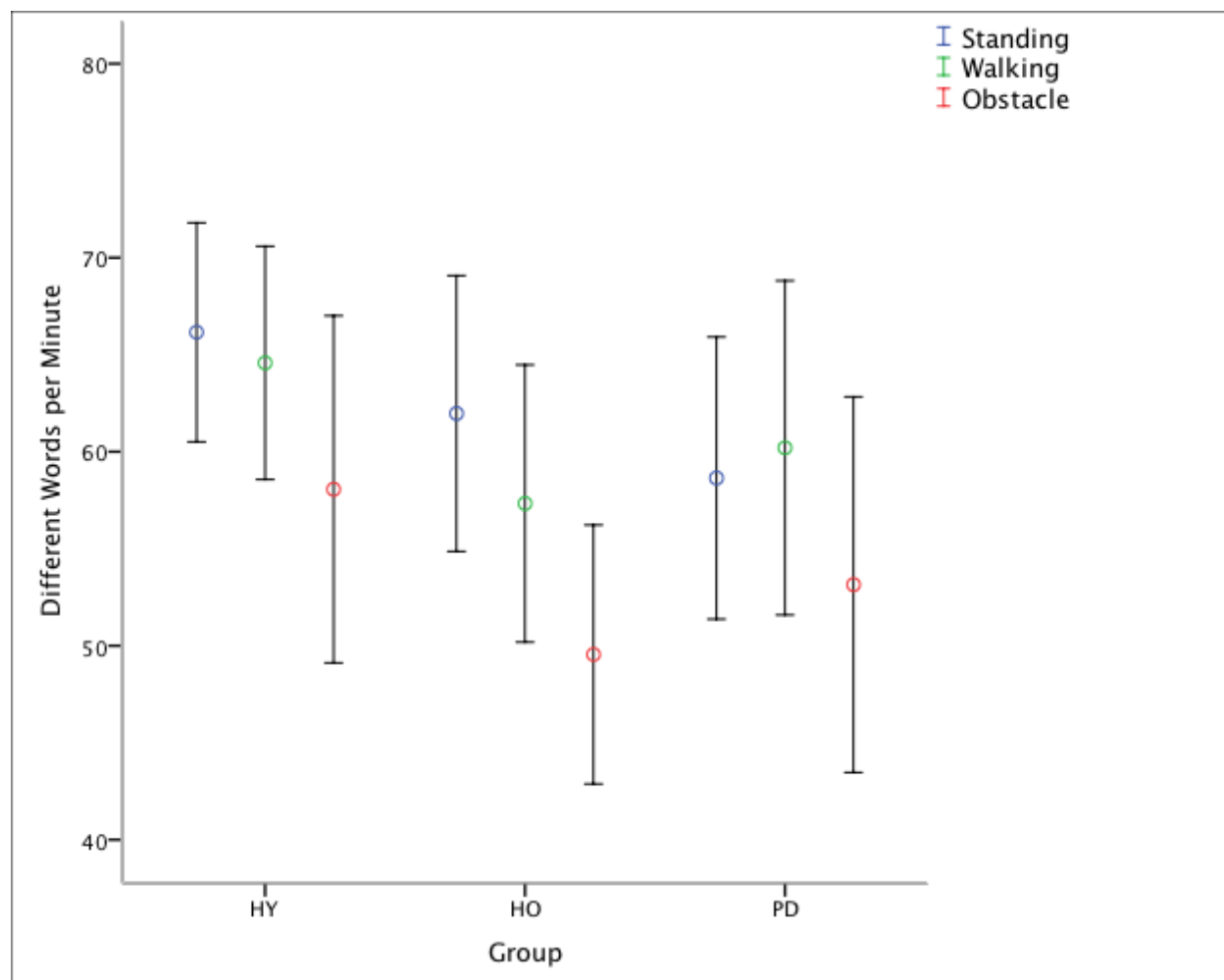


Figure 2. Mean (and 95% confidence interval) for different words per minute.

The number of adverbial clauses per minute differed across the conditions of standing, walking, and obstacle. Although this difference was not statistically significant at $p < .05$, a downward trend was noted, $F(2, 62) = 2.949$, $p < .06$, $\eta_p^2 = .087$. Figure 3 shows the number of

adverbial clauses per minute for each condition and group. Within-subject contrasts revealed a significant decrease in the number of adverbial clauses per minute between the conditions of standing and walking, $F(1,31) = 4.731, p < .037, \eta_p^2 = .132$. There was also a decrease in the number of adverbial clauses per minute between the conditions of standing and obstacle, $F(1, 31) = 4.153, p < .050, \eta_p^2 = .118$. There was a significant between subjects effect, $F(2, 31) = 4.974, p < .013, \eta_p^2 = .243$. Figure 3 shows that the HY group produced more adverbial clauses per minute than the HO and PD groups. Post hoc comparisons showed a statistically significant difference between HY and HO, $p < .047$ and HY and PD, $p < .023$.

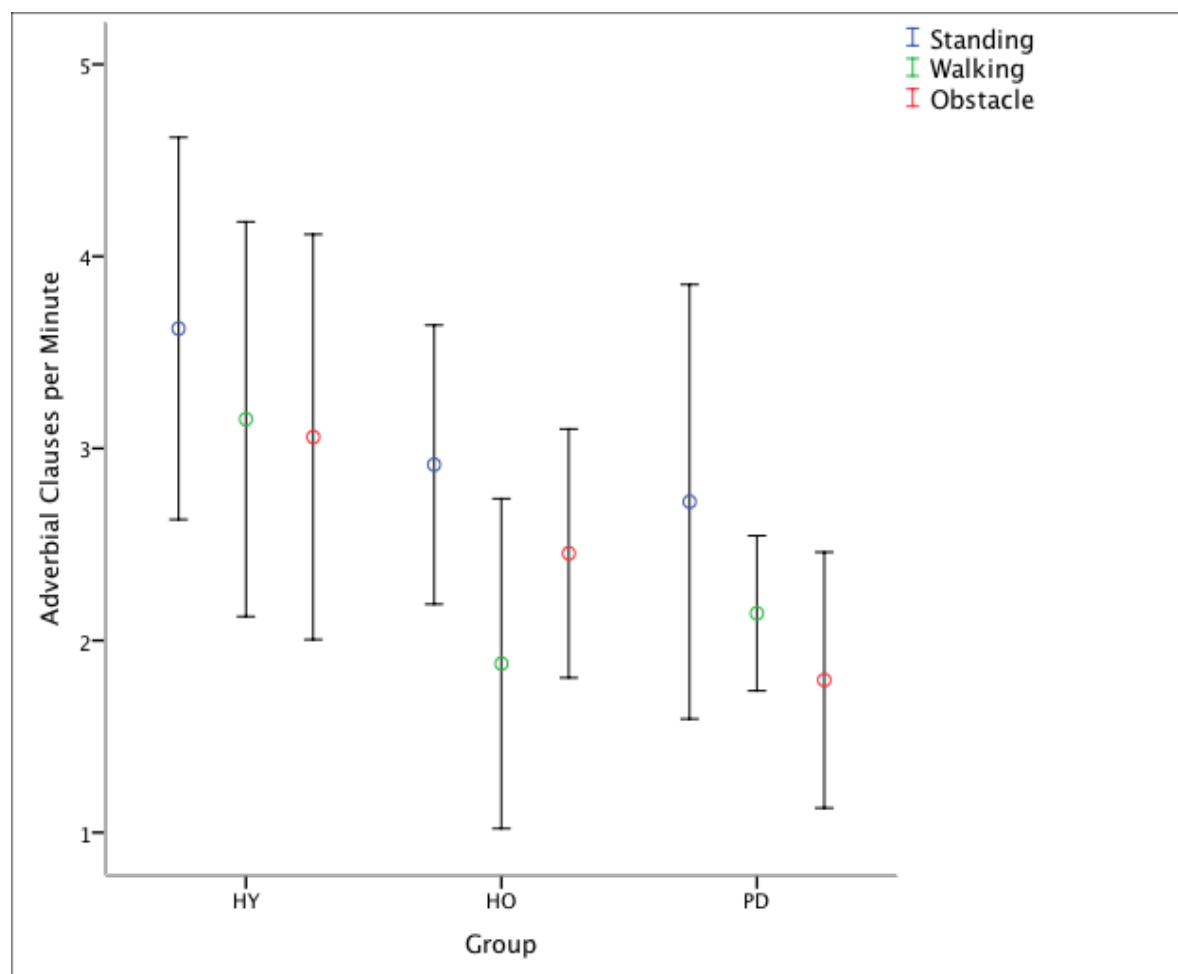


Figure 3. Mean (and 95% confidence interval) for adverbial clauses per minute.

The number of noun clauses per minute differed significantly across the conditions of standing, walking, and obstacle, $F(2,62) = 3.428$; $p < .039$, $\eta_p^2 = .100$. Figure 4 shows the number of noun clauses per minute for each condition and group. There was a decrease in the number of noun clauses per minute between the conditions of standing and obstacle. The within-subject contrast revealed this effect to be significant, $F(1,31) = 5.130$, $p < .031$, $\eta_p^2 = .142$. There was a significant between subjects effect for group, $F(1,31)=3.971$; $p < .029$, $\eta_p^2 = .204$. Post hoc results revealed that number of noun clauses for the HY group was significantly greater than for the PD group ($p < .023$).

