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Variables contributing to listener effort in speakers with Parkinson's disease

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Graduate Program in Health and Rehabilitation Sciences
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Abstract

Reduced speech intensity or hypophonia is a common speech deficit observed in hypokinetic dysarthria associated with Parkinson's disease (PD). The introduction of background noise is a particularly relevant context to study in relation to this speech symptom. Previous research has indicated that listeners have more difficulty understanding dysarthric speech, and must exert more effort when listening. However, little is known of the specific features of the speech signal that contribute to perceived listener effort in the speech of individuals with PD and hypophonia. The purpose of this study is to investigate two speech features (1. Articulatory Imprecision 2. Reduced Loudness) that may contribute to perceived listener effort and that are commonly impaired in individuals with PD. This study also aims to determine potential relationships among ratings of listener effort and speech intelligibility in two noise conditions (no added background noise and 65 dB multi-talker background noise). Listener participants orthographically transcribed audio recordings of each speaker with PD reading three sentences from the Sentence Intelligibility Test (SIT). Intelligibility, listener effort, articulatory imprecision, and reduced loudness of these sentences was also rated in each noise condition using visual analogue scaling (VAS). Results revealed that the noise condition had a significant impact on the ratings of intelligibility, listener effort, articulatory imprecision, and reduced loudness. The results of this study revealed that individuals with PD and hypophonia were rated to have less intense speech, less precise speech, and reduced speech intelligibility in background noise, and ratings of listener effort were also significantly higher in background noise.

Keywords: Parkinson's disease, hypophonia, speech intelligibility, listener effort, articulation, loudness, motor speech disorders, hypokinetic dysarthria, speech perception, background noise.

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Chapter 1

1 Introduction

In 1817 a surgeon named James Parkinson wrote and published an influential essay in which he discussed shaking palsy. The symptoms of shaking palsy that he described included involuntary tremors, shuffling gait, and unaffected senses and cognitive abilities (Parkinson, 1917). In 1879, Dr. Jean-Martin Charcot added rigidity to this list of symptoms and renamed shaking palsy as Parkinson's disease (PD) (Parkinson Society, 2015). Much of the research on Parkinson's disease focuses on overall bodily movement and treatment options. Many individuals with Parkinson's disease experience symptoms that include speech and voice irregularities, usually defined as hypokinetic dysarthria, which can have a negative effect on communication. The ability to communicate effectively is paramount in order to succeed in any social environment, and research on this topic may help to guide treatment provided by speech-language pathologists (Dykstra, Hakel, & Adams, 2007).

1.1 Epidemiology

Parkinson's disease is considered the second most common neurodegenerative disease after Alzheimer's. PD affects 1% of the population worldwide after the age of 65, with an increase to 1-3% of the population after 80 years of age (Tanner & Goldman, 1996; Schneider & Obeso, 2014). The average age of onset of PD is 60 years of age, with approximately 10% of the PD population exhibiting early onset PD, which occurs before the age of 40 (Adams & Jog, 2009). In Canada nearly 100,000 people live with PD, however many individuals remain undiagnosed; therefore the actual incidence is thought to be underestimated (Parkinson Society, 2015; Twelves, Perkins, & Counsell, 2003). The prevalence rate of PD is approximately

1-2/1,000 while the incidence rate is approximately 1-2/10,000 (Parkinson Society, 2015). Many studies suggest that there is a higher incidence in men than women, but this needs further exploration to be confirmed (Twelves et al., 2003; Wirdefeldt, Adami, Cole, Trichopoulos, & Mandel, 2011). The underlying cause of PD is generally unknown, however it is assumed that both genetic and environmental factors play a part. About 15% of individuals with PD who have a first-degree relative are also affected by PD (Adams & Jog, 2009; Wirdefeldt et al., 2011; Schneider & Obeso, 2014).

1.2 Pathophysiology

Individuals with Parkinson's disease can demonstrate impairments in motor control, initiation, and termination of voluntary movements (Duffy, 2013). The basal ganglia and dopaminergic pathways are responsible for and contribute to motor control, initiation, and termination of voluntary movements, as well as maintenance of posture and static muscle contraction (Duffy, 2013). The basal ganglia is a group of nuclei that are located in the brain within the white matter. This area in the brain is comprised of the globus pallidus, putamen, caudate nucleus, substantia nigra, and subthalamic nucleus (Duffy, 2013). The striatum is another part of the basal ganglia that is relevant in PD, because it is also involved with motor control. Within the striatum are two important neurotransmitters, acetylcholine and dopamine. Acetylcholine is the synaptic transmitter for axonal terminations in the striatum whereas dopamine is produced in the substantia nigra and travels to the striatum (Duffy, 2013). In normally functioning basal ganglia, dopamine ensures that there is an appropriate amount of activity occurring at the synapses, and when there is dopamine deprivation the basal nuclei become overactive (McKim, 2007). Acetylcholine is an excitatory transmitter, meaning that

when it is present, an action potential across neurons is more likely to occur and that the message will result in intended motor movements (Campbell et al., 2008). Therefore, to maintain normal motor control, it is important that these neurotransmitters are chemically balanced.

In PD there are lesions in the basal ganglia that cause neurochemical loss of dopaminergic pathways within the substantia nigra, which in turn causes cell death and a chemical imbalance (Adams & Jog, 2009). Therefore, a lack of dopamine is responsible for the motor symptoms related to PD. As the dopaminergic neurons deteriorate, dopamine stores are reduced and when approximately 80-85% of the dopaminergic content is depleted, symptoms of PD start to appear (Wirdefeldt et al., 2011). As the dopaminergic content continues to deplete, the symptoms of PD increase in severity (Wirdefeldt et al., 2011). This is where some medications such as levodopa, carbidopa or sinemet become important. These medications can help to stall and reduce the speed of dopaminergic depletion by providing a substitute for the missing dopamine because they are metabolically similar to dopamine (McKim, 2007). This can help to reduce symptoms of PD and improve an individuals' ability to function in their daily life (Adams & Jog, 2009). However, as neurons continue to die, the medications become less effective. Often within 10-15 years following diagnosis individuals with PD are significantly disabled and need to have specialized care (Parkinson Society, 2015).

1.3 Clinical Features

The cardinal clinical features of Parkinson's disease include rest tremor, rigidity, bradykinesia, and disturbances of posture and gait. In order to be diagnosed with PD, an individual must present with bradykinesia and at least one of three other clinical features including rigidity, tremor and/or postural instability (Sethi, 2002). A neurologist or general

practitioner usually makes the diagnosis; however there are no tests currently available to confirm the presence of PD aside from postmortem examination of the brain (Parkinson Society, 2015). Therefore, the cardinal clinical features are what are relied upon for diagnosis.

The tremor that is present in Parkinson's disease is classified as a rest tremor. This resting tremor occurs most often while the individual is at rest, and it may reduce or stop when voluntary movement occurs (Duffy, 2013). A rest tremor can occur in any of the limbs, as well as the head and orofacial regions such as the lips and jaw. The rest tremor can be accompanied by a "pill-rolling" action made by the thumb and index finger which can be a primary manifestation of PD in 70% of individuals that are diagnosed (Parkinson Society, 2015). PD often emerges first with symptoms on one side of the body (unilateral), which eventually evolve to affect both sides of the body (bilateral) (Parkinson Society, 2015). It appears that for the most part, individuals with PD do not experience motor symptoms and dyskinesia in the same body region (Latorre et al., 2014). Dyskinesia, which refers to abnormal, involuntary movements, is usually a side effect of medication, such as Levodopa. This may indicate that dyskinesia and motor symptoms are not entirely related, and perhaps that there are differences in the individual physiological changes that occur during PD (Latorre et al., 2014).

Rigidity is resistance to passive movement that can be felt across a full range of movement in all directions. Rigidity is generally characterized by a stiff feeling that is accompanied by slowness of movement (Duffy, 2013). Typically the wrist and neck are most noticeably affected, with the movement being described as sustained or cogwheel (Schneider & Obeso, 2014). Cogwheel rigidity is identified with a stiff and jerky movement during a passive stretch and can cause muscular discomfort (Duffy, 2013; Schneider & Obeso, 2014).

Issues with planning, initiation, and execution of movement often co-occur with basal ganglia disorders and are referred to as bradykinesia (Duffy, 2013). Clinical signs of bradykinesia include an impaired ability to complete complex motor tasks, reduction of arm swing, reduction in blinking and facial expressiveness (i.e., masked facial features), monotone pitch, monotone loudness level, and difficulty initiating speech production (Pal, Samii, & Calne, 2002).

The disturbances of posture in PD can be characterized by an involuntary stooped appearance, referred to as trunk flexion, in which the neck and shoulders droop forward, and over time, this causes the spine to curve (Schneider & Obeso, 2014). This tends to be a sign that becomes more prevalent and worsens later in the course of PD. There are also signs of postural instability such as poor balance and loss of the above-mentioned postural reflexes, which can result in falling (Duffy, 2013). This is a debilitating aspect of PD because it is not easy to treat.

Gait disturbance is a common impairment in PD. Gait disturbance refers to the way in which individuals with PD walk, which is usually characterized by a change in stride length and walking speed (Duffy, 2013). Specifically, gait disturbances can be associated with shuffling and/or festination of gait. Festination of gait refers to an increase in walking speed coupled with a forward leaning posture, which can result in a fall unless interrupted (Schneider & Obeso, 2014). Some individuals with PD can also “freeze” in doorways or cluttered spaces, and can have difficulty when trying to turn quickly. Together these gait disturbances can also result in falls (Duffy, 2013; Schneider & Obeso, 2014).