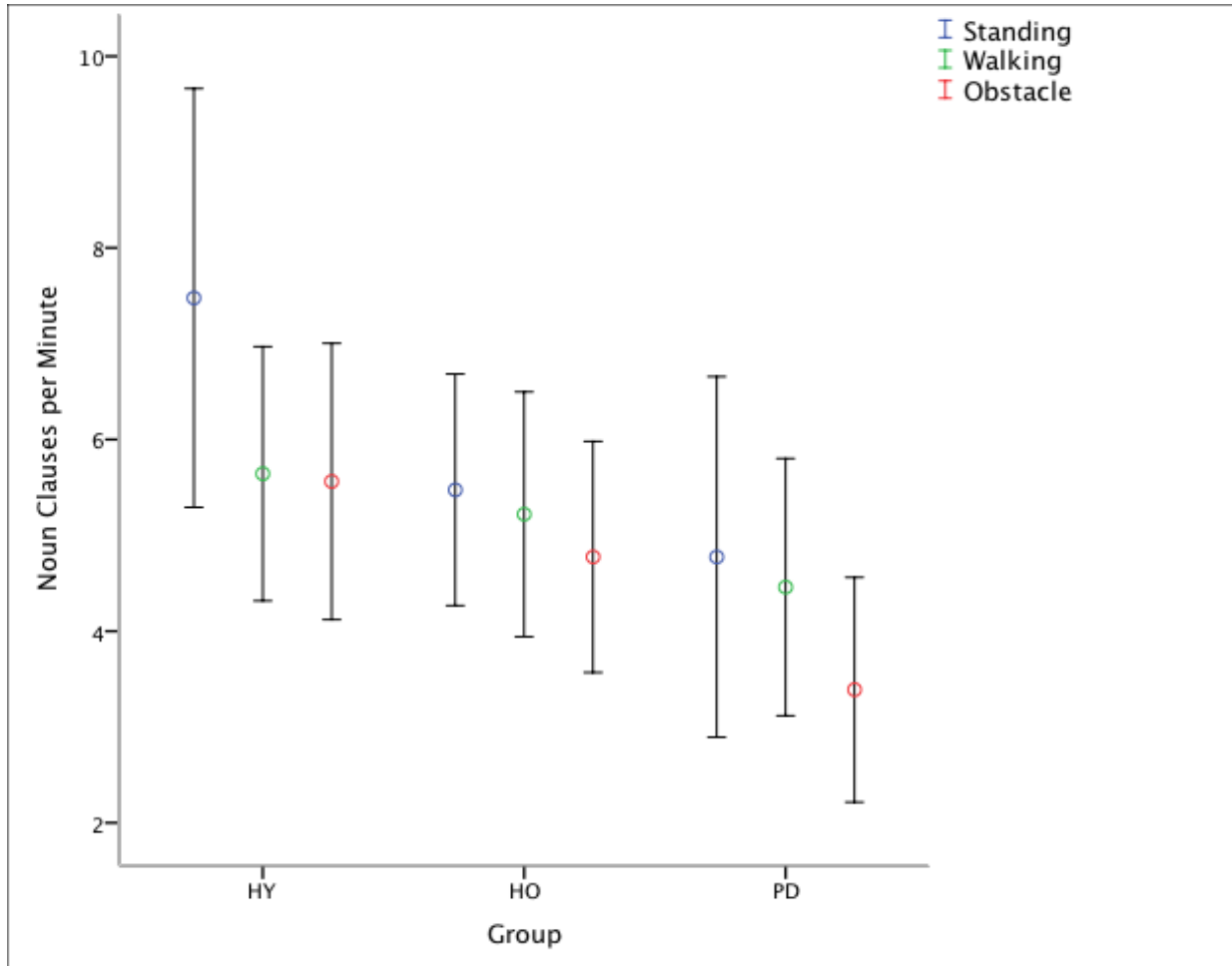


Figure 4. Mean (and 95% confidence interval) for noun clauses per minute.

The number of total clauses per minute differed significantly across the conditions of standing, walking, and obstacle, $F(2, 62) = 5.885$; $p = .005$, $\eta_p^2 = .160$. Figure 5 shows that the number of total clauses per minute decreased from the standing condition to the walking condition for all three groups. The number of total clauses per minute further decreased to the obstacle condition. The within-subjects contrasts showed that the difference between the standing and walking conditions was significant, $F(1, 31) = 4.620$, $p = .040$, $\eta_p^2 = .130$. The difference between the standing and obstacle conditions was also significant, $F(1, 31) = 9.244$, $p < .005$, $\eta_p^2 = .230$. There was a significant between subjects effect, $F(2, 31) = 4.560$, $p < .018$, $\eta_p^2 = .227$. Post hoc comparisons showed a significant difference between HY and PD, ($p = .016$).

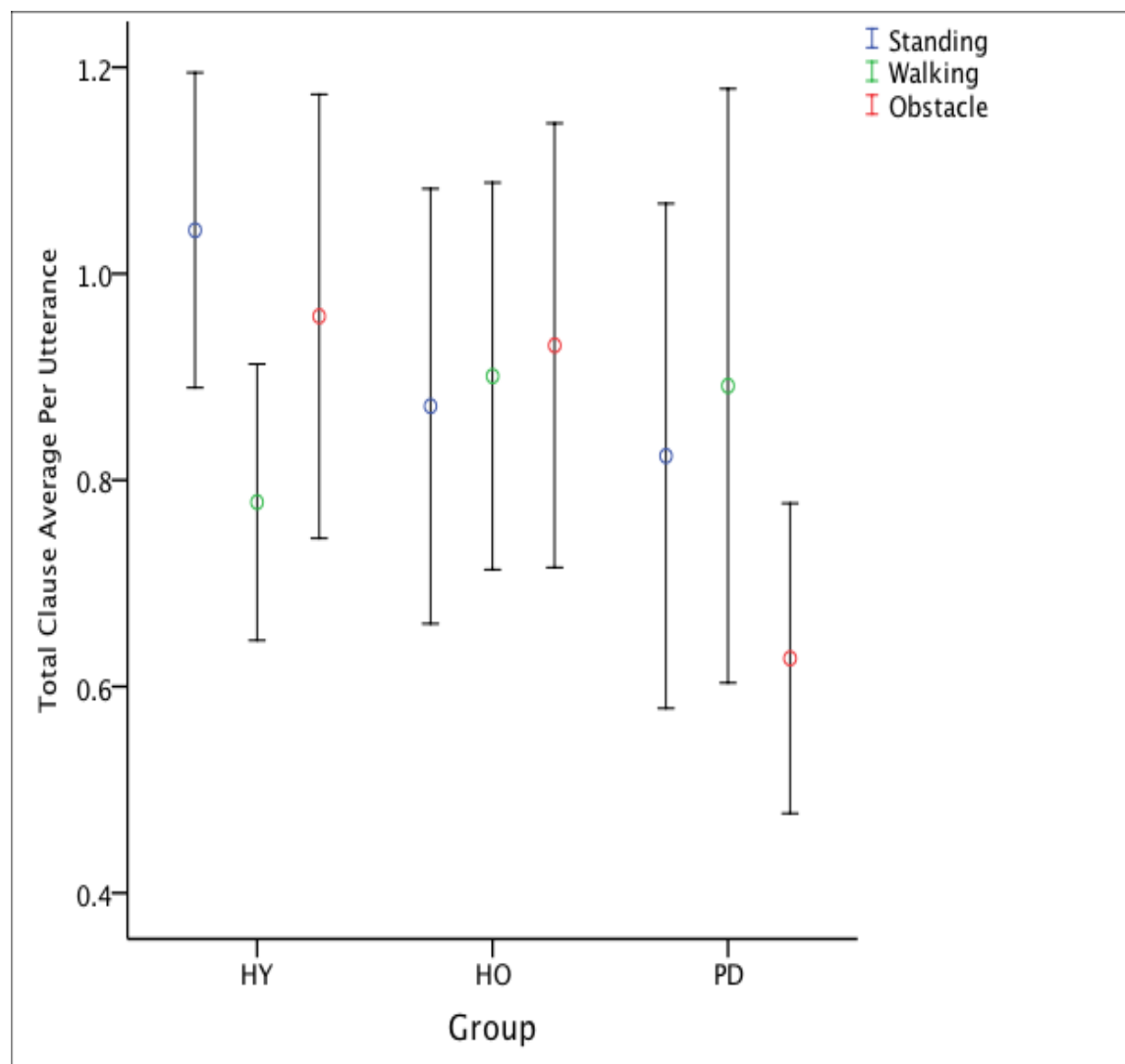


Figure 5. Mean (and 95% confidence interval) for total clauses per minute.

The number of utterances per minute differed significantly across the conditions of standing, walking, and obstacle, $F(2, 62) = 4.287$; $p < .018$, $\eta_p^2 = .121$. Figure 6 shows that the number of utterances per minute decreased between the conditions of standing and obstacle for all groups. The within-subjects contrast showed this difference to be significant, $F(1, 31) = 6.516$, $p < .016$, $\eta_p^2 = .174$. There was a significant condition by group interaction, $F(4, 62) = 3.324$, $p = .016$, $\eta_p^2 = .177$. As seen in Figure 6, the HO group showed a decrease in number of utterances per minute compared to the HY group. The within-subject contrast for the

condition by group interaction was significant between the standing and obstacle conditions, $F(2,31) = 6.701, p = .004, \eta_p^2 = .302$.

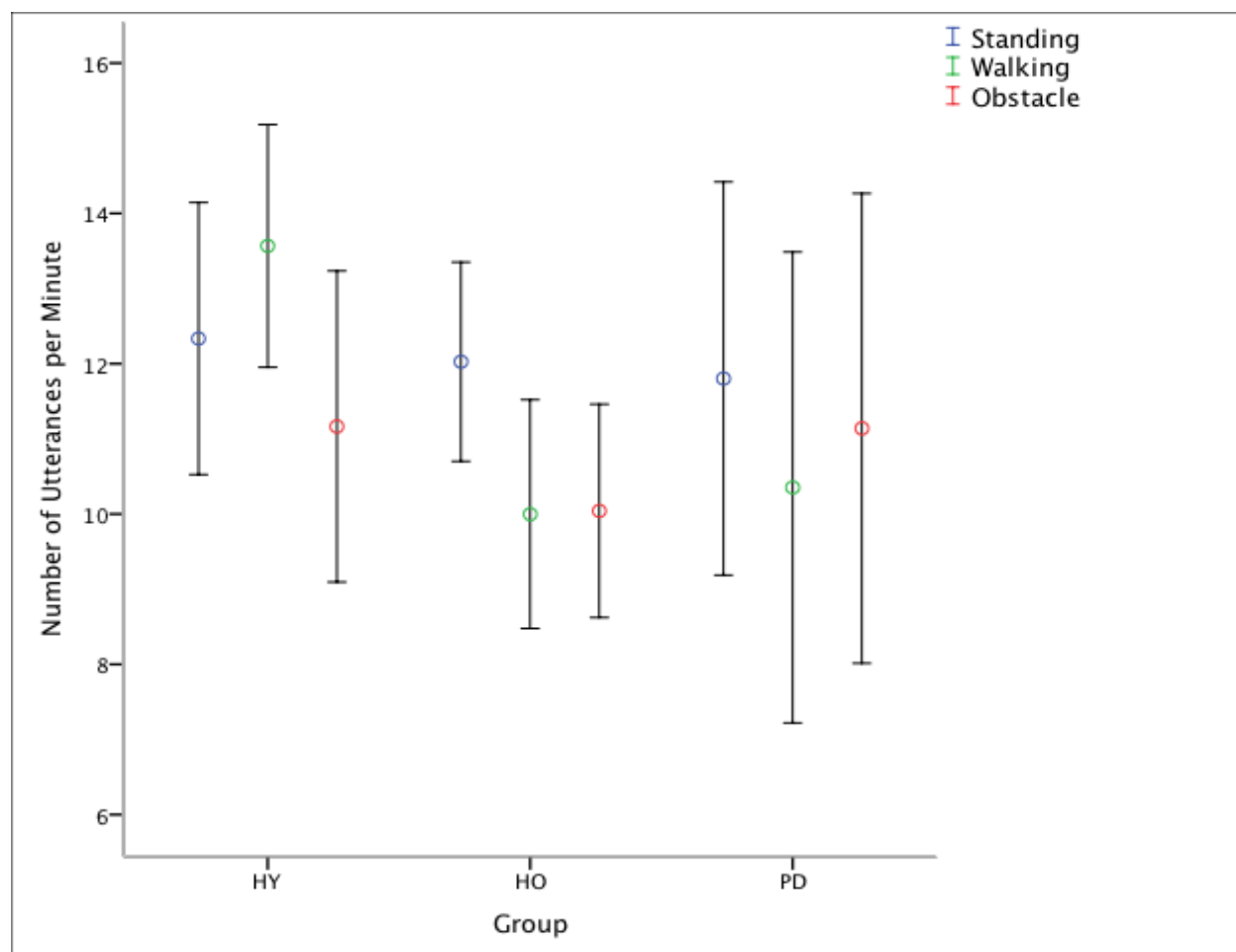


Figure 6. Mean (and 95% confidence interval) for number of utterances per minute.

The noun clause average per utterance across three conditions did not differ significantly as a main effect. However, there was a significant condition by group interaction,

$F(4, 62) = 2.578, p = .046, \eta_p^2 = .143$. As seen in Figure 7, the HY group had a decrease in the number of noun clauses per utterance between the condition of standing and walking and a small decrease between standing and obstacle. The HO group showed the opposite pattern of an increase in noun clauses per utterance from standing to walking and a small increase from standing to obstacle. This difference in the effect of condition across groups resulted in a

significant condition by group contrast between the standing and walking conditions

$F(1, 31) = 3.656, p = .038, \eta_p^2 = .191$.

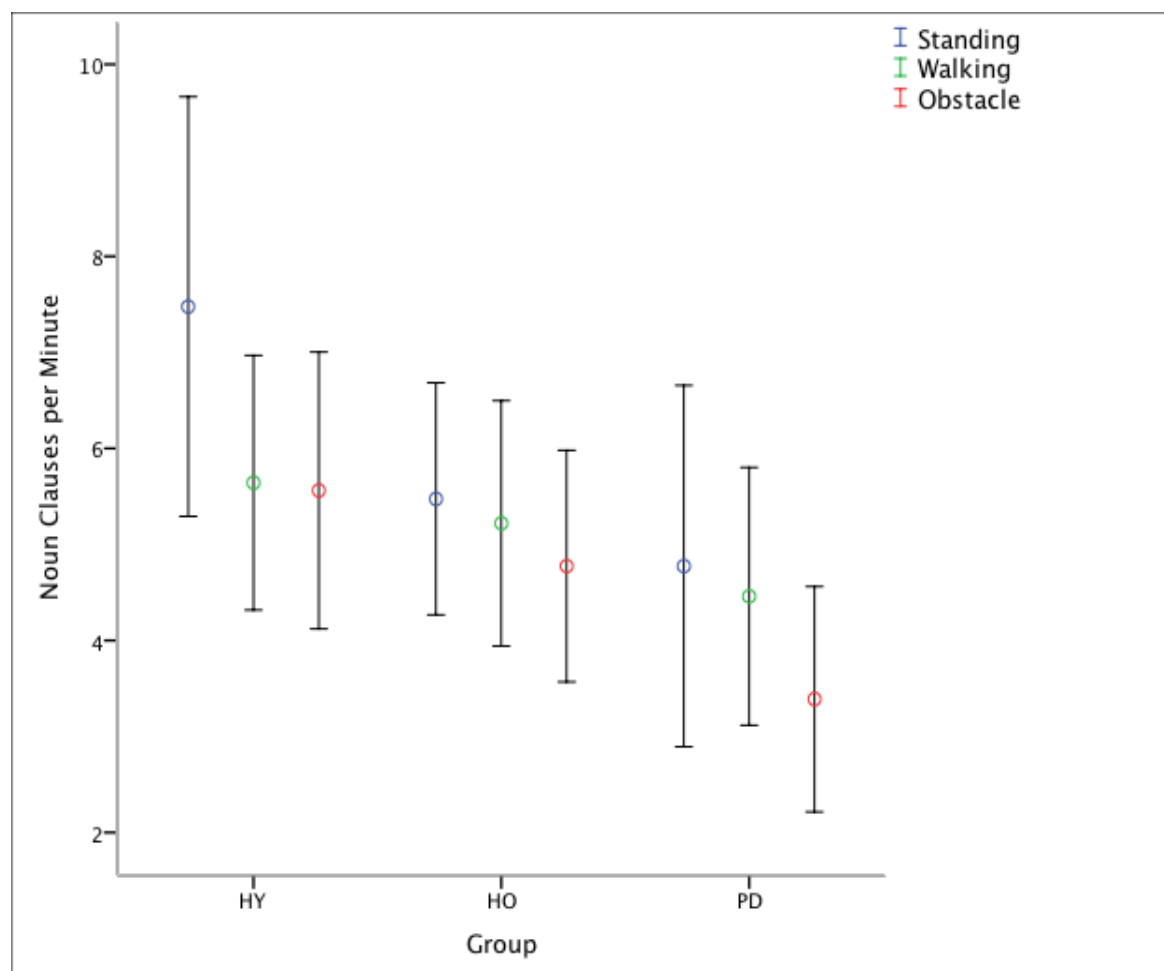


Figure 7. Mean (and 95% confidence interval) for noun clause average per utterance.

The total clause average per utterance across three conditions did not differ significantly as a main effect. However, there was a significant condition by group interaction, $F(4, 62) = 3.108; p = .021, \eta_p^2 = .167$. Figure 8 shows that the HY group had a decrease in the total clause average per utterance between standing and walking and a smaller decrease between standing and obstacle. The HO group showed an opposite trend, with a small increase in total clause average per utterance from standing to walking and another small increase from standing

to obstacle. None of the contrasts between conditions were significant for main effects of condition or interaction with group.

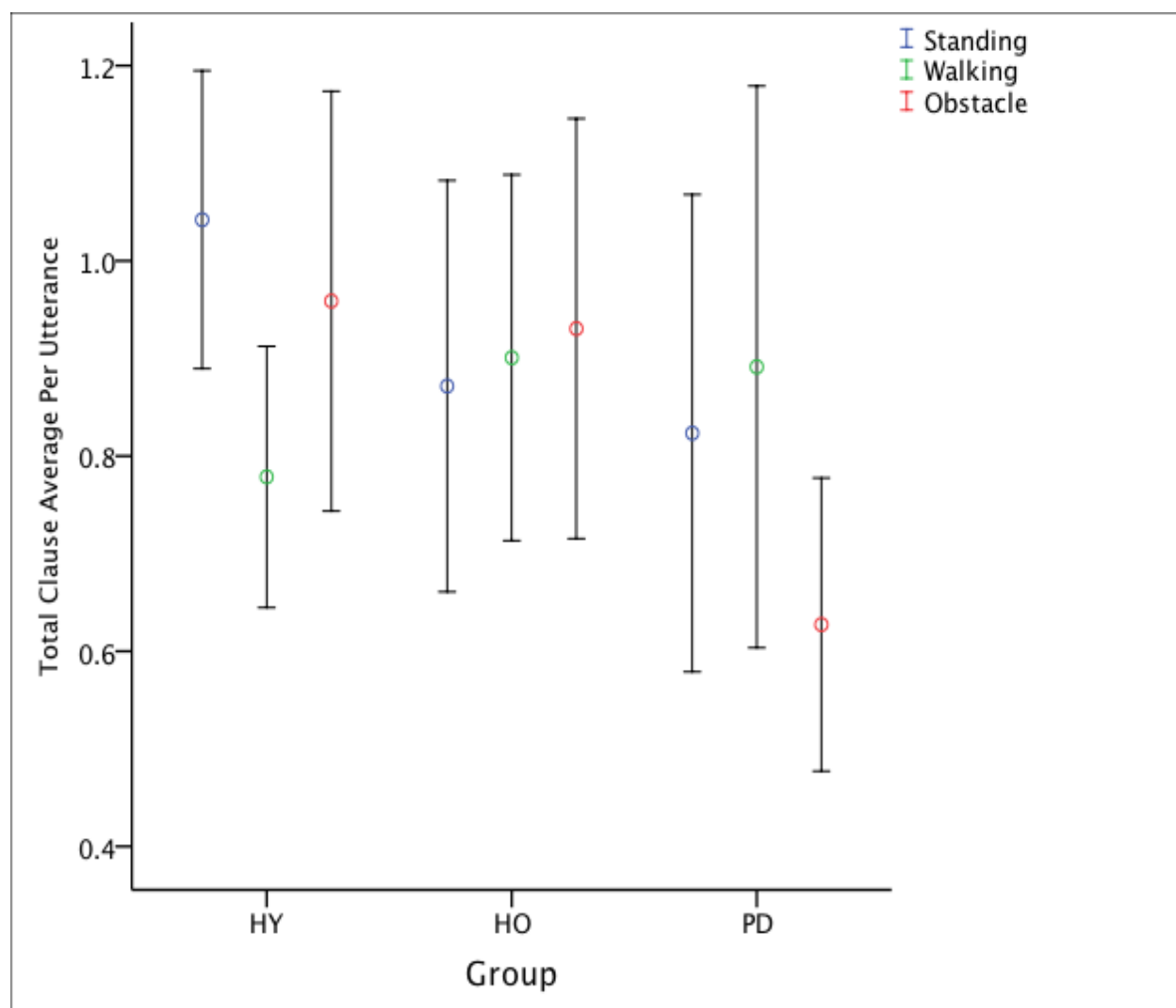


Figure 8. Mean (and 95% confidence interval) for total clause average per utterance.

Discussion

Walking and talking are two higher-level tasks that draw on finite cognitive resources. This study examined the effects of dual tasking on several measures of language complexity in individuals with PD and in the control groups, HO and HY. The number of words per minute, the number of different words per minute, the number of noun clauses per minute, the number of total clauses per minute, and the number of utterances per minute decreased significantly as the

motoric task complexity increased from standing to walking to obstacle conditions. Also, a downward trend was found for the number of adverbial clauses per minute as the treadmill task increased in complexity. These effects suggest that as motoric tasks became more complex, there was a cost to the production of complex language. In other words, when attentional resources normally used for the production of language are directed to an increasingly challenging motor task, language complexity will significantly decrease.

The novelty of the current study lies in its focus on the effects of a dual condition on language complexity. An examination of the current literature shows that previous studies have generally focused on the effects of a speaking task on the kinematic aspects of gait, (LaPointe et al., 2010). Two studies represent an exception to the general trend of focusing on gait rather than speech/language in dual-task studies. The current study results are consistent with the findings from these earlier works (Cheung, 1992; Kemper, Schmalzried, Hoffman, & Herman, 2010). These studies found that language production variables were negatively impacted by a dual-task condition. Although these studies used different language variables than those used in the current study, there was an overlap for MLU and for what they referred to as mean clause per utterance (MCU) that could be loosely compared to our measure of total clauses per utterance.

Subordinate clauses are syntactic elements used to increase complexity (Nippold, 2007). Post hoc results of the current study revealed significant differences between the PD and HY groups. The PD group produced fewer adverbial clauses per minute, noun clauses per minute, and total clauses per minute than the younger speakers. Illes, Metter, Hanson, and Iritani (1988) found that syntactic complexity during spontaneous speech decreased according to the severity of PD. The current study lends support to previous findings of reduced syntactic complexity in speakers with PD.