In general, individuals with PD have difficulty maintaining the amplitude of their movements. Hypokinesia is when this amplitude of movement is greatly reduced and this is

another common feature of PD (Duffy, 2013). Due to this, individuals with PD can have difficulty completing complex or sequential motor movements and may seem to be lacking in dexterity (Schneider & Obeso, 2014). This is thought to be one of the reasons that small/untidy handwriting, referred to as micrographia, is common in PD (Schneider & Obeso, 2014).

There are also other manifestations of PD, which can include cognitive disturbances, autonomic disturbances (i.e., sleep and bladder issues, constipation, dysphagia), and neuropsychiatric symptoms (i.e., depression, anxiety) (Sethi, 2002; Parkinson Society, 2015). It is thought that the clinical features of PD are also influenced by perceptual or sensory problems that may distort the way that individuals with PD perceive the world (Duffy, 2013). It is suggested that the basal ganglia play a role in the sensorimotor integration process. For example, studies have suggested that inaccurate estimation of distance when walking, and speech intensity regulation are disturbances that may be attributed to perceptual or sensory deficits (Abbruzzese & Berardelli, 2003; Ho, Bradshaw, & Ianssek, 2000).

1.4 Hypokinetic Dysarthria

It is estimated that over 75% of individuals with PD may also experience speech and voice irregularities directly related to disease progression, generally referred to as hypokinetic dysarthria (Logemann, Fisher, Boshes, & Blonsky, 1978; Adams & Jog, 2009; Skodda, 2011). Damage to the basal ganglia can also cause deficits of language formulation and motor programming (Altmann & Troche, 2011). As these symptoms continue to worsen they can be very disabling to the point that some individuals with PD lose their communication abilities and can feel socially isolated (Skodda, Gronheit, Mancinelli, & Schlegel, 2013; Dykstra et al., 2007). Hypokinetic dysarthria is generally associated with reduced overall movement in the orofacial

regions. This can present as speech related movements that are abnormally reduced in size and force (Duffy, 2013; Adams & Dykstra, 2009; Rusz, Cmejla, & Tykalova, 2013). Due to this reduction, articulation, speech intensity, and speech expressivity can all seem to be compressed (Adams & Dykstra, 2009). The most common cause of hypokinetic dysarthria is PD, however vascular trauma (i.e., stroke, aneurysm, anoxia), other degenerative disorders (i.e., Multiple System Atrophy, Progressive Supranuclear Palsy), toxic or metabolic conditions (i.e., carbon monoxide poisoning), and infection (i.e., post-encephalitic PD) can all result in a diagnosis of hypokinetic dysarthria (Duffy, 2013). The clinical description of hypokinetic dysarthria can include imprecise articulation, prosodic abnormalities such as monotony in loudness and pitch variation, rate abnormalities, disturbances to vocal quality, and hypophonia (Duffy, 2013).

Articulation. Individuals with hypokinetic dysarthria can have difficulty with the accurate production of vowels and consonants (Adams & Dykstra, 2009). Rusz and colleagues (2013) suggested individuals with PD have impairments in vowel production during spontaneous speech. They also suggested that imprecise vowel production might be an early marker of PD (Rusz et al., 2013). These researchers hypothesized that deficits in vowel production in the early stages of PD begin with the vowel /u/ and then /i/, and finally /a/. They suggest that /a/ may be more resistant to change because it might be easier to produce due to the posture of the articulators and orofacial musculature involved (Rusz et al., 2013). Logemann and Fisher (1981) described the features of imprecise consonant articulation in PD, which included distortions in stop, fricative, and affricate production. Logemann and Fisher (1981) suggested that these distortions may be the result of inadequate narrowing of the vocal tract. For example, stops and affricates were found to be produced more like fricatives, and fricatives were produced with less

frication (Adams & Dykstra, 2009).

Prosodic abnormalities: monoloudness and monopitch. Individuals with PD can also present with prosodic abnormalities such as deficits in loudness and pitch variation, commonly referred to as monoloudness and monopitch, respectively. Monoloudness can reduce contrast resulting in the perception of flat sounding speech (Duffy, 2013). Monopitch can reduce the expected contrast in speech and make speech sound flat (Duffy, 2013). Specifically, many individuals with PD have issues with contrastive stress patterns, for example “The *girl jumped on the bed*” (Pell, Cheang, & Leonard, 2006). Pell and colleagues (2006) found that when listeners heard the speech of individuals with PD, they had trouble identifying the intended meaning of sentences when there were two possible intentions that should have been made obvious by pitch or intonation changes. In addition, listeners were often unable to tell whether the participants with PD were asking questions or making statements (Pell et al., 2006). Together, the presence of monoloudness and monopitch can give the perceptual impression of a flat and attenuated speech pattern (Duffy, 2013). This indicates that there may be an increase in communication errors or misunderstandings when speaking to individuals with PD.

Rate abnormalities. Individuals with hypokinetic dysarthria and PD can experience rate abnormalities during speech production. Examples of rate abnormalities can include a variable speech rate, which can manifest as a slower than normal speech rate, a faster than normal speech rate, or as short rushes of speech (Adams & Dykstra, 2009). These rate abnormalities can impair successful communication by reducing intelligibility. Individuals with PD can also have trouble altering their rate of speech when prompted (Adams & Dykstra, 2009; Skodda, 2011; Skodda et al., 2013). The overall impression of rate disturbances associated with hypokinetic dysarthria can

be described as a ‘blurring of contrasts’ which can result in the perception of an increased rate of speech. The perception of ‘blurring’ can be the result of the presence of a rapid or accelerating rate combined with reduced excursions of the articulators (Duffy, 2013). Overall, the abnormalities in rate of speech observed in hypokinetic dysarthria are heterogeneous. However, rate abnormalities are often a distinctive feature of hypokinetic dysarthria, and the perception of a rapid rate of speech is unique to hypokinetic dysarthria (Duffy, 2013).

Voice Quality. Abnormal voice quality can also be present in the speech of individuals with hypokinetic dysarthria (Adams & Dykstra, 2009). In their study involving 200 patients with PD, Logemann and colleagues (1978) reported voice disorders in 89% of their sample.

Therefore, individuals with PD are likely to develop a voice quality disorder at some point in their disease progression (Logemann et al., 1978). The most common vocal tract disorders in PD include breathiness, hoarseness, roughness, or tremulousness (Logemann et al., 1978).

Logemann and colleagues’ findings may relate to the laryngeal issues observed in PD because there can be a co-occurrence of a breathy and a harsh voice quality. This suggests that there can be a combination of bowed vocal folds and problems with airflow (Duffy, 2013). As well, voice quality disorders can often co-occur with imprecise articulation (Logemann et al., 1978).

Logemann and colleagues (1978) also suggest that the appearance of a voice quality disorder may begin the progression of vocal tract dysfunction in an individual with PD.

Hypophonia. One of the most prevalent and distinctive speech symptoms of hypokinetic dysarthria is hypophonia, also referred to as low speech intensity. Hypophonia often emerges as an initial speech symptom in the beginning stages of PD (Logemann et al., 1978). Ludlow and Bassich (1984), and Gamboa and colleagues (1997) found that hypophonia was present in 42%

and 49% of individuals they studied with hypokinetic dysarthria, respectively. Therefore hypophonia is a very common symptom of PD that requires treatment (Adams, Haralabous, Dykstra, Abrams, & Jog, 2005). The primary characteristic of hypophonia is a speech intensity deficit. This speech symptom can decrease speech intelligibility and hinder verbal communication in a multitude of social contexts (Darley, Aronson, & Brown, 1975). Individuals with hypophonia are often asked to repeat themselves and to speak louder. This can be very disabling and frustrating as it hinders fluid conversation, especially when the individual is unaware of their inappropriately soft voice. Generally when asked to speak louder individuals with hypophonia are able to increase their speech intensity, but indicate that they feel they are speaking at an inappropriately loud level (Clark, Adams, Dykstra, Moodie, & Jog, 2014). It is of interest that there is a dichotomy between clinical and perceptual impressions of hypophonia. For example, in clinical settings individuals with PD may seem appropriately loud due to the lack of background noise, or they may increase their speech intensity because they know what is expected of them in a treatment setting (Dykstra et al., 2007; Dykstra, Adams, & Jog, 2013).

Lombard effect. In 1911, an otolaryngologist named Étienne Lombard discovered a phenomenon that is relevant for both the speech and hearing sciences. He discovered that when an individual is speaking and there is noise present, he or she unconsciously increases the loudness of their speech until the noise is stopped. This phenomenon is referred to as the Lombard effect (Lane & Tranel, 1971). The Lombard effect is a feedback loop that allows an individual to self-monitor his or her speech levels. The purpose of the increase in speech intensity is thought to ensure that the message is accurately and optimally delivered from the speaker to the listener (Lane & Tranel, 1971). In order to understand speech intensity regulation

in background noise both in normal speakers and in individuals with hypophonia, the Lombard effect is particularly relevant. It is of interest to explore the Lombard effect through the introduction of background noise when studying individuals with PD and hypophonia because hypophonia is often exacerbated in this context. In the presence of background noise, healthy individuals without PD will increase the duration, intensity, and fundamental frequency of their speech, specifically for informationally important words, in order to get the correct message across (Patel & Schell, 2008). The difficulty healthy individuals without PD face when speaking in background noise is assumed to be increased for individuals with hypophonia (Adams et al., 2005).