Adverbial clauses decreased, as the gait task became more challenging; however the decrease was not significant. While noun clauses per minute and total clauses per minute decreased significantly as the gait task became more challenging, relative clauses per minute did not. This is likely because very few relative clauses were produced during the monologues. This may be because the prompts that were supplied to the participants were open-ended question tasks that elicited conversational style monologues, and were more likely answered using adverbial clauses that explain when, where, why, or how, and noun clauses that are direct objects of *I think this* or *I feel this*. Relative clauses function as adjectives, and answer questions such as which one, how many, and what kind. Relative clauses are more conducive to expository language that is used to convey information, e.g. *Queen bees, who have larger bodies, live longer than worker bees*.

Limitations of Current Study and Directions for Future Research

Language samples were collected by a physical therapist who was also collecting gait data for other purposes. One limitation of the current study was that the recordings were not regulated for duration; therefore the length of the recordings varied across conditions and speakers. During the recordings, the participants could be interrupted during their monologues to replace a body marker used for gait kinematic measures or for management of equipment. These interruptions could have affected language behavior. To compensate for the varying recording lengths, a *per minute* calculation was employed for the language variables that were used for this current study. It is recommended that future studies control for the recording of uninterrupted language production for a predetermined length of time when gathering language samples. This would allow a more straightforward comparison of language performance across the experimental conditions.

Previous work has shown that adults tend to produce longer sentences when using an expository style of language, so it is recommended that expository discourse be used in the collection of language samples for future studies. In the current study, the experimenter provided the participants with a long topic list, and asked them to choose several that they would be comfortable speaking about. As a topic from the list of preferred questions was provided during the experiment, the participant chose to either talk about that topic, or they could pass and move on to the next topic. The monologues they produced typically reflected their opinions regarding the chosen topic. Expository language draws on the personal knowledge of the speaker/writer (Nippold, 2007). In a future study, the participants could be asked to explain the rules of their favorite game or give a “how to” tutorial. So while the study would dictate the language style of the presentation, the participant would choose the topic from their personal knowledge base. Because this style of discourse has been found to produce longer sentences, the measure of MLU may reflect differences. It would be interesting to measure and compare T-units (complete sentences) and C-units (utterances that are incomplete sentences). For this current study, SALT analyses counted both incomplete and complete sentences as utterances. Based on the observation of the raw data, it is predicted that the measurement of T-units and C-units would bear significant differences.

Clinical Implications

The findings of the current study have clinical implications for both the assessment and treatment of patients with communication disorders. In a clinical setting language is usually assessed in relative isolation. The clinician and patient typically interact in a quiet, distraction-free environment. The results from the current study suggest that deliberately assessing language under divided attention conditions could allow a more realistic evaluation of how our patients

function in everyday life.

There are also implications for therapy. The dual-task condition could be used as a therapy tool. After an individual shows improvement in performing a language task in a distraction-free condition, a concurrent task could be added to therapy in gradual steps to help them become more robust in their everyday language performance. A recommendation for single task communication could be made and reinforced as well.

Another consideration for therapy is conversation between communication partners. Often, the beginning of a serious phone conversation begins with the words “Are you sitting down?” or a face-to-face conversation might begin with “Perhaps you should sit down.” The current findings suggest that sitting or creating a single-task condition would allow for the use of more complex language during conversation. This may lead to better communication with family and friends.

Conclusion

Only a handful of studies have considered the effects of dual tasking on language. The current findings support previous work by suggesting that in the dual-task condition, language complexity decreases as a motoric task’s difficulty increases. The language variables that were adversely affected by the motoric dual task of walking while talking were the number of words per minute, the number of different words per minute, the number of noun clauses per minute, the number of total clauses per minute, and the number of utterances per minute. One or more of these variables reflected a decrease in the language complexity of all three groups: HY, HO, and PD. The language complexity decreases of the HO group and the PD group were greater than those of the HY group. The ability to communicate effectively allows individuals to express their wants and needs and is foundational in developing and maintaining familial and social

relationships. The findings of the current study suggest that further research in this area is warranted.

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APPENDIX A: ANNOTATED BIBLIOGRAPHY

Berg, E., Björnram, C., Hartelius, L., Laakso, K., & Johnels, B. (2003). High-level language difficulties in Parkinson's disease. *Clinical Linguistics & Phonetics*, 17,63-80.
doi:10.4061/2011/238956

Objectives: The objective of this study was to identify language difficulties in individuals with PD who have normal cognition. *Methods:* Twenty-six individuals with PD and normal cognition were matched by age, gender, and level of education with a control group of 26 healthy individuals. The participants were tested in high-level language that included repetition of long sentences, recreating sentences, making inferences, comprehension, word definitions, word fluency, the Boston Naming Test, sentence analysis, and morphological completion. *Results:* The primary deficit for the individuals with PD was making inferences or drawing conclusions from presented or implied information or recognizing when information was omitted. The other subtest with a significant difference was the ability to analyze sentences. Other language subtests that were presented did not show significant deficits. *Conclusion:* The authors noted a correlation between the performances on the high-level language test battery with the performance on the test of cognitive function. This correlation may indicate a functional interplay between cognition and language. The clinical implication would be that documenting speech and language difficulties may lead to the development of intervention procedures. Another important outcome was that even though the participants with PD did not perform with a significant difference in some of the language subsets, they reported subjective language problems in those areas that need to be addressed. The authors also suggested that further studies should increase the number of subjects, and that language tasks should be carefully designed and analyzed. *Relevance to the current study:* When comparing individuals with PD to the healthy control group, there was little difference in performance in most areas of high-level language tasks, even though the deficits were self-reported. In the current study, the participants were given topics in order to generate monologue speech. This approach may expose more significant language difficulties, similar to those reported by the individuals with PD in this article.

Brauer, S. G., & Morris, M. E. (2010). Can people with Parkinson's disease improve dual tasking when walking? *Gait & Posture*, 229-233. doi:10.1016/j.gaitpost.2009.10.011

Objective: The first goal of this study was to determine if practice helps individuals with PD to walk with large steps while performing additional tasks. The second goal was to find out if training individuals with PD to walk while completing working memory tasks would lead to improvements in gait when walking and performing other tasks simultaneously. *Methods:* Twenty participants with mild-moderate idiopathic PD were tested within an hour of taking their medication. A test-retest design was used with gait measured during a single task (gait only) and 6 dual task conditions using an 8m GAITRite electronic walkway. The tasks included: carrying a tray with four wine glasses (motor-postural), transferring coins between pockets (motor-manipulation), speaking cognitive words (oral word association test: speaking as many words as able when given an alphabet letter), counting backwards by 3 (cognitive-count), a cognitive-auditory task of responding to sound, and a cognitive-visuospatial task of comparing spatial patterns. The participants were measured at baseline and again following a 20 minute training session in dual task situations that concentrated on increased step length, while concurrently performing working memory language and counting tasks with verbal responses. Both gait and the concurrent tasks were measured. *Results:* After training, step length increased in the single

task condition and in the dual-task condition across all domains except motor-postural. The only improved performance on task interaction was with words and visuospatial tasks. *Conclusion:* This study provides preliminary evidence that training can improve gait length in the single and dual task condition. It also showed that training of working memory transferred across 5 of the 6 the tested domains. In addition, individuals with a longer diagnosis of PD were able to show improvement of gait in dual task conditions after training. The authors state that further research is required to understand the mechanisms behind the improvements in people with PD. Clinically, the results of this test indicate that training of gait while performing working memory language tasks could result in better gait and language *Relevance to the current study:* This study examined the effect of training on gait performance and on language. The current study is an examination of the effects of concurrent gait tasks on language. The results of the current study could be complementary to this study by revealing specific conditions under which language breaks down. This information could give clinical direction for therapy.

Chaudhuri, K. R., Healy, D. G., & Schapira, A. H. (2006). Non-motor symptoms of Parkinson's disease: diagnosis and management. *The Lancet Neurology*, 5, 235-245.
doi:10.1016/S1474-4422(06)70373-8

This article is a review of the non-motor symptoms of PD. Although PD is considered a motor disease, it has many non-motor symptoms. The article points out that non-motor symptoms progress with advancing age and the severity of the disease. The Braak hypothesis states that PD has a six stage pathological process. The first two stages are non-motor. The first stage involves degeneration of the olfactory bulb. Stage 2 involves a progression of the pathological process to the lower brain stem. Non-motor symptoms include cognitive impairment, depression, anxiety, pain, restless legs and more.

Cheung, H., & Kemper, S. (1992). Competing complexity metrics and adults' production of complex sentences. *Applied Psycholinguistics*, 13, 53-76.
doi:10.1017/S0142716400005427

Objectives: This study involved two experiments. The first experiment was to compare the reliability of the measurement of language complexity methods and their use as models of language change in aging adults. Experiment 2 was designed to determine whether syntactic complexity determines sentence comprehensibility and to evaluate each metric as a measurement of sentence comprehensibility. *Methods:* Experiment 1: Language samples from narratives that contained at least 50 sentences were collected from 30 English speaking adults, 10 from each of the age groups of 60-69 years, 70-79 years, and 80-90 years. The education level, vocabulary score, and forward and backward digit score from each speaker was available. Each sample was analyzed for complexity. The measures included Mean Length of Utterance (MLU), a measure of linguistic development; Mean Clauses per Utterance (MCU), a measure of adults' linguistic development; Developmental Sentence Scoring (DSS), an assessment of children's grammatical development (eight different categories of grammatical forms were scored); Developmental Level (DLevel), used to evaluate grammatical competence of adults with intellectual disability; Directional Complexity (DComplexity), a measurement of the linguistic difficulty of texts; two ways of measuring the Yngve depth, both the total Yngve depth and the maximum Yngve depth of syntactic trees with nodes and branches and two measures of Frazier count (Local Frazier node count and Total Frazier node count). Experiment 2: Five graduate students from speech-language-hearing or related fields served as judges. None of them knew the purposes of the study

of the source of the narratives. They listened to the sentences and rated the sentences' comprehensibility and attempted to recall the sentences verbatim. *Results:* Experiment 1 found that MLU, MCU, DSS, DLevel, DComplexity, Maximal and Total Yngve depth, and Local and Total Frazier node count are sensitive to the effects of advancing age, verbal ability, and working memory on the production of complex language. MLU, Amount of Embedding, and Type of Embedding determine overall complexity of adult language. Experiment 2 validated the model of linguistic complexity developed from the language analysis in Experiment 1. *Conclusion:* Experiment 1 confirmed early research that concluded that the complexity of adults' speech decreases as they age and is related to working memory rather than education or vocabulary differences. Language complexity was found to have a relationship to sentence length. Embedding clauses increases MLU. Experiment 2 showed the measures were sensitive to language complexity. *Relevance to current study:* The current study will use some of the same measures from this study to evaluate the language complexity of narratives, particularly MLU and DSS. Experiment 2 from this study confirms that the metrics we will use are valid.