In 2005, Adams and colleagues studied the relationship between background noise and speech intensity regulation in individuals with PD and hypophonia. Using the concept of the Lombard effect, participants with PD and control participants repeated sentences in different intensity levels of multi-talker background noise conditions (i.e., 50, 55, 60, 65, 70 dB (decibel)). Both the PD and control groups showed an increase in speech intensity as the level of background noise increased. However, the participants with PD had a parallel but consistently lower speech intensity of 2 to 5 dB SPL (sound pressure level) when compared to that of the control participants (Adams et al., 2005). In 2006, Adams et al. completed a similar study that evaluated three different types of background noise; multi-talker noise, music, and pink noise. Similar to the results of the previous study by Adams and colleagues (2005), control participants had consistently higher speech intensity across all types of background noise, while the participants with PD had a lower but parallel change in speech intensity (Adams et al., 2006). These studies demonstrate that under a variety of background noise conditions, individuals with

hypophonia and PD have reduced speech intensity. Therefore, individuals with PD do demonstrate a Lombard effect, but their speech is consistently less intense than control participants, suggesting an attenuated pattern of response.

1.5 Speech Intelligibility

Speech intelligibility has been defined as the “degree to which the speaker’s intended message is recovered by the listener” (Kent, Weismer, Kent, & Rosenbek, 1989, p. 483). Having adequate speech intelligibility provides support in conversations that allows effective and efficient communication through spoken language. In order to determine the severity of the speech intelligibility deficit, speech pathologists and researchers use severity measures of intelligibility, which measure different aspects of speech production. These measures can assess the intelligibility of phonemes, single words, sentences, narratives, or conversational speech. Sentence intelligibility measures commonly cited in the literature include the AIDS (Assessment of Intelligibility of Dysarthric Speech; Yorkston & Beukelman, 1981), CAIDS (Computerized Assessment of Intelligibility of Dysarthric Speech; Yorkston, Beukelman & Traynor, 1984), and SIT (Sentence Intelligibility Test; Yorkston, Beukelman & Tice, 2011). In these tests a severity index is generated based on the number of words that are understood correctly by a listener when transcribed orthographically. The intelligibility score is derived by dividing by the total number of words correctly transcribed by the total number of words spoken and multiplied by 100. Intelligibility can also be measured via scaling techniques such as a visual analog scale (VAS). Using VAS, listeners evaluate intelligibility based on a global impression of a speaker’s intelligibility along a 100mm line. Since VAS provides information about an individual’s impression of speech intelligibility, visual analogue scaling can provide information on other

aspects of speech production such as, but not limited to, rate of speech, prosody, and voice quality that may factor into a global impression on intelligibility. This scaling method varies from transcription based intelligibility testing since it provides a more global impression of speech intelligibility beyond the correct identification of words that transcription based intelligibility measures provide. Yorkston, Beukelman, and Bell (1998) suggested that severity based intelligibility measures are the “primary measure of disability” in speakers with dysarthria.

As previously described in the section above, individuals with hypokinetic dysarthria can present with deficits and impairments in articulation, prosodic aspects of speech production, rate of speech, voice quality, and speech intensity regulation. Since speech intelligibility is based on a combination of articulatory, respiratory, laryngeal, velopharyngeal, and prosodic aspects of speech production (Dykstra et al., 2007), many individuals with hypokinetic dysarthria can present with reduced speech intelligibility. Each speech subsystem likely contributes to speech intelligibility in a cumulative and differential manner; however, many studies have demonstrated that the articulatory subsystem contributes a significant role to speech intelligibility. For example, imprecise articulation was identified by Darley, Aronson, and Brown (1969) as one of the most deviant perceptual features associated with hypokinetic dysarthria. Furthermore, De Bodt, Hernandez-Diaz Huici and Van de Heyning (2002) demonstrated that articulation was the most dominant dimension affecting speech intelligibility, when compared to the relative impact of other speech dimensions (i.e., voice quality, articulation, nasality, prosody) typically impaired in dysarthric speech production. Articulatory undershoot, or the failure to reach and sustain articulatory contacts has been suggested to be a factor contributing to reduced speech intelligibility in some individuals with hypokinetic dysarthria (Duffy, 2013).

In addition to the role of the articulatory subsystem contributing to reduced speech intelligibility, deficits in speech intensity regulation also can contribute to reductions in speech intelligibility in individuals with hypokinetic dysarthria. The empirical literature suggests that hypophonia is most evident in conversational speech tasks (Fox & Ramig, 1997; Ho et al., 1999). Therefore, the assessment of intelligibility in conversation should be considered for individuals with hypophonia and PD (Adams et al., 2006). This is especially relevant considering that many speech intelligibility tests focus on single word or sentence intelligibility and these tests are typically administered in quiet testing conditions. Therefore, the speech intelligibility of individuals with PD can appear relatively unimpaired (Dykstra et al., 2013). Unfortunately, when intelligibility tests are conducted in a quiet environment they can overestimate everyday speech intelligibility levels (Miller, 2013). This is why including background noise should be considered an important aspect of assessment, because it is relevant to the ability to make valid and real world inferences concerning the impact that a speech intelligibility deficit has in an individual's daily life. Naturally occurring conversation does not often occur in a quiet testing environment, but rather out in the world where adverse communication conditions exist. Adams, Dykstra, Jenkins, and Jog (2008) incorporated various intensities of multi-talker background noise (i.e., 0, 60, 65, 70 dB SPL) into the assessment of conversational intelligibility in individuals with PD and hypophonia. The conversational samples were transcribed, and conversational speech intelligibility was determined by dividing the number of words understood by the number of words produced (Adams et al., 2008). This study demonstrated that individuals with hypophonia had significantly overall lower conversational intelligibility scores when compared to control participants, despite relatively unimpaired speech intelligibility when tested in quiet conditions

(Adams et al., 2008). Speech intelligibility also significantly decreased as multi-talker noise levels increased for both controls and PD participants, and this was also a parallel relationship (Adams et al., 2008). This research highlights that although individuals with hypophonia can be intelligible in quiet conditions, the introduction of background noise can have a negative effect on the maintenance of intelligible speech production.

In 2013, Dykstra and colleagues also studied the conversational intelligibility of individuals with hypophonia, with a focus on using visual analog scaling for rating speech intelligibility. Similar to the methods previously discussed (Adams et al., 2008), conversational intelligibility was assessed in different intensity levels of background noise (i.e., 0, 60, 65, 70 dB SPL). This study found that without added background noise there was no significant difference in the intelligibility scores of individuals with PD versus control participants; however the speech intensity of the PD group was lower and had more variability than the control participants (Dykstra et al., 2013). When background noise at different intensities was introduced, participants with PD had lower conversational intelligibility scores. These conversational intelligibility scores were most dramatically compromised in higher levels of background noise (i.e., 65 dB SPL and 70 dB SPL). For example, for participants with PD, in 70 dB SPL of multi-talker background noise, conversational intelligibility was 57% as compared to 89% in quiet testing conditions. This is in contrast to the control participants who maintained 85% intelligibility in the same intensity of background noise (Dykstra et al., 2013). This research further demonstrates the negative impact of background noise on speech intelligibility for individuals with PD and hypophonia.

1.6 Listener Effort in Parkinson's Disease

During speech production, various speech symptoms (i.e., articulatory precision, rate of speech, prosodic factors, voice quality, speech intensity) can differently affect how well a message is understood by impacting speech intelligibility. In addition to affecting speech intelligibility, these perceptual speech disturbances may also contribute to increased listener effort (Duffy, 2013). Previous research has indicated that listeners have more difficulty understanding disordered speech in comparison to normal speech (Dykstra et al., 2007). This increased difficulty can cause a breakdown or a barrier to communication such that listeners may be forced to reallocate their resources, which may reduce opportunities to communicate due to the increased difficulty and cognitive load (Dykstra et al., 2007). The difficulty experienced by a listener may be attributed to the extra effort he or she is required to exert in order to understand a distorted speech signal. Listener effort can be defined as “the amount of work needed to listen to a speaker” (Whitehill & Wong, 2006, p.337). Specifically, there is empirical literature suggesting that listeners need to exert an increased amount of effort when listening to dysarthric speech (e.g., Whitehill & Wong, 2006; Dykstra et al., 2007; Landa et al., 2014). It is important to keep in mind that although speech intelligibility and listener effort are related, they are separate concepts (Whitehill & Wong, 2006; Hustad, 2008; Nagle & Eadie, 2012).

In 2006, Whitehill and Wong investigated the speech of 22 participants with various dysarthria types. Participants read sentences from the SIT and listeners transcribed the sentences, rated listener effort, and selected perceptual features that contributed to their effort rating. The results of this study indicated that disruptions in voice quality such as strangled, breathy, or harsh voice increased listener effort (Whitehill & Wong, 2006). Whitehill and Wong (2006) also

observed a strong correlation between speech intelligibility scores and listener effort. They discerned that listener effort and articulation errors were highly related, suggesting that articulation plays an important role in the understandability of speech (Whitehill & Wong, 2006). Landa and colleagues (2014) demonstrated that when listeners rated 'ease of listening' for dysarthric speech, poorer intelligibility scores were associated with increased listening effort. Furthermore, McAuliffe and colleagues (2014) sought to investigate the effect of habitual, loud, and slow speech on the perceptual processing of healthy individuals. They demonstrated that when 5 PD participants with a fast speech rate were asked to speak at half of what they considered their normal rate of speech, their average intelligibility scores improved dramatically from 45.23% to 69.28% (McAuliffe, Kerr, Gibson, Anderson, & LaShell, 2014). McAuliffe and colleagues (2014) also suggested that the observed reduction on speech rate approximated typical speech rates, which allowed listeners to reduce their cognitive resources necessary to process the information (McAuliffe et al., 2014). In 2007, Hustad examined the relationship between speech intelligibility and confidence ratings of dysarthric speech. Listeners transcribed the speech of individuals with dysarthria and then indicated how confident they were in what they wrote. There were no strong correlations found between intelligibility scores and perceived confidence ratings, indicating that there may be a mismatch in how well listeners think they understand dysarthric speech and how well they really understood it (Hustad, 2007). This finding also suggests that confidence ratings may be capturing the processing load required by the listener when transcribing dysarthric speech (Hustad, 2007). Whitehill, Ciocca, & Yiu (2004) suggested that the impairment in suprasegmental factors can increase listener effort, thereby reducing understanding of the intended message. It also demonstrates that intelligibility scores are not the

only measure that should be used when determining the impact of dysarthric speech on listener effort.