Dromey, C., Jarvis, E., Sondrup, S., Nissen, S., Foreman, K. B., & Dibble, L. E. (2010). Bidirectional interference between speech and postural stability in individuals with Parkinson's disease. *International Journal of Speech-Language Pathology, 12*, 446-454. doi:10.3109/17549507.2010.485649

Objectives: This study aimed to collect detailed measures of both speech and postural performance in order to assess the effect of bidirectional interference in people with PD as it relates to healthy age-matched and younger control groups. *Methods:* Twenty-six individuals participated in the study. They were comprised of 9 individuals diagnosed with mild to moderate PD, 7 healthy age-matched controls, and 10 healthy young controls. Motion Capture instrumentation and a headset microphone was used. The procedure called for each participant to perform both single and dual tasks. Two target sentences: *The boot on top is packed to keep* and *The boy gave a shout at the sight of the cake* were produced by the participants. The postural control task called for the participants to intentionally move from a stable to an unstable posture. For the single task condition, the participant sat in a chair while speaking. The dual task condition required the execution of the postural and speaking task together. Testing for individuals with PD occurred 1-2 hours after taking medication. *Results:* (1) Participants with PD showed deficits in postural motor performance in comparison to both healthy age-matched controls and healthy young controls. (2) Speech articulation was negatively impacted by dual task performance; (3) Participants with PD had more bidirectional interference effects when performing the dual tasks of speech articulation and postural motor performance in comparison to the control groups. *Conclusion:* Performance interference during the dual task of speech and postural stability was insignificant in the healthy subjects; however, the subjects with PD experienced interference during the dual task condition. This suggests that prioritizing of tasks for those with PD should be a consideration. *Relevance to current study:* If speech articulation was degraded during postural stability task, we may find that the dual task of talking while walking will affect language. Also, the indication of prioritization of tasks for those with PD in this study may be replicated in the current study.

Dromey, C., & Shim, E. (2008). The effects of divided attention on speech motor, verbal fluency, and manual task performance. *Journal of Speech, Language, and Hearing Sciences, 51*, 1171-1182. doi:10.1080/2050571X.2015.1133757

Objectives: This study evaluated aspects of the functional distance hypothesis to determine if right-handed activity would lead to interference with speech and language performance.

Methods: The participants consisted of 20 young adults, 10 men and 10 women, who were right-handed and were native American English speakers. Each participant performed a speech task, verbal fluency task, and right- and left-handed motor tasks in isolation and concurrently. All tasks were fully randomized. Participants practiced the tasks a day before the study to become familiar with the tasks and the equipment. *Results:* The data showed that during concurrent performance of manual tasks, peak velocity and lip displacement decreased. Conversely, sound pressure level increased. There was a significant decrease on manual motor scores when performed with a verbal fluency task, but not with sentence repetition. There was also increased spatiotemporal variability when the nondominant hand was used for a motor task. *Conclusion:* The functional distance hypothesis predicts that tasks controlled by brain regions in closer anatomic proximity will have greater interference with each other than those regulated by areas with greater spatial distance. This study found that the control of concurrent tasks may be more complex than what is suggested by the function distance hypothesis. *Relevance to current study:* The functional distance hypothesis is one theory of what can happen while a person is dual tasking. The current study examines two dual task conditions.

Ferreira, V. S., & Pashler, H. (2002). Central bottleneck influences on the processing stages of word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 1187-1199. doi:10.1037/0278-7393.28.6.1187

Objectives: The objective of this study was to see if the production of words would be slowed by an unrelated concurrent task. *Methods:* Sixty members of the University of California San Diego (UCSD) community participated in the first experiment and English was their first language. Experiment 1 used pictures of words that were needed to complete a cloze sentence. Experiment 2, the words were presented with simultaneous distractor words. PsyScope software was used to present stimuli and to collect the responses. Auditory stimuli were presented through speakers and the voice responses were recorded using a unidirectional microphone worn on the head and recorded onto a cassette player. Picture naming results were recorded by hand. *Results:* The results indicate that early word production (lemma and phonological word form selection) is related to central processing and later stages (phoneme selection) are not. *Conclusions:* Central processes are used during word production and are not available to nonrelated tasks during the process. In picture naming, low frequency words were processed more slowly than high frequency words. Phoneme selection was not tied to central processing. Interference from a dual task appears to affect response selection more than response execution. Linguistic processes are carried out through central processing and not in a modular, cognitively independent way. *Relevance to current study:* The current study examines the effects of the dual task condition on language complexity. This study examines the mechanism of dual tasking and what occurs during the stages of word production.

Galletly, R. & Brauer, S. G. (2005). Does the type of concurrent task affect preferred and cued gait in people with Parkinson's disease? *Australian Journal of Physiotherapy*, 51, 175-180. doi:10.1016/S0004-9514(05)70024-6

Objectives: The objectives of this study were two fold. The first aim was to compare dual task condition of gait and a cognitive task (math and language) on individuals with PD. The second aim was to determine if gait performance was affected by adding visual cues to normalize gait during the dual task condition. *Methods:* Sixteen participants with PD were age- and gender-matched with 16 neurologically healthy participants. All were tested with Mini Mental State Examination to establish that cognitive abilities were within the study criteria. Each participated in multiple tasks including gait only and dual task gait. *Results:* Participants with PD showed more reduced stride length during the dual task conditions of completing mathematical calculations and language than when performing dual motor skills. *Conclusion:* The complexity of the task type is a consideration when participants with PD perform concurrent tasks. Although concurrent motor tasks did not lead to a change in gait, both mathematical calculations and language did. The language task was considered more complex than the mathematical calculations, yet gait changes were similar. This indicates that task type as well as complexity should be a consideration. *Relevance to the current study:* Concurrent or dual tasks showed a reduced gait performance in mathematical skills and language, both complex tasks. Although the current study will not consider change in gait during dual-task conditions, the effects of the dual-task condition on language will be measured. This study could support the results of the current study.

Holmes, R., M. Oates, J., J. Phylard, D., & J. Hughes, A. (2000). Voice characteristics in the progression of Parkinson's disease. *International Journal of Language & Communication Disorders*, 35, 407-418. doi:10.1080/136828200410654

Objectives: The objective of this study was to describe the voice features of patients with early and late stage PD to see if the accompanying voice symptoms were associated with the clinical progression of PD. *Methods:* Sixty participants with PD participated in the study. They were divided into two groups of 30 males and 30 females. Half of each group was in the early PD stages and half of each group was in the late PD stages. There was also a control group of 30 individuals, 15 males and 15 females. Voice recordings of each participant were made and analyzed for multiple acoustical and perceptual variables. *Results:* Patients with early stage PD had significantly more limited pitch variability, limited loudness variability, harshness and breathiness than the controls. Patients with early stage PD had softer voices than what would be expected compared to normal. Early stage males had higher modal pitch than male controls. Both males and females with early stage PD are more restricted than the control group for maximum phonational frequency range (MPFR). Later stage subjects with PD had greater levels of limited pitch and loudness variability, harshness, breathiness and tremor than control subjects. They also had lower modal loudness and higher jitter levels. *Conclusions:* The acoustic and perceptual results that were collected from the subjects with PD may be used initially as a baseline measure to guide clinical understanding of the voice characteristics of those with early and late stage PD. *Relevance to current study:* The current study is concerned with individuals with PD. This study is relevant to the current study in understanding the clinical progression of individuals with PD.

Illes, J., Metter, E. J., Hanson, W. R., & Iritani, S. (1988). Language production in Parkinson's disease: Acoustic and linguistic considerations. *Brain and Language*, 33, 146-160.
doi:10.1016/0093-934X(88)90059-4

Objectives: The objectives of this study were two fold. First, spontaneous language production of individuals with PD was examined in comparison to the spontaneous language production of healthy speakers. The second objective was to use acoustical analysis of speech to see if there was a relationship between the changes of spontaneous language production of those with PD and the motoric features of PD. *Methods:* The subjects consisted of 20 male individuals; 10 with PD and 10 aged matched healthy subjects. Subjects were recorded reading the "Grandfather passage", and while producing spontaneous speech. The "Grandfather passage" recordings were analyzed using a microprocessor controlled speech analyzer. The spontaneous speech was transcribed. *Results:* The acoustic measures revealed increased elevation of fundamental frequency and reduced intensity in those with PD. Linguistically, the individuals with PD composed shorter chunks of uninterrupted speech but had longer sentences. Many utterances were list style and participants with moderate PD displayed reduced syntactic complexity, reduction of the amount of words used in filled hesitations, and more frequent and longer silent hesitations within sentences. *Conclusion:* Two possible interpretations were made. The first was that linguistic changes are an intrinsic part of the PD process. Unlike those with other types of neurodegenerative disease, individuals with PD were found to produce more open class optional phrases. The second was that as the PD progresses and dysarthria increases, patients with PD employ an adaptive strategy to compactly convey as much information as possible within a sentence. *Relevance to the current study:* Although this study considered the interaction between acoustic and linguistic aspects of spontaneous speech, the spontaneous speech results can serve as a comparison to the performance of subjects with PD during spontaneous speech in the current study.

Kemper, S., Kynette, D., Rash, S., & O'Brien, K. (1989). Life-span changes to adults' language: Effects of memory and genre. *Applied Psycholinguistics*, 10, 49-66.
doi:10.1017/S0142716400008419

Objectives: The objectives of this study were to examine the oral and written language of adults aged 60 and above to determine the sources of individual variance in language and to learn whether the syntactic complexity of adult language varies across genres. This study examined how education, memory ability, vocabulary, and health affect adults' language. *Methods:* Thirty young adults and 78 adults age 60 and older participated in this study. Each subject was given an interview that consisted of an oral questionnaire used to elicit information about the adult, then they were administered the vocabulary test and digits forward and backward subtests from the Wechsler Adult Intelligence test. Lastly, each adult was asked to write a short essay to describe the most significant event in his or her lives. Interviews were audio recorded so that language samples from the oral questionnaire could be transcribed and coded. *Results:* It was found that adults with better education had better oral and written language. They had a larger vocabulary and more right-branching clauses. Regardless of educational differences, the young adults with greater memory capacity produced more complex sentences with more left-branching clauses than their elderly counterparts, who had less memory capacity. Education and memory capacity correlated with individual difference measure across all three language genres of oral question answering, oral expository statements, and written expository statements. Language samples from the young adults show that oral question answering displayed the least complex syntax and

written expository statements produced the most complex syntax. However, elderly adults oral answering language samples had similar syntactic complexity to their written prose, suggesting that elderly adults were not able to overcome working memory limitations. *Conclusion:* This study shows that language development is a life-long process of change in response to changing cognitive abilities and working memory. Loss of syntactic complexity by elderly adults seems to be in response to loss of memory capacity. *Relevance to current study:* This study examines syntactic complexity by examining the use of clauses. The current study also evaluates syntactic complexity in the same way.

Kinsbourne, M., & Hicks, R. E. (1978). Functional cerebral space: A model for overflow, transfer and interference effects in human performance. *Attention and Performance VII*, 345-362.