Although speech intelligibility is an important component of the perception of listener effort, speech intelligibility likely does not determine listener effort alone. Beukelman et al. (2011) evaluated the perceived attention allocation of listeners who transcribed the speech intelligibility of individuals with amyotrophic lateral sclerosis (ALS). Beukelman and colleagues (2011) demonstrated that when speakers with ALS were almost 100% intelligible, the perceived attention allocation was low. However, as the intelligibility scores decreased to 75% the perceived attention allocation scores increased dramatically (Beukelman et al., 2011). This result indicates that as the severity of dysarthria increases, the amount of attention allocation required to understand the message accurately also increases. This suggests that an increase in the cognitive load of the listener is present when listening to dysarthric speech. Evaluating the perceived attention allocation load of listeners may be an important aspect to measure in addition to speech intelligibility. Since the purpose of transcription based speech intelligibility tests is to identify the percentage of words correctly understood by a listener, this measure does not provide information on the perceptual load experienced by a listener when transcribing a disordered speech signal (Beukelman et al., 2011). Furthermore, Beukelman and colleagues (2011) discussed that intelligibility tests do not differentiate listener effort since similar intelligibility scores could be obtained at the expense of unequal resources allocated by the listener. Beukelman et al. (2011) provide a poignant example that family members often report working very 'hard' to understand the speech of an individual with ALS, despite relatively high objective measures of speech intelligibility.

1.7 Rationale for the Current Study

Numerous research studies have evaluated the speech intelligibility of individuals with hypokinetic dysarthria. Fewer studies, however, have investigated perceptions of listener effort when transcribing dysarthric speech. Furthermore, little is known of the specific features of the speech signal that contribute to perceived listener effort in the speech of individuals with PD and hypophonia. It is of interest, therefore, to determine whether two common speech symptoms associated with hypokinetic dysarthria contribute to judgements of listener effort. It is also of interest to determine the effect of background noise on listener ratings of intelligibility and effort since hypophonia is a common speech symptom of hypokinetic dysarthria.

The purpose of this study is to investigate two speech symptoms (1. Articulatory imprecision, 2. Reduced loudness) that may contribute to perceived listener effort and that are commonly impaired in individuals with Parkinson's disease (Darley et al., 1975). The relationships of these speech symptoms to ratings of listener effort in speakers with Parkinson's disease and hypokinetic dysarthria will be investigated in two conditions: (1) a no added background noise condition and; (2) in a 65 dB SPL multi-talker background noise condition. A 65 dB multi-talker background noise condition was chosen to investigate the effect of background noise on ratings of listener effort because it represents a moderate level of background noise commonly encountered in everyday communicative situations. This study also aims to determine potential relationships among ratings of listener effort and speech intelligibility in both noise conditions (i.e., no added background noise, 65 dB multi-talker background noise).

Four main objectives were examined in this study. These objectives sought to:

1. Evaluate and compare transcription based speech intelligibility scores, ratings of VAS speech intelligibility, ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness in both a no added background noise condition and in 65 dB of multi-talker background noise condition.
2. Determine the relationships among transcription based sentence intelligibility scores and VAS sentence intelligibility scores with ratings of listener effort in both a no added background noise condition and in 65 dB of multi-talker background noise.
3. Examine the strength of the relationship between ratings of listener effort and severity ratings of the two speech symptoms (1. Articulatory imprecision, 2. Reduced loudness) in both a no noise condition and in 65 dB of multi-talker background noise condition.
4. Examine the strength of the relationships among ratings of transcription based speech intelligibility scores and VAS speech intelligibility scores with two speech symptoms (1. Articulatory imprecision, 2. Reduced loudness) in both a no-added background noise condition and in a 65 dB background noise condition.

It is anticipated that this research will help to identify the specific aspects of speech production that impact ratings of listener effort across each of these two speech symptoms. It is also anticipated that this research will have the potential to inform novel therapy techniques and procedures that may serve to tailor interventions by targeting the most salient dysarthric speech symptoms to maximize intelligibility and minimize listener effort.

Chapter 2

2 Method

2.1 Participants

Speakers with PD. Data for the current study were obtained from archived audio-recordings of 22 adults with PD and hypophonia during their participation in studies examining speech intensity regulation in noise. The speakers with PD consisted of 17 men and 5 women ranging in age from 58 to 80 years ($M=69.41$, $SD=6.91$). All participants were: a) fluent in English (written and spoken); b) able to read sentences from a piece of paper; c) diagnosed with PD and hypokinetic dysarthria. The archived audio-recordings consisted of 13 to 15 word sentences taken from the Sentence Intelligibility Test (SIT) (Yorkston, Beukelman & Tice, 2011) that were read aloud in different background noise conditions (i.e., no added background noise and 65 dB SPL of multi-talker background noise). Table 1 contains specific data for each speaker at the time the audio recordings were made. This table includes information about the speakers's sex, age, years since diagnosis, and medication.

Table 1.

Demographic information of speakers with PD.

Speaker ID	Sex	Age	Years Since Diagnosis	Medication Type
PD1	M	59	12	Sinemet, Requip
PD2	F	70	5	Sinemet
PD3	M	79	1	Sinemet, Levodopa/Carbidopa
PD4	M	74	14	Levodopa
PD5	F	76	16	Levodopa/Carbidopa
PD6	F	72	7	Levodopa

Speaker ID	Sex	Age	Years Since Diagnosis	Medication Type
PD7	F	74	3	Levodopa
PD8	F	67	9	Levodopa
PD9	M	73	15	Sinemet
PD10	M	58	1	No medication
PD11	M	63	5	Sinemet
PD12	M	62	16	Sinemet & slow release Apotriex
PD13	M	74	16	Sinemet
PD14	M	73	5	Sinemet
PD15	M	67	2	Sinemet
PD16	M	75	2	Sinemet
PD17	M	80	1	No medication
PD18	M	59	1	Sinemet
PD19	M	78	4	Sinemet
PD20	M	60	5	Levodopa/Carbidopa
PD21	M	67	6	Sinemet/Levodopa
PD22	M	67	3	Sinemet

Listener Participants. Ten naïve individuals ($n=10$) were recruited to participate in this study as listeners. These listeners were undergraduate and graduate level students from Western University and consisted of 2 men and 8 women ranging in age from 18 to 43 years ($M = 24.1$, $SD = 6.89$). All listeners: a) spoke English as a first language; b) had no speech, hearing, or neurological impairments; c) did not have extensive research or clinical experience with dysarthric speech or Parkinson's disease. Additionally, all listeners passed a 25dB HL hearing screening bilaterally at 500, 1000, 2000 and 4000 Hertz (Hz) before participating in the listening tasks to ensure that their hearing was within a normal range.

All listener participants were required to read and comprehend a letter of information

(Appendix A) about the study. All questions from participants were answered prior to their providing written consent (Appendix B) as per Western University's Research Ethics Board approval protocol. Each participant was also informed that they would be asked to return for a second visit as a continuation of the study. Participants provided written consent prior to beginning the second experimental session. Prior to the experiment, all listener participants completed an intake survey in which they provided basic demographic information including their age so that a mean age could be calculated (Appendix C). Listeners were blinded to all information about the speakers and the archived speech data obtained from speakers with PD was de-identified to ensure anonymity. This study received approval from Western University's Research Ethics Review Board (Appendix D).

2.2 Materials

Noise Conditions. The archived speech recordings of speakers with PD were originally recorded in a no added background noise condition and a 65 dB SPL multi-talker background noise condition which is described below.

For the no added background noise condition, there was no added background noise in the room when the participant with PD was reading the sentences from the SIT. Each participant was tested in an audiometric soundproof booth (Industrial Acoustic Company). With the examiner present in the room, the participant, a loudspeaker, and a boom-mounted floor microphone (Shure SM48) were situated in an equilateral triangle, 150 centimetres (cm) away from each other. The loudspeaker presented free-field multi-talker noise (Audiotech – 4 talker noise). The original examiner adjusted the sound level (dB SPL level) of multi-talker noise via a diagnostic audiometer (GSI 10) located within the audiometric booth. The participant also wore a

headset microphone (AKG-C420) to record his or her utterances. This microphone served as the primary source for obtaining measures of speech intensity. This microphone was placed 6 cm from the participant's mouth and it was calibrated using a sound level meter placed 15 cm from the mouth of the participant. In order to calibrate the microphone, the participant was asked to produce /a/ at 70 dB SPL as indicated by a sound level meter. The boom-mounted microphone was placed on a support boom at a height of 100 cm from the floor (150 cm from the participant's mouth), and this microphone served as the primary source for obtaining listener ratings of intelligibility (transcription and VAS), effort, articulatory imprecision, and loudness. The boom-mounted microphone was calibrated by a free-field 1000 Hz tone and a sample of the multi-talker noise was presented at 70 dB SPL from the loudspeaker (150 cm away). In the 65 dB multi-talker background noise condition, a loudspeaker presented free-field multi-talker noise (Audiotech – 4 talker noise) calibrated at 65 dB SPL while each participant read sentences from the SIT. The recordings were made by attaching the boom-mounted floor microphone and headset microphone to a USB pre-amplifier system (M-Audio; Pre-Mobile USB system) via dual XLR connectors. The USB pre-amplifier was then attached to a laptop computer via a USB port. The laptop had the audio recorder software associated with PRAAT (version 5.2.14; Boersma & Weenik, 2011) installed, and the speech analysis program digitized the dual (stereo) microphone acoustic signals at 44.1 kHz and 16 bits per channel.