Objectives: Because current theories did not adequately account for the organization of biological systems, an alternative approach for the explanation of interference from dual tasking was sought. *Methods:* Empirical data from literature was integrated to build the functional distance model. Also, the authors referred to past experiments where the functional distance model was explicitly tested. *Results:* They found that diagonally paired limbs (e.g. lower left limb and upper right limb) were most efficient, followed by ipsilateral paired limbs (e.g. right side arm and leg). The least efficient pairing was mirrored limbs (e.g. right arm, left arm). In the dual task condition of humming and playing an instrument, the best outcomes for both humming and playing occurred when playing was done with the right hand. They also found that nervous systems of more mature subjects responded better than the nervous systems of immature subjects. They also found greater interference when speakers tapped with their left hand than their right hand. *Conclusions:* The functional distance theory of performing concurrent tasks states that different cognitive tasks are processed in particular anatomic locations in the brain. Because neuronal space is highly linked, interference is greater when dual tasks are processed in areas of the brain that are anatomically closer. This study found this theory to be a better explanation of performing concurrent tasks than the single channel limited capacity model. With the exception of automatized tasks, there will always be limitations due to finite functional cerebral space. *Relevance to current study:* The current study considers the effect of walking, a motoric activity, on language complexity. The functional distance theory is one explanation of how attention is divided when performing concurrent activities.

LaPointe, L. L., Stierwalt, J. A. G., & Maitland, C. G. (2010). Talking while walking: Cognitive loading and injurious falls in Parkinson's disease. *International Journal of Speech-Language Pathology*, 12, 455-459. doi:10.3109/17549507.2010.486446

Objectives: The purpose of this study was to bring attention to the high cost of injury causing falls to those with PD and to measure the effect of cognitive-linguistic loading on gait, balance, and ambulation. *Methods:* The participants consisted of 25 individuals with PD and 13 age-matched healthy participants. The PD participants were measured at the peak of their medication cycle. The GAITRite Portable Walkway System was used to measure, interpret, and record gait data. All participants completed the Dementia Rating Scale-2 to identify additional contributions to gait impairment. Measures collected for gait were stride length, step velocity, and percentage of double support time. *Results:* Gait measures were affected by the complexity of the cognitive-linguistic tasks. Compared to baseline, stride length and velocity were reduced in the high cognitive-linguistic load condition for individuals with PD. Unlike those with PD, the control

group showed the ability to compensate in dual task condition in order to control their lower extremities. There was a significant increase of double support time for the control group in the dual task condition that showed the ability to compensate by spending more time on the right and left lower extremities as the cognitive load increased. *Conclusion:* Cognitive-linguistic load affects the gait of the elderly and more significantly the gait of those with PD. Healthcare professionals and caregivers should monitor the cognitive load of those with PD who are talking while walking to guard against injurious falls. Compensatory strategies of increased double support time could be considered. *Relevance to the current study:* Relative to the cognitive load, the dual task of walking while talking put patients at risk for injurious falls.

Lewis, F. M., LaPointe, L. L., Murdoch, B. E., & Chenery, H. J. (1998). Language impairment in Parkinson's disease. *Aphasiology*, 12, 193-206. doi:10.1080/02687039808249446

Objectives: The objective of this study was to compare the assessment results of language abilities of subjects with PD to those of matched control subjects; and to compare the subsets of subjects with PD with normal cognition to those with below normal cognitive status. *Methods:* Twenty volunteers with idiopathic PD from the Parkinson Syndrome Society of Queensland were subjects for this study. All twenty were rated as Stage 3 (mild to moderate disability but physically independent) on the Hoehn and Yahr Scale (1967). The control group of 20 individuals was matched for sex, age, and educational level. Subjects were assessed via a language battery and were given the Mattis Dementia Rating Scale to assess cognitive function. Each subject was assessed in the quiet of his or her homes. Subjects with PD were assessed at the optimal testing time in the medication cycle. *Results:* Subjects with PD performed worse than the control group on five language variables- *Boston Naming Test (BNT)*, *Definition*, *Ambiguous Sentences*, *Figurative Language*, and the total score for the *Test of Language Competence-Expanded Edition*. The PD group was divided into two groups. Subjects with PD with normal cognitive functioning (PDA) had significantly lower scores on *Definitions* and *Recreating Sentences* than control subjects with normal cognitive functioning. There were also significant differences in performance when subjects with PD with below normal cognitive function (PDB) were compared to the PDA group. PDB compared significantly lower *BNT*, *Definitions*, *Recreating Sentences*, *Ambiguous Sentences*, and *Multi-Definitions*. *Conclusion:* The results supported the authors' hypothesis that individuals with idiopathic Parkinson's disease may present with different language processing skills and a different language profile than those without PD. The results of language impairment and difficulty across complex linguistic tasks in those with PD suggest support for compromise of the cortico-striatopallido-thalamo-cortical loop in PD. *Relevance to the current study:* The results of this study indicate that subjects with PD had language impairments. This should support the expected results from the current study.

Murray, L. L. (2000). Spoken language production in Huntington's and Parkinson's diseases. *Journal of Speech, Language, and Hearing Research : JSLHR*, 43, 1350-1366. doi:10.1044/jslhr.4306.1350

Objectives: The objective of this study was to identify and characterize spoken language deficits of individuals with PD and HD. Spoken language of those with PD and HD were compared to the spoken language of non-brain-damaged adults on quantitative, syntactic, and informativeness measure of verbal output. Spoken language of individuals with HD was compared to spoken language of those with PD. Also, the language severity of those with PD and HD was compared to the severity of their motor speech deficits and cognitive deficits to see if there was a

correlation. *Methods:* The study included 10 individuals with HD, 9 non-brain-damaged individuals who were aged-matched to the HD group, 10 individuals with PD, 9 non-brain-damaged individuals who were aged-matched to the PD group. All participants were native speakers of English and had no history of head trauma or pre-existing communication, memory, neurologic, or psychiatric problems. All the individuals passed the Arizona Battery for Communication Disorders of Dementia with 80% accuracy and had adequate visual discrimination skills. All the individuals completed spoken language tasks as well as a battery of standardized tests. Individuals gave two separate narratives. One was based on the picture “cookie theft” and the other was based on the picture “grocery scene”. All individuals with PD were taking dopaminergic medication. Codes for Human Analysis of Transcripts (CHAT) was used to code spoken language samples. Computerized Language Analysis (CLAN) performed automatic analyses. The language variables of quantity of output, syntactic aspects of output and informativeness of output were considered. *Results:* Language analyses show that individuals with PD had no significant group differences for total number of utterances produced. Between group results show that individuals with HD produced shorter, less syntactically complex utterances with fewer embeddings per utterance than those with PD. When compared to their control group, individuals with PD produced a smaller proportion of grammatical sentences. Individuals with PD also had a significantly smaller percentage of correct information units (%CIU) and proportion of informative utterances than their control group. For the individuals with PD, there was a negative correlation between the number of years with a PD diagnosis and their total number of output. *Conclusion:* For individuals with PD, spoken language abilities appear to be more related to neuropsychological changes than motor speech issues. The spoken language profile of individuals with PD tended to be similar to that of patients with frontal lobe involvement. Clinically, the study identified linguistic deficits of form and informativeness in individuals with PD. This can help SLPs in managing the communicative aspects of PD. *Relevance to current study:* Like the current study, this study used automatic analyses of spoken language samples that were audiotaped and transcribed. Although the mode of automatic analyses is different than the current study, some of the measurements are the same.

Nippold, M. A. (2007). Syntactic Attainments. In *Later language development: School-age children, adolescents, and young adults* (3rd ed., pp. 257-284). Austin, TX: PRO-ED. Syntactic complexity increases through the school-age years, adolescence, and early adulthood. Mean length of utterance (MLU) is a slow and continuous process. One way MLU increases is through the use of subordinate clauses. MLU varies across discourse genres, with expository and narrative genres having longer sentence lengths than conversational genre. Over time, syntactic complexity increases through the use of low-frequency syntactic structures, conjunctions, intersentential growth, and lexical cohesion.

Pashler, H. (1990). Do response modality effects support multiprocessor models of divided attention? *Journal of Experimental Psychology: Human Perception and Performance*, 16, 826-842. doi:10.1037/0096-1523.16.4.826

Objectives: This study involved three experiments. The first two experiments had two goals. The first was to determine how subjects’ knowledge of the order of stimuli affects or does not affect performance in a dual-task situation. Experiment 1 had participants use a manual/manual response and Experiment 2 had them use a manual/vocal response. Experiment 3 was to determine if spatially homologous response errors occurred often in the unknown-order block.

Methods: Experiment one had 18 undergraduate participants. A tone stimulus was presented and a second stimulus of a centrally positioned letter on a screen was presented. The experiment had 3 types of presentation blocks; tone-first, letter-first, and unknown order. Each stimulus was to be responded to by pushing a button as quickly as possible. The tone was responded to with the left hand and the letter was responded to with the right hand. Experiment 2 was the same as the first; however, the response for the tone was given vocally. Both Experiments 1 and 2 had random foreperiods (an amount of blank screen time before a trial began). Experiment 3 had 12 undergraduate participants. The apparatus and stimuli were the same as Experiment 1 except that the both stimuli were visual. The experiment had two blocks. One was known order and the second was unknown order. A push button was used for the responses. The foreperiod was constant. *Results:* Experiments 1 and 2 showed that response separation did not eliminate dual task interference and probably did not even attenuate the interference. The authors also found that the interaction of response separation is dramatically affected by predictability or unpredictability of the order of the stimulus. It is greatly affected when both responses are manual and less so when one response is manual and the second is vocal. Experiment 3 showed that the results of Experiment 1 were not dependent on having a randomly varying foreperiod or a visual and an auditory stimulus. *Conclusions:* Experiments 1 and 2 found slowing of processing during unpredicted order of stimulus to keep one hand from responding in place of the correct hand (spatially homologous response error). This suggests that multiprocessor models do not account for modality effects. Experiment 3 showed that homologous response errors are a result of the lack of knowledge about stimulus order. The results support the hypothesis that unknown order condition produces a large increase in spatially homologous response errors. *Relevance to current study:* Pashler discussed the single channel and the multiprocessor modalities with regard to dual task interference.

Shewan, C. M., & Henderson, V. L. (1988). Analysis of spontaneous language in the older normal population. *Journal of Communication Disorders, 21*, 139-154.
doi:10.1016/0021-9924(88)90002-0

Objective: The objective of this study was to collect data on the older normal population in order to make valid comparisons across subject groups. *Methods:* Sixty (7 males and 53 females) normal, native English-speaking adults participated in the study. Participants had no history of neurological deficit or communicative disorder. Fifteen participants were in each of the 40-49, 50-59, 60-69, and 70-79 age groups. The picture from the *Minnesota Test for Differential Diagnosis of Aphasia* (MTDDA) was used because it is included in two widely used diagnostic aphasia batteries, it provided an opportunity for consistent language sample content, and no previous information on older normal response was available for this test. The participants were comparable for educational level. *Results:* Consistent trends for expressive language parameters to decline as the population aged were not found. Neither decreases in specific speech and language measures in the older population, nor increases in the number of utterances were found. The percentage of complex sentences was not greater in the older group, which conflicted with findings from previous studies. The lengths of utterances were not found to be shorter. *Conclusion:* The study added important information to the knowledge about communication in older persons. This study did have limitations. The effects of generational differences were not taken into account and sample size was relatively small. The subjects were not randomly chosen. *Relevance to current study:* Like the current study, this study analyzed the production of

spontaneous language. Although the study had some limitations, the results are relevant to the current study.

Stegemöller, E. L., Wilson, J. P., Hazamy, A., Shelley, M. C., Okun, M. S., Altmann, L. J. P., et al. (2014). Associations between cognitive and gait performance during single- and dual-task walking in people with Parkinson disease. *Physical Therapy, 94*, 757-766. doi:10.2522/ptj.20130251

Objective: The object of this study was to consider the relationship between gait performance and cognitive performance in consideration of multiple cognitive domains in individuals with PD. *Methods:* Thirty-five PD individuals participated in this study. All individuals were tested in the on-medication state. They were evaluated during single task walking and the dual task of walking and cognition. The 12 cognitive tests were in the domains of processing speed, working memory, and executive function and attention. Gait was measured using a Vicon Plug-in-Gait marker system. Measurements of cognition and gait were compared. *Results:* Concurrent performance of walking while participating in a cognitive processing speed factor had a moderate to strong adverse affect on the gait of the PD participants. Neither working memory nor executive function/attention factors had a significant affect on gait spatiotemporal measures. However, there was a significant moderate to strong negative association between executive function/attention and step width. Processing speed and working memory factors had no significant associations with gait variability. In the single task vs. the dual task condition, participants walked slower with shorter steps while spending more time with both feet on the ground during the dual task condition. Reduced walking performance occurred in all dual task conditions. *Conclusion:* The results indicate that stride length and gait speed were significantly associated with processing speed measures, and step width variability was associated with executive function and attention measures. Working memory factors showed no associations. There may be a shared neural system of movement and cognitive load and that both mechanisms are affected relative to constrained resources. *Relevance to the current study:* This study shows that cognitive performance and physical performance were impaired in individuals with PD during dual-task performances. Language is a cognitive process. A shared neural system of gait and cognitive performance would require prioritization possibly resulting in falls.

Stierwalt, J., LaPointe, L. L., Maitland, C. G., & Toole, T. (2008). Effects of cognitive-linguistic load on parameters of gait in Parkinson disease. *Journal of Medical Speech-Language Pathology, 16*, 259-265.

Objectives: The purposes of this study were two-fold. The first was to expand the current literature on the effects of talking while employing the cognitive-linguistic complexity of verbal tasks on those with and without PD. The second purpose was to measure the effects that talking while walking had on speech measures. *Methods:* Participants were 25 individuals with PD and 13 healthy volunteers who were age and education matched. GAITRite instrumentation was used to analyze gait. Participants also completed the Dementia Rating Scale-2 and the Beck Depression Inventory. *Results:* Stride length measures showed not significant changes between groups but individual stride length was significantly reduced from baseline in the high-load condition. The same result occurred for velocity of gait. Gait was negatively impacted by the dual task of talking while walking. The control group significantly increased double support time across conditions. This is probably a compensatory strategy. Difficulty with gait increased as the cognitive load required for talking increased. Speech rate was unaffected in the low load

cognitive measure however loads that require formulations or calculation were affected according to the nature of different tasks. Speech execution and task accuracy were minimally affected. *Conclusion:* Cognitive/linguistic load has a negative affect on gait in individuals with PD. Caregivers, especially in consideration of more difficult tasks like negotiating stairs and difficult surfaces, should consider these results as those with PD may become more prone to falls in the dual task condition. *Relevance to the current study:* This study hypothesized that speech and gait would each have a reciprocal effect on the other. Although there was some effect on speech, it was not very significant. Gait seemed to incur the greatest impact as cognitive load was increased.

Troche, M. S., & Altmann, L. J. P. (2012). Sentence production in Parkinson disease: Effects of conceptual and task complexity. *Applied Psycholinguistics*, 33, 225-251.
doi:10.1017/S0142716411000336

Objectives: This study examined language production and cognitive performance and the relationship between the two. This study compared individuals with PD to gender and age-matched individuals during the performance of sentence repetition and sentence generation. The study asked three questions. 1) "How does performance on sentence repetition and sentence generation compare between healthy older adults and older adults with PD?" 2) "Does complexity of sentence structure or of the message have an exaggerated effect on the sentence repetition or sentence generation, respectively, of older adults with PD compared to healthy older adults?" 3) "Finally, do differences in cognitive abilities account for group differences in performance?" *Methods:* Nineteen individuals with PD were aged match with 19 healthy aged matched adults. All participants were non-demented according the Dementia Rating Scale. Participants were studied in their homes and performed a sentence repetition task and a sentence generation task. *Results:* PD individuals were significantly more impaired than healthy older adults during sentence repetition and sentence generation. PD individuals were also found to have more grammatical errors during sentence generation. *Conclusion:* In response to the three questions for sentence repetition, 1) there was an overall group effect on sentence repetition performance, 2) there was no effect of complexity on repetition, 3) cognitive variables accounted for a large portion of the variance in sentence fluency and overall sentence repetition performance. The presence or absence of PD only played a small role in task performance. In response to the three questions for sentence generation, 1) Participants with PD were significantly impaired in all language measures. 2) Complexity contributed to performance but was not significant. 3) When both working memory and executive function were factored in, the groups still differed in fluency scores. Most relevant to this study is that individuals with PD had pervasive language difficulties during the sentence generation task that were not attributed to working memory or executive function. Completeness was also impaired in the group with PD *Relevance to the current study:* Although this study did not have the component of dual tasking, their results suggest difficulty in sentence generation for those with PD. This current study will go a step further than asking participants for generated sentences. Monologues will be generated and compared between those with PD, healthy older, and healthy younger subjects.

APPENDIX B: INFORMED CONSENT

You are being asked to take part in a multi-part research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with friends and relatives if you wish. Ask the research doctor or staff if there is anything that is not clear or if you would like more information. Take time to decide whether or not to volunteer to take part in this research study.

The purpose of the study is to collect information on how people normally navigate obstacles and changes in terrain such as climbing stairs, moving from seated to standing positions, walking on gravel, etc. so we can understand how to graphically represent this terrain in virtual environments and develop new technology and training procedures to improve stability and reduce the chance of falls.

STUDY PROCEDURES

There are 3 major parts to the study. You are being asked to agree to the parts of the study for which you are eligible, and they should be clearly marked with a checkmark (***If you do not see a checkmark next one or more parts, or are unsure which part of the consent document is applicable to you, please see one of the research staff immediately before proceeding.***).

[] PART 1 - DEVELOPMENT OF THE PHYSICAL ENVIRONMENT

The purpose of this part of the study is to determine and characterize aspects of your environment that you find challenging to navigate. Once we identify these activities, physical representations of these situations will be created in the Motion Analysis Core Facility (MOCAP) and Ergonomics and Safety (E & S) Laboratory for two purposes: (1) To evaluate the validity of the simulated environment of the lab and to collect movement data during these mobility challenging activities, and (2) To develop a virtual reality environment that simulates these real-world challenges.

To accomplish this, you may participate in a recorded interview with a questionnaire to define common environments and situations that cause mobility challenges for you. For example, do you trip and stumble sometimes when you walk on an uneven sidewalk? A physical environment in the laboratory will be constructed that includes the common themes identified from the interview. For participants with Parkinson disease that are already using dopamine replacement medications, all testing will be done within 1-2 hours of taking the regular dosage of dopamine replacement medications to assure medication levels are consistent.

Part one of this study will take place in two separate locations on the university campus. At both locations, you can expect the following progression of events:

- You will enter one of the motion analysis labs.
- If applicable, you will be interviewed and a questionnaire will be completed about your self-report of difficulty in various mobility challenging environments.
- Next, you will be provided with a black tight fitting shirt and shorts for testing.
- Demographic and body measurement data will be collected from you.
- Reflective markers will be placed on you.

- You will be fitted with a ceiling mounted fall harness and support system to prevent falls to the ground.
- You will be directed to stand on a special square on the floor or treadmill called a force platform.
- Next, you will be asked to complete several tasks such as walking, jumping, standing up from sitting, climbing stairs, rising up on your toes, and remaining upright when your balance is challenged. You will also be asked to engage in a recorded speech task during some of these activities.
- You will be asked to perform 5 trials of each task.
- After the tasks are complete, the markers will be removed and you can change back into your street clothes.
- Additional questions and assessments will be made using standard questionnaires to assess other factors that may be related to balance, and perceptions of difficulty during walking and interactions with your environment. For example, we will ask you to remember a list of five things and repeat them in order back to the researcher.

[_____] PART 2 - SHOE DEVELOPMENT

A new form of insole, or "Smart Shoe" has been created and rigorously tested in a laboratory testing fixture. Our purpose is to evaluate the changes in movement while wearing the smart shoe compared to not wearing it, and obtain feedback from you as a user to evaluate and improve smart shoe designs and identify features that provide the most benefit for providing assistance during mobility challenging activities.

Testing will include the functional gait assessment (FGA), the 6 minute walk test (6MWT), and gait analysis in a physical environment presented in the MOCAP, E&S Labs. The following is the progression of events you should expect in Part 2:

- You will enter one of the motion analysis labs.
- Next, you will be provided with a black tight fitting shirt and shorts for testing. A private changing room will be provided.
- You will be given instructions about the Smart Shoes and what to expect while wearing them.
- Demographic and body measurement data will be collected from you.
- Reflective markers will be placed on you.
- You will be fitted with a ceiling mounted fall harness and support system to prevent falls to the ground.
- You will be directed to stand on a special square on the floor called a force platform.
- Next, you will be asked to complete several tasks such as walking, jumping, standing up from sitting, climbing stairs, rising up on your toes, and remaining upright when your balance is challenged.
- You will be asked to perform 5 trials of each task.
- After the tasks are complete, the markers will be removed and you can change back into your street clothes.
- Additional questions and assessments will be made using standard questionnaires to assess other factors that may be related to balance, and perceptions of difficulty

during walking and interactions with your environment. For example, we will ask you to remember a list of five things and repeat them in order back to the researcher.

- This completes this part of the study.

[] PART 3 - VIRTUAL REALITY TRAINING

The purpose of this part of the study is to learn more about the potential benefits of training on a treadmill and virtual environment system known as the Treadport Active Wind Tunnel-Terrain Display Simulator (TPAWT-TDS). Conventional training is often limited and becomes even more complicated due to weather or being able to simulate an environment accurately in a laboratory setting. There is evidence to suggest that training activities in virtual reality may improve motor function and balance recovery after a minor perturbation. You are being asked to participate in a study to determine if the immersive virtual environment system and a Smart Shoe developed to provide realistic sensations of walking on irregular terrains in the TPAWT-TDS is more beneficial as a training device than training without VR and Smart Shoe technology. Pretesting will include the functional gait assessment (FGA), the 6 minute walk test (6MWT), gait analysis and biomechanical analysis in a physical environment presented in the MOCAP and E&S Labs. Pretesting should require approximately 2 and a half hours of your time. The following is the progression of events you should expect for pretesting:

- You will enter the MOCAP or E&S lab.
- Next, you will be provided with a black tight fitting shirt and shorts for testing.
- Demographic and body measurement data will be collected from you.
- Reflective markers will be placed on you.
- You will be fitted with a ceiling mounted fall harness and support system to prevent falls to the ground. You will be directed to stand on a special square on the floor called a force platform.
- Next, you will be asked to complete several tasks such as walking, jumping, standing up from sitting, climbing stairs, rising up on your toes, and remaining upright when your balance is challenged.
- You will be asked to perform 5 trials of each task.
- After the tasks are complete, the markers will be removed and you can change back into your street clothes.
- Additional questions and assessments will be made using standard questionnaires to assess other factors that may be related to balance, and perceptions of difficulty during walking and interactions with your environment. For example, we will ask you to remember a list of five things and repeat them in order back to the researcher.