Speech intelligibility. A measure of sentence speech intelligibility was obtained from each speaker with PD using the Sentence Intelligibility Test (SIT) (Yorkston, Beukelman & Tice, 2011). The SIT is comprised of a list of 11 sentences that can be randomly selected from. Sentences range in length from 5-15 words. In the present study only sentences 13-15 words long

were used to determine speech intelligibility and to rate listener effort (Appendix E). Each participant with PD read aloud a randomly generated list of sentences unique from that of the other participants. No two participants received identical lists of sentences. Different sentences were read aloud by each participant with PD in the two background noise conditions. Each participant with PD was instructed to read aloud 11 sentences of the SIT that were presented on a standard 8 ½ by 11 inch piece of white paper in 18 point Times New Roman font. Each participant's production of the SIT was recorded by attaching the boom-mounted floor microphone and headset microphone to a USB pre-amplifier system (M-Audio; Pre-Mobile USB system) via dual XLR connectors. The USB pre-amplifier was then attached to a laptop computer with PRAAT (version 5.2.14; Boersma & Weenik, 2011) via a USB port. This audio recording system recorded the participant's speech at 44.1 kHz and 16 bits per channel sampling rate.

Speech sample editing. Audio-recorded speech samples were compiled into playlists for each of the two listening sessions in the open-source program PRAAT version 5.4.04 (Boersma & Weenink, 2013). Each audio-recorded speech sample was comprised of 3 sentences (13, 14, and 15 words in length) from the SIT. With 22 PD speech samples and the samples from four randomly selected speakers with PD repeated within each playlist for determination of intra-listener reliability, the playlists were 26 samples long, with 4-second pauses between sentences. The order of presentation of the sentences was randomized so that there were 5 orders for each condition (i.e., no added background noise and 65dB). This allows for inter-rater reliability, since two different listeners heard each playlist.

2.3 Procedure

Informed consent was first obtained, after which each listener participant was asked to

complete the perceptual tasks while seated at a desk in a quiet dedicated laboratory space, located in the Communicative Participation Lab. Listener participants were informed that they would complete the listening protocol individually over two 1.5 to 2 hour listening sessions, with breaks as required. Listener participants listened to the no added background noise condition during one session, and the 65dB multi-talker background noise condition during the other session. The order of which noise condition was presented first was counterbalanced so that half of the participants listened to the no added background condition first, and the other half listened to the 65dB multi-talker background noise condition first. Participants were seated at a desk with copies of the perceptual task sheets (Appendices F and G) in front of them. The examiner (C.W.) was seated in the room during experimental sessions to ensure that the set-up of equipment was consistent among participants. All listener participants listened to these audio-recordings through AV 40 (M-Audio) speakers connected to a Sony Vaio laptop. Listeners were asked to rate speech intelligibility using orthographic transcription (i.e., word-for-word) and via visual analogue scaling, and make judgments of effort using visual analogue scaling on the perceptual task sheets (Appendices F and G). Finally, listeners rated, using visual analogue scaling, the severity of the two individual speech symptoms (i.e., articulatory imprecision, reduced loudness). This procedure was repeated for each of the 22 speakers with PD based on their audio-recordings of three sentences from the SIT. The details of each task are presented below.

Familiarization and training session. During a 10-minute familiarization and training session immediately preceding the experimental protocol, listeners were provided with verbal explanations of the terms and definitions required to complete the study. They were also given an opportunity to listen to examples of impaired speech characteristics (i.e., articulatory

imprecision, reduced loudness) common in hypokinetic dysarthria. This familiarization and training session allowed listener participants to ask questions prior to the start of the listening protocol and they also gained an understanding of the speech parameters being investigated in this study.

Speech intelligibility. During the entire listening protocol, listeners were seated 24 inches from two M-audio speakers, which were fixed at a predetermined volume of 65 dB. The examiner, with the use of a multi-talker noise calibration file, predetermined the intensity level to 65 dB. Listeners rated speech intelligibility based on 13-15 word sentences using the scoring procedures outlined in the Sentence Intelligibility Test (Yorkston, Beukelman & Tice, 2011). Participants orthographically transcribed audio recordings of the three sentences from the Sentence Intelligibility Test (SIT) (Yorkston et al., 2011). Listeners rated the intelligibility of spoken sentences that were audio-recorded in the no added background noise condition or in 65 dB SPL multi-talker background noise condition. An intelligibility score was calculated by comparing transcribed words and sentences to the stimuli on the master list. Listeners also rated speech intelligibility using a 100mm visual analogue scale with the anchors: “0% intelligibility” on the left end of the scale and “100% intelligibility” on the right of the scale.

Listener effort rating. Directly following the orthographic transcription task, listeners indicated the amount of ‘perceived effort’ they expended when orthographically transcribing the three spoken sentences in either the no added background noise condition, or the 65 dB SPL multi-talker background noise condition. This effort judgement was rated on a 100mm visual analogue scale with the anchors: “no effort required” and “maximum effort required” (Appendices F and G).

Severity rating. Listeners were presented with the audio-recorded PD speech samples again (i.e., three spoken sentences). Listeners rated using visual analogue scaling two perceptual speech symptoms (i.e., 1. Articulatory imprecision, 2. Reduced loudness) based on severity. The anchors on the 100mm long VAS across the two speech symptoms corresponded to the anchors "normal" and "severely abnormal/impaired" (Appendices F and G).

2.4 Statistical Analyses

Four objectives were investigated in this study. An alpha level of $p=0.05$ was used for all statistical analyses. The first objective evaluated and compared intelligibility scores (transcription based and VAS), ratings of listener effort, ratings of articulatory imprecision and ratings of reduced loudness across both noise conditions (i.e., no added background noise and 65dB multi-talker background noise). The second objective sought to determine relationships among ratings of listener effort and sentence intelligibility (based on transcription and VAS scores) in both a no added background noise condition and in 65 dB SPL of multi-talker background noise condition. The third objective examined the strength of the relationship between ratings of two speech symptoms (1. Articulatory imprecision, 2. Reduced loudness) based on severity ratings of listener's judgments of effort in both a no added background noise condition and 65 dB SPL of multi-talker background noise condition. The final objective examined the strength of the relationship between ratings of speech intelligibility (transcription based and VAS) and the two speech symptoms (articulatory imprecision and reduced loudness) in both a no added background noise condition and 65 dB SPL of multi-talker background noise condition. These objectives were addressed using the statistical analyses outlined below.

2.4a) Objective 1: Evaluate and compare transcription based intelligibility scores, VAS ratings of speech intelligibility, ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness across two noise conditions. Five paired samples t-tests were used to evaluate the intelligibility scores (transcription, VAS), ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness in the two background noise conditions: no added background noise condition versus 65 dB multi-talker background noise condition. The comparisons are as follows: 1. Transcription based sentence intelligibility scores: no added background noise vs. 65 dB of multi-talker background noise; 2. VAS speech intelligibility ratings: no added background noise vs. 65 dB of multi-talker background noise; 3. Ratings of listener effort: no added background noise vs. 65 dB of multi-talker background noise; 4. Ratings of articulatory imprecision: no added background noise vs. 65 dB of multi-talker background noise; 5. Ratings of reduced loudness: no added background noise vs. 65 dB of multi-talker background noise.

2.4b) Objective 2: Determine the relationship between speech intelligibility (transcription, VAS) and ratings of listener effort across noise conditions. Four separate Pearson correlations were performed on this data to determine the degree of correlation among speech intelligibility scores (transcription, VAS) and ratings of listener effort: 1. Sentence intelligibility scores (transcription) and ratings of listener effort in the no added background noise condition; 2. Sentence intelligibility scores (transcription) and ratings of listener effort in the 65 dB multi-talker background noise condition; 3. Speech intelligibility ratings (VAS) and ratings of listener effort in the no added background noise condition; 4. Speech intelligibility ratings (VAS) and ratings of listener effort in the 65 dB multi-talker background noise condition.

2.4c) Objective 3: Examine the strength of the relationship between ratings of listener effort and two speech symptoms (articulatory imprecision, reduced loudness) across noise

conditions. Four correlational analyses were conducted to determine the degree of correlation between ratings of listener effort and the two speech symptoms: 1. Listener ratings of effort and articulatory imprecision in the no added background noise condition; 2. Listener ratings of effort and articulatory imprecision in the 65 dB multi-talker background noise condition; 3. Listener ratings of effort and reduced loudness in the no added background noise condition; 4. Listener ratings of effort and reduced loudness in the 65 dB multi-talker background noise condition.

2.4d) Objective 4: Examine the strength of the relationship between ratings of speech intelligibility (transcription, VAS) and two speech symptoms (articulatory imprecision, reduced loudness) across noise conditions.

Eight correlational analyses were conducted to determine the degree of correlation among ratings of speech intelligibility (transcription, VAS) with the two speech symptoms: 1. Sentence intelligibility scores (transcription) and articulatory imprecision scores in the no added background noise condition; 2. Sentence intelligibility scores (transcription) and articulatory imprecision scores in the 65 dB of multi-talker background noise condition; 3. Speech intelligibility ratings(VAS) and articulatory imprecision scores in the no added background noise condition; 4. Speech intelligibility ratings (VAS) and articulatory imprecision scores in the 65 dB multi-talker background noise condition; 5. Sentence intelligibility scores (transcription) and reduced loudness scores in the no added background noise condition; 6. Sentence intelligibility scores (transcription) and reduced loudness scores in the 65 dB multi-talker background noise condition; 7. Speech intelligibility ratings (VAS) and reduced loudness scores in the no added background noise condition; 8. Speech intelligibility

ratings (VAS) and reduced loudness scores in the 65 dB multi-talker background noise condition.

Chapter 3

3 Results

3.1 Statistical Power

Statistical power is based on a relationship between sample size, variance in the data, effect size, and statistical significance (Portney & Watkins, 2000). Power reflects the ability to detect treatment differences and the chance of replication (Keppel, 1991). Statistical power was judged to be satisfactory in the present study. Power was calculated to be 0.80 for an effect size of 0.5 ($t(25)=1.708$, $p<0.05$) (GPower Version 3.1).

3.2 Reliability

Inter-rater estimates of reliability were calculated for ratings of intelligibility (both transcription based scores and VAS ratings), listener effort, articulatory imprecision and reduced loudness in both noise conditions (i.e., no added background noise and 65 dB of multi-talker background noise). The ICC values obtained for inter-rater reliability ranged from 0.871 to 0.973, $p<0.01$ in the no added background noise condition. The ICC values for the 65dB multi-talker background noise condition ranged from 0.884 to 0.989, $p<0.001$. These ICC values demonstrate overall good reliability between listeners for the ratings of sentence intelligibility (transcription based & VAS), listener effort, articulatory imprecision, and reduced loudness.

Scores from each listener for each listening task were measured against each other to obtain intra-rater reliability values. Each of the ten listener participants re-measured 18.18% of the data to determine intra-rater reliability. Cronbach's alpha revealed an overall intra-rater

reliability estimate of 0.891, $p < 0.01$ across tasks, which indicates good intra-rater reliability across all task measurements.

Table 2 summarizes the interclass correlation coefficient and Cronbach's alpha values in obtaining overall inter-rater and intra-rater reliability values. Table 3 summarizes the descriptive statistics and the results of interclass coefficient analyses used to obtain inter-rater estimates of reliability. Statistical output of the overall inter-rater reliability analyses can be found in Appendix H. Statistical output of the overall intra-rater reliability analyses can be found in Appendix I.

Table 2.

Summary of intra-rater and inter-rater estimates of reliability across all task measurements.

	Intra-rater reliability	Inter-rater reliability
Intra-class correlation coefficient (ICC)	0.898 $p < 0.01$	0.960 $p < 0.01$
Cronbach's alpha	0.891	0.963

Table 3.

Summary of inter-rater estimates of reliability for transcription based sentence intelligibility, VAS speech intelligibility, listener effort, articulatory imprecision, and reduced loudness tasks in both noise conditions (i.e., no added background noise and 65dB of multi-talker background noise).

	L1*	L2	L3	L4	L5	L6	L7	L8	L9	L10	ICC	Cronbach's alpha
SIT ¹	88.20	86.79	84.95	86.14	85.38	84.63	85.17	86.79	78.02	89.39	0.973 <i>p</i> <.01	0.977
VAS ²	80.05	64.14	57.81	68.45	65.09	85.27	81.95	73.18	96.00	80.36	0.920 <i>p</i> <.01	0.950
Effort ₃	32.50	34.95	53.55	50.36	64.18	14.55	33.05	39.27	6.18	25.73	0.894 <i>p</i> <.01	0.947
Artic ₄	22.77	44.81	45.77	56.14	39.41	22.77	19.82	37.50	9.55	27.5	0.871 <i>p</i> <.01	0.917
Loud ₅	27.32	30.91	48.95	47.22	33.86	25.91	35.91	33.36	12.63	30.95	0.935 <i>p</i> <.01	0.950
SIT ⁶	56.49	43.72	44.47	44.58	46.75	46.86	51.19	47.83	33.91	45.88	0.989 <i>p</i> <.01	0.992
VAS ⁷	61.18	36.45	34.73	43.41	47.09	35.77	54.55	48.55	72.68	40.00	0.959 <i>p</i> <.01	0.973
Effort ₈	53.86	65.23	80.91	83.64	77.68	70.77	81.00	79.14	33.00	61.00	0.924 <i>p</i> <.01	0.957
Artic ₉	32.55	50.44	57.17	58.90	47.56	55.65	32.00	44.11	41.14	50.00	0.884 <i>p</i> <.01	0.906
Loud ₁₀	43.27	53.36	63.27	69.09	59.00	45.91	52.73	55.68	45.86	60.82	0.958 <i>p</i> <.01	0.964

¹ Sentence intelligibility measured by orthographic transcription in no added background noise

² Speech intelligibility measured by visual analog scale in no added background noise

³ Overall listener effort measured by visual analog scale in no added background noise

⁴ Articulatory imprecision measured by visual analog scale in no added background noise

⁵ Reduced loudness measured by visual analog scale in no added background noise

⁶ Sentence intelligibility measured by orthographic transcription in 65dB multi-talker background noise

⁷ Speech intelligibility measured by visual analog scale in 65dB multi-talker background noise

⁸ Overall listener effort measured by visual analog scale in 65dB multi-talker background noise

⁹ Articulatory imprecision measured by visual analog scale in 65dB multi-talker background noise

¹⁰ Reduced loudness measured by visual analog scale in 65dB multi-talker background noise

* L1 = Listener 1, L2 = Listener 2, etc.

3.3 Objective 1: Evaluate and compare transcription based intelligibility scores, VAS ratings of speech intelligibility, ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness across two noise conditions.

The purpose of the first objective evaluated how:

1. Transcription based sentence intelligibility scores compared across the two noise conditions;
2. VAS speech intelligibility ratings compared across the two noise conditions;
3. Ratings of listener effort compared across the two noise conditions;
4. Ratings of articulatory imprecision compared across the two noise conditions;
5. Ratings of reduced loudness compared across the two noise conditions.

Five paired samples t-tests were conducted to evaluate these variables across the two noise conditions. More specifically, the following comparisons were made:

- A) Transcription based sentence intelligibility scores: no added background noise vs. 65 dB of multi-talker background noise;
- B) VAS speech intelligibility ratings: no added background noise vs. 65 dB of multi-talker background noise;
- C) Ratings of listener effort: no added background noise vs. 65 dB of multi-talker background noise;
- D) Ratings of articulatory imprecision: no added background noise vs. 65 dB of multi-talker background noise;
- E) Ratings of reduced loudness: no added background noise vs. 65 dB of multi-talker

background noise.

Table 4 shows the means and standard deviations comparing the transcription based sentence intelligibility scores, ratings of VAS speech intelligibility, ratings of listener effort, ratings of articulatory imprecision, and reduced loudness ratings across the no added background noise and 65 dB of multi-talker background noise conditions.

Table 4.

Comparison of speech intelligibility scores, ratings of listener effort, ratings of articulatory imprecision and ratings of reduced loudness across noise conditions.

	No added background noise	65dB multi-talker background noise
Intelligibility (Transcription)	$M = 85.54$ $SD = 14.44$	$M = 46.17$ $SD = 32.37$
Intelligibility (VAS)	$M = 75.23$ $SD = 19.83$	$M = 47.44$ $SD = 30.86$
Listener Effort	$M = 35.43$ $SD = 22.46$	$M = 68.62$ $SD = 25.77$
Articulatory Imprecision	$M = 32.60$ $SD = 19.07$	$M = 52.00$ $SD = 26.74$
Reduced Loudness	$M = 32.70$ $SD = 24.38$	$M = 54.80$ $SD = 29.90$

A) The comparison of transcription based sentence intelligibility scores revealed significant differences between the no added background noise condition ($M=85.54$, $SD= 14.44$) and the 65dB multi-talker background noise condition ($M= 46.17$, $SD= 32.37$) ($t(21)= 7.192$, $p=0.000$) (Figure 1). This result suggests that listeners had more difficulty accurately

transcribing the sentences presented in the 65 dB multi-talker background noise condition.

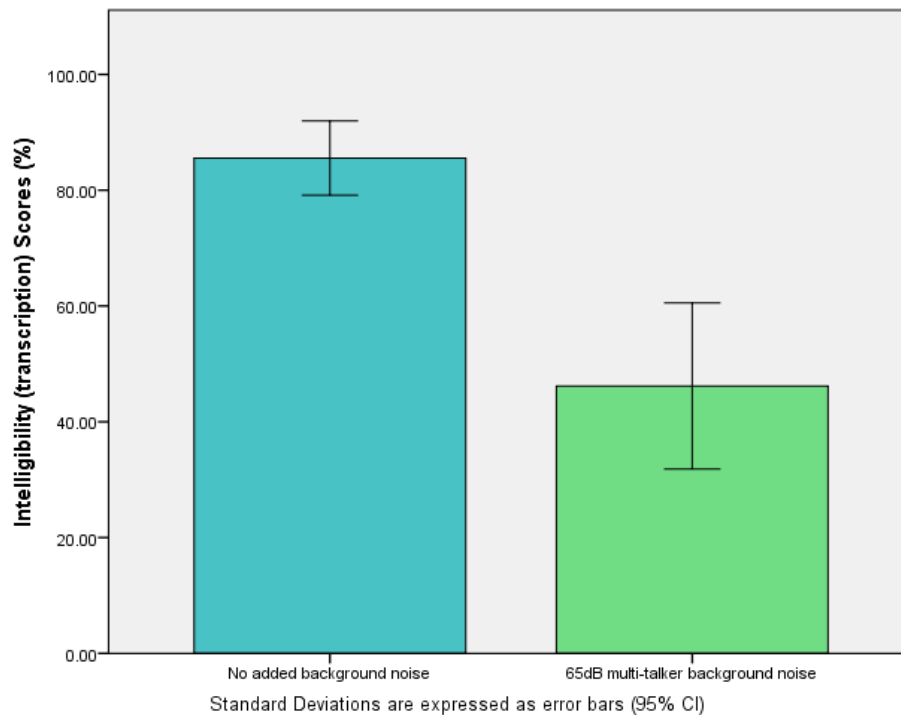


Figure 1. Transcription based intelligibility scores: no added background noise vs. 65dB multi-talker background noise.