Following pretesting, you will undergo training. Training will be performed in the TPAWT-TDS. The treatment regimen will last 6 weeks (3x/wk) for a total of 18 sessions. The duration of each session will be approximately 45 minutes with a 5 minute warm-up period of walking on the treadmill without VR or haptic display. In addition, you will be given up to 5, three minute rest breaks, as needed. During this study your movement will be evaluated and recorded. During training you will be presented with various virtual terrains that represent mobility challenging environments. You will be tethered with a safety device during all trials. The following is the progression of events you should expect during each training regimen:

- You will enter the TPAWT-TDS.
- Next, you will be provided with a black tight fitting shirt and shorts for testing. A private changing room will be provided.
- Demographic and body measurement data will be collected from you.
- Reflective markers will be placed on you.
- Next, you will be tethered to the system with a support to prevent falls to the ground and warm up on the treadmill with the virtual environment for 5 minutes
- Following warm up, a training session lasting 45 minutes where you will be presented with virtual terrain and a realistic virtual representation of a common setting (for example, walking on a sidewalk with uneven slabs, or walking from a room with wood flooring to a carpeted floor), during which you will experience some mobility challenging conditions.
- After the training session, the markers will be removed and you can change back into your street clothes.

Following training you will be scheduled for a final post-testing appointment at the MOCAP and E&S labs. Post-testing will include the functional gait assessment (FGA), the 6 minute walk test (6MWT), gait analysis and biomechanical analysis in a physical environment presented in the MOCAP and E&S Labs. Post-testing should require approximately two and a half hours of your time. The following is the progression of events you should expect:

- You will enter the MOCAP or E&S lab.
- Next, you will be provided with a black tight fitting shirt and shorts for testing.
- Demographic and body measurement data will be collected from you.
- Reflective markers will be placed on you.
- You will be directed to stand on a special square on the floor called a force platform.
- Next, you will be asked to complete several tasks such as walking, jumping, standing up from sitting, climbing stairs, rising up on your toes, and remaining upright when your balance is challenged.
- You will be asked to perform 5 trials of each task.
- After the tasks are complete, the markers will be removed and you can change back into your street clothes.
- This completes this part of the study.

RISKS

For this study, markers are attached to the skin with hypoallergenic tape. There may be some minor discomfort experienced when the small pieces of tape are removed from your skin. This is similar to removing very small Band-Aids. In addition, because of the need for you to perform balance activities, the risk for falling is increased. However, you will be supervised at all times by a researcher with experience in fall prevention and you will also be attached to a fall restraint tether secured to the ceiling. In the event of an unprotected fall resulting in an injury, first aid will be provided. If additional medical care is required, the appropriate emergency medical services will be provided.

RESEARCH RELATED INJURY

If you are injured from being in this study, medical care is available to you at the University of

Utah Medical Center, as it is to all sick or injured people. The University of Utah has not set aside any money to pay the costs for such care. The University will work with you to address costs from injuries. Costs would be charged to you or your insurance company (if you have insurance), to the study sponsor or other third party (if applicable), to the extent those parties are responsible for paying for medical care you receive. Since this is a research study, some health insurance plans may not pay for the costs. By signing this consent form you are not giving up your right to pursue legal action against any parties involved with this research.

The University of Utah is a part of the government. If you are injured in this study, and want to sue the University or the doctors, nurses, students, or other people who work for the University, special laws may apply. The Governmental Immunity Act of Utah is a law that controls when a person needs to bring a claim against the government, and limits the amount of money a person may recover. See sections 63G -7-101 to -904 of the Utah Code.

BENEFITS

There are no direct benefits to you from your taking part in this study. We hope that the information we gain from this study will help us understand and discover effective treatments to improve balance and decrease the risk of falling for individuals with mobility challenging disorders such as Parkinson disease.

ALTERNATIVE PROCEDURES

If you do not want to take part in the study, you can choose not to participate. There are no alternate procedures offered.

CONFIDENTIALITY

We will keep all research records that identify you private to the extent allowed by law. Records about you will be kept locked in filing cabinets or on computers protected with passwords. Only those who work with this study will be allowed access to your information. Results of the study may be published; however, your name and other identifying information will be kept private. However, if we learn about actual or suspected abuse, neglect, or exploitation of a disabled or elderly person, we will report that to the proper authorities.

The nature of this study requires that we record video to evaluate activities and quantify biomechanics. These videos are used for reference and will only be used for educational reasons and at research conferences. Your name will not be used, and the face of the images will be blurred when possible, but they will never have your name associated with their images. During your movement trials, a reference video will be recorded to evaluate motion data integrity and as a quality check.

Portions of this study (part 1 only) require audio recordings for reference and evaluation. The video and audio files will only be stored until all analyses are completed for the study. Only qualified research personnel will have access to these video and audio files and access will be controlled on encrypted, password-protected computers. Measures will be taken to prevent identifiability when possible by blurring identifying features (face), and using ID numbers instead of names on audio recordings. There may be instances in an educational or teaching environment when this is not possible.

Please indicate by initialing below that you understand that images and audio recordings of you may be used in presentations for teaching and research purposes, but all efforts will be made to prevent identifiability.

Initial _____

PERSON TO CONTACT

If you have any questions, complaints or concerns about this study, or if you feel you have been harmed as a result of participation, you can contact any of the research staff included in the following list. If you need to contact someone for an injury that resulted from being in this study, please call Dr. Bo Foreman at 801.581.3496 or Dr. Lee Dibble at 801.581.4637 during business hours Monday through Friday. Dr. Foreman can also be reached after hours by calling 801.243.9111. If you need to speak with any of the other investigators related to this study their contact information is listed below:

- Mark Minor (PI): 801.587.7771
- Andrew Merryweather: 801.581.8118
- John Hollerbach: 801.585.6978

INSTITUTIONAL REVIEW BOARD:

Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

RESEARCH PARTICIPANT ADVOCATE: You may also contact the Research Participant Advocate (RPA) by phone at (801) 581-3803 or by email at participant.advocate@hsc.utah.edu.

VOLUNTARY PARTICIPATION

It is up to you to decide whether or not to take part in this study. If you decide to take part you are still free to withdraw at any time and without giving a reason. Refusal to participate or the decision to withdraw from this study will involve no penalty or loss of benefits to which you are otherwise entitled. If you don't take part, you can still receive all standard care that is available to you. This will not affect the relationship you have with the research staff.

UNFORESEEABLE RISKS

In addition to the risks listed above, you may experience a previously unknown risk or side effect.

COSTS AND COMPENSATION TO PARTICIPANTS

You will be compensated for your time and participation in this study. You will not be charged, nor will your insurance company be charged, for any test or visit that is completed solely for the purpose of this study. Since you will be paid for participating in this study, it is necessary for us to collect your Social Security Number. You will provide this information for a Federal W-9 Form that is filed with our Accounts Payable department. Accounts Payable will have limited access to the study information (e.g. the name of the study) for payment purposes. The amount

you receive for taking part in this study will be turned into the Internal Revenue Service (IRS) as taxable income. You can choose not to provide us with your Social Security Number for this form and still participate in this study; however we will not be able to pay you as outlined in this consent form.

NUMBER OF PARTICIPANTS

We expect to enroll a total of 80 participants at the University of Utah (40-Part 1, 10-Part 2, and 30-Part 3).

CONSENT

By signing this consent form, I confirm I have read the information in this consent form and have had the opportunity to ask questions. I will be given a signed copy of this consent form. I voluntarily agree to take part in this study.

I agree to take part in (circle parts of the study you agree to participate in):

- **Part 1**
- **Part 2**
- **Part 3**

of this research study and authorize you to use and disclose health information about me for this study, as you have explained in this document.

Participant's Name

Participant's Signature

Date

Name of Person Obtaining Consent

Signature of Person Consent

Date

APPENDIX C: NARRATIVE TRIGGERS

Personal

- Would you quit if your values did not match your employer?
- If you could be rich, famous, or influential, which would you choose and why?
- How would you define faith?
- How do you define wealth?
- Do you believe people make happiness or stumble across it?
- Which is more important, talent or hard work?
- Are you an introvert or an extrovert? What are the pros and cons of each?

Media

- Are antidrug and antismoking ads effective?
- What video game would you like to redesign?
- Do social media campaigns stimulate real change?
- Should people be allowed to obscure their identities online?
- Is TV stronger than ever or becoming obsolete?
- What ideas do you have for a reality show?
- What is your opinion about violence on television and in video games?
- What artists of today are destined for the rock and roll hall of fame?

Generations

- What is the difference between your generation and my generation and why?
- Is your generation more self-centered than earlier generations?
- Are young people generally more selfish than their parents and grandparents?
- How will our current culture be remembered in history books?
- Do children today have good manners?
- Does age make you more aware of and caring for others?
- Should adults try to teach young people lessons or should they leave them alone to find out about things themselves?
- Should parents continue to financially support their children after the children are 18?
- Is modern culture ruining childhood?

Local Issues

- If you could expand the tax system, what changes would you make?
- What do you see as the pros and cons of the proposed rebuilding of the salt lake airport?
- Is it important to shop at locally owned businesses?
- What could be done about Salt Lake's homeless population?
- What are the pros and cons of the Sugarhouse trolley?

Social

- What has caused the obesity epidemic in America?
- Should people get plastic surgery?
- Should rich people have to pay more taxes?
- What is your opinion about cloning?
- What are the ethical implications of eating meat?
- Are children of illegal immigrants entitled to a public education?
- Should welfare recipients be required to take drug tests?
- If you were a philanthropist, what groups would you finance and why?
- When should juvenile offenders receive life sentences?
- Should women soldiers be in combat?
- What is your opinion about legalizing marijuana?
- Are we losing the art of listening?
- Do attractive people have advantages that others don't?
- What are the most important changes in the world since the year 2000?

Education & Related

- Is online learning as good as face-to-face learning?
- How necessary is a college education?
- Should cash-strapped schools cut arts education?
- Should guns be permitted on college campuses?
- What do you think about home school vs. public vs. private school?
- How would you make over the university system?
- Whose fault is it if a child is failing in school?
- Should parents/grandparents give cash rewards to kids for good test scores?
- Should university students be required to take drug tests?
- Should junk foods and soda pop be sold in elementary school or high school vending machines?
- How well do you think standardized tests measure people's abilities?