B) The comparison of ratings of VAS speech intelligibility also revealed significant differences between the no added background noise condition ($M= 75.23$, $SD=19.83$) and the 65dB multi-talker background noise condition ($M= 47.44$, $SD=30.86$) ($t(21)= 5.355$, $p=0.000$) (Figure 2). This result suggests that listeners consistently assigned a higher rating of speech intelligibility to speakers in the no added background noise condition as compared to the 65dB multi-talker background noise condition.

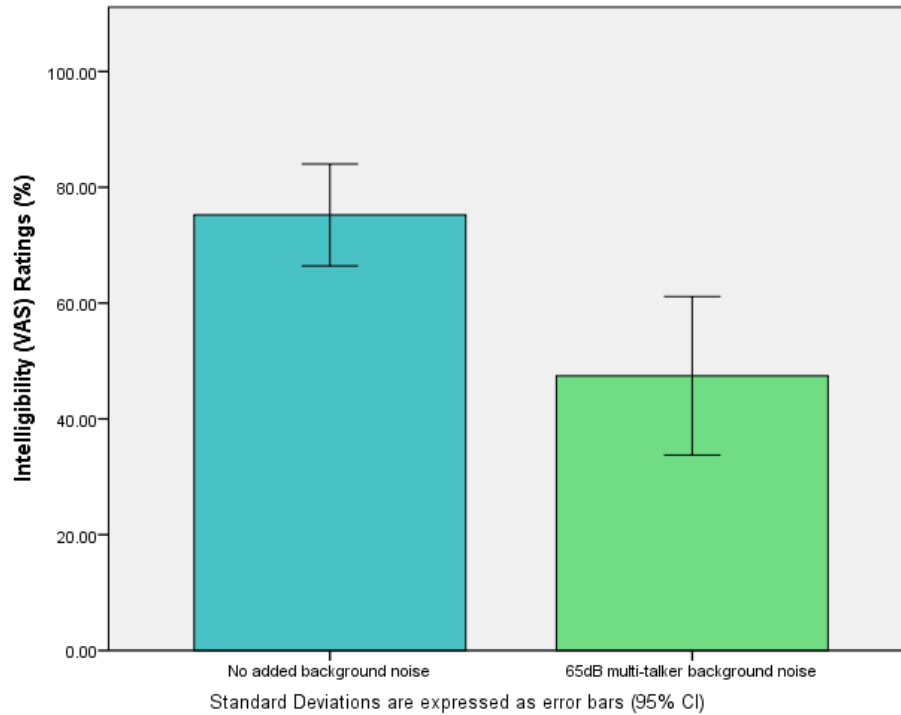


Figure 2. Speech intelligibility (VAS) ratings: no added background noise vs. 65dB multi-talker background noise.

C) The comparison of ratings of listener effort revealed significant differences between listener ratings in the no added background noise condition ($M= 35.43$, $SD= 22.46$) and the 65dB multi-talker background noise condition ($M= 68.62$, $SD= 25.77$) ($t(21)= -7.997$, $p=0.000$) (Figure 3). This result suggests that listeners perceived that they used an increased amount of effort to understand the speakers with PD in the 65 dB multi-talker background noise condition.

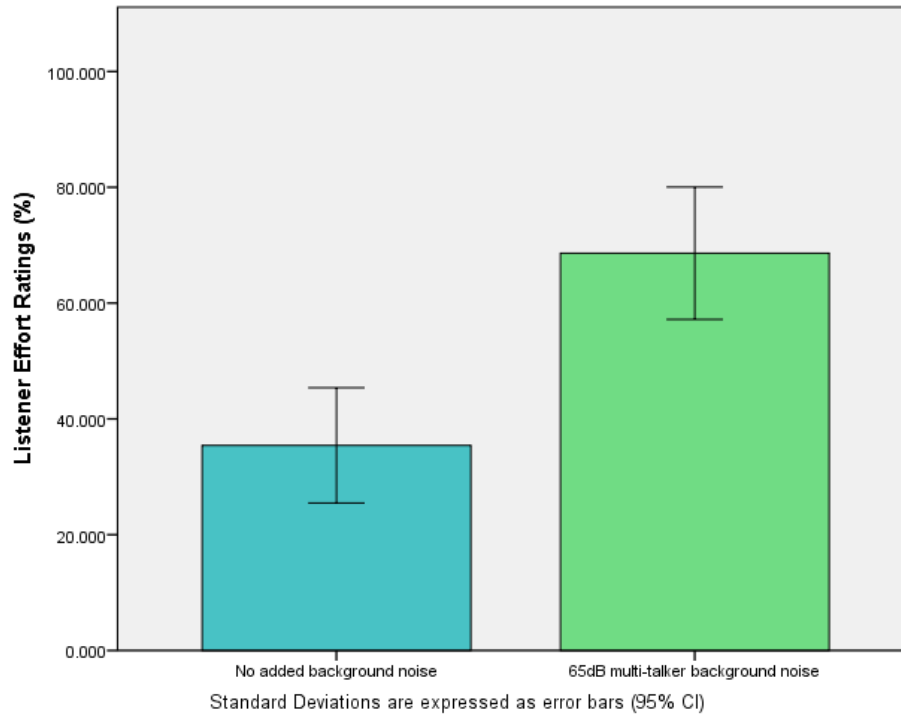


Figure 3. Ratings of listener effort: no added background noise vs. 65dB multi-talker background noise.

D) The comparison of ratings of articulatory imprecision revealed significant differences between listener ratings in the no added background noise condition ($M = 32.60$, $SD = 19.07$) and the 65 dB multi-talker background noise condition ($M = 52.00$, $SD = 26.74$) ($t(21) = -4.822$, $p = 0.000$) (Figure 4). This result suggests that listeners consistently assigned a higher rating of articulatory imprecision to speakers in the 65dB multi-talker background noise condition as compared to the no added background noise condition.

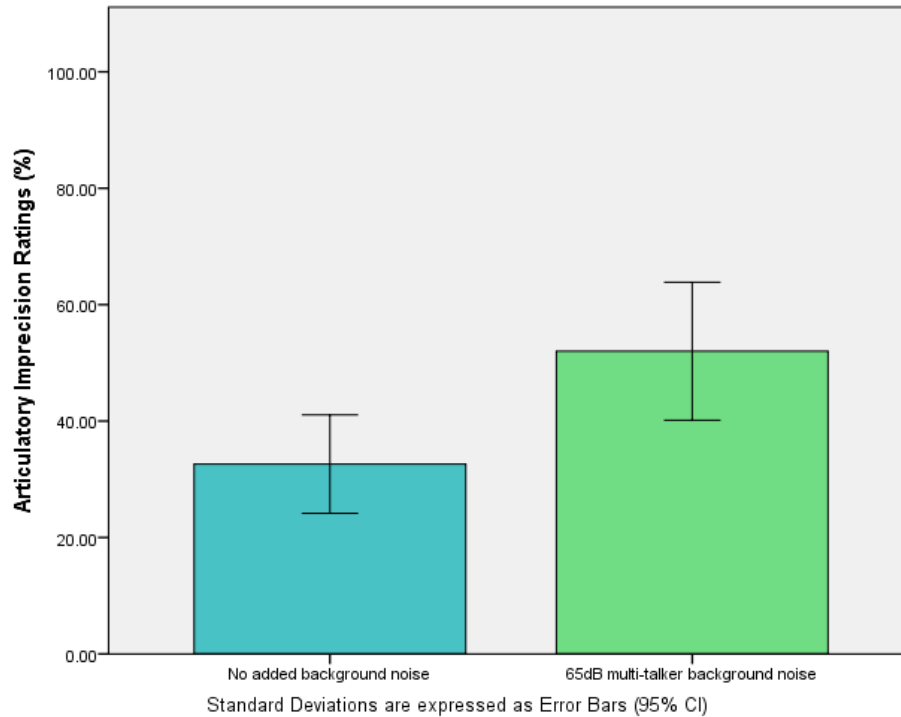


Figure 4. Ratings of articulatory imprecision: no added background noise vs. 65 dB of multi-talker background noise.

E) The comparison of reduced loudness ratings revealed significant differences between listener ratings in the no added background noise condition ($M = 32.70$, $SD = 24.38$) and the 65 dB multi-talker background noise condition ($M = 54.80$, $SD = 29.90$) ($t(21) = -4.185$, $p = 0.000$) (Figure 5). This result suggests that listeners consistently assigned a higher rating of reduced loudness to speakers in the 65dB multi-talker background noise condition as compared to the no added background noise condition.

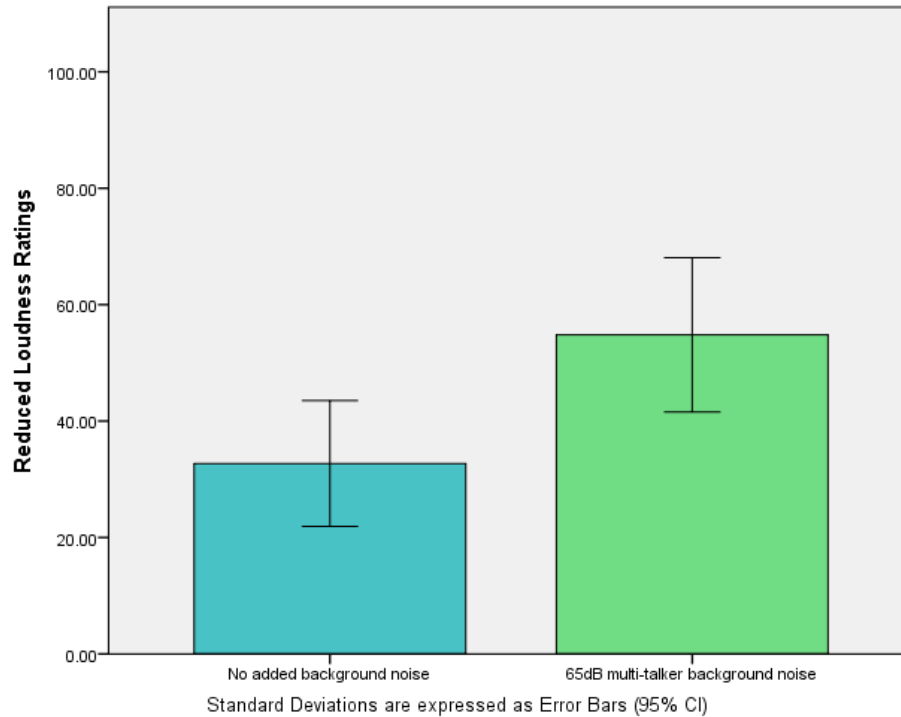


Figure 5. Ratings of reduced loudness: no added background noise vs. 65 dB of multi-talker background noise.

Overall, these results suggest that the introduction of a moderate intensity level of multi-talker background noise significantly reduced listener ratings of both transcription based sentence intelligibility scores and VAS speech intelligibility ratings of the speakers with PD. In addition, the introduction of 65dB of multi-talker background noise also increased ratings of listener effort significantly as compared to the no added background noise condition. This suggests that background noise may not only impair a listener's understanding of what is being said by an individual with PD, but also that moderate intensity levels of background noise creates a more effortful listening environment for individuals listening to the speech of individuals with PD. These results also suggest that both reduced loudness and articulatory imprecision were

perceived as more impaired in the background noise condition than in the no noise condition.

3.4 Objective 2: Determine the relationship between speech intelligibility (transcription, VAS) and ratings of listener effort across noise conditions.

The second objective addressed ratings of listener effort and speech intelligibility from both transcription scores and VAS ratings, in both noise conditions. In order to determine the degree of correlation, four Pearson's correlations were conducted. More specifically, the following four comparisons were made:

- A) Transcription based sentence intelligibility scores vs. ratings of listener effort (no background noise)
- B) Transcription based sentence intelligibility scores vs. ratings of listener effort (65dB multi-talker background noise)
- C) Visual analog scale speech intelligibility ratings vs. ratings of listener effort (no added background noise)
- D) Visual analog scale speech intelligibility ratings vs. ratings of listener effort (65 dB multi-talker background noise)

These analyses were conducted to answer the following research questions:

1. Do ratings of listener effort relate to listener transcription based sentence intelligibility scores and VAS speech intelligibility ratings?
2. Does added background noise have an effect on the relationship between listener effort ratings and speech intelligibility scores?

A) Pearson's correlation between sentence intelligibility scores (transcription) ($M=85.54$, $SD=14.44$) and ratings of listener effort ($M= 35.43$, $SD=22.46$) in the no added background noise condition was $r(21)= -0.892$, $p=0.000$ (Figure 6). This suggests that 79.57% of variance in listener effort is explained by transcription-based intelligibility scores when no added background noise is present. Figure 6 shows a strong negative linear relationship between sentence intelligibility (transcription) and listener effort in no added background noise.

B) Pearson's correlation between sentence intelligibility scores (transcription) ($M=46.16$, $SD=32.36$) and ratings of listener effort ($M=68.62$, $SD=25.77$) in the 65 dB multi-talker background noise condition was $r(21)= -0.963$, $p=0.000$ (Figure 7). This suggests that 92.74% of variance in listener effort is explained by transcription-based intelligibility scores with the addition of 65 dB of multi-talker background noise. Figure 7 shows a strong negative linear relationship between sentence intelligibility (transcription) and listener effort in 65dB multi-talker background noise.

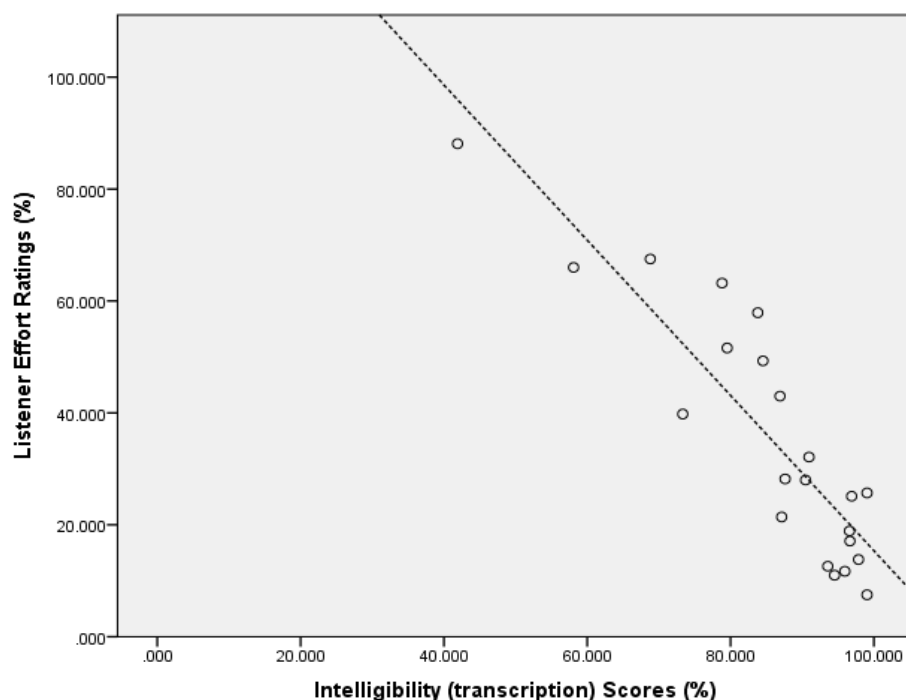


Figure 6. Transcription based intelligibility scores vs. ratings of listener effort (no added background noise).

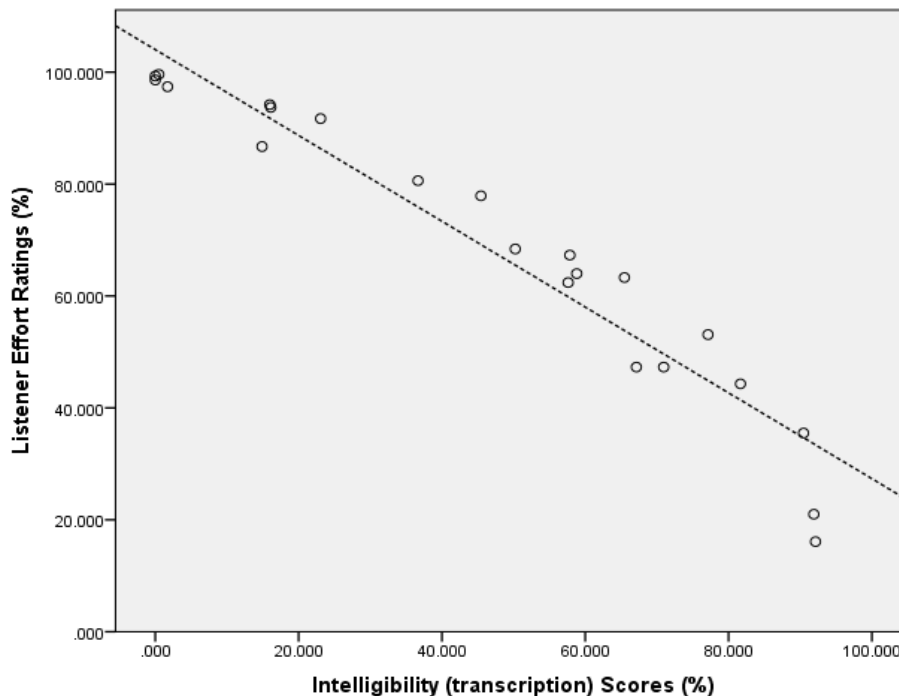


Figure 7. Transcription based intelligibility scores vs. ratings of listener effort (65dB multi-talker background noise).

C) Pearson's correlation between VAS speech intelligibility ratings ($M=75.23$, $SD=19.82$) and ratings of listener effort ($M=35.43$, $SD=22.46$) in the no added background noise condition was $r(21) = -0.946$, $p=0.000$ (Figure 8). This suggests that 89.49% of variance in listener effort is explained by VAS intelligibility scores when no added background noise is present. Figure 8 shows a strong negative linear relationship between sentence intelligibility (VAS) and listener effort in no added background noise.

D) Pearson's correlation between VAS speech intelligibility ratings ($M=47.44$, $SD=30.86$) and ratings of listener effort ($M=68.62$, $SD=25.77$) in the 65 dB multi-talker background noise condition was $r(21) = -0.959$, $p=0.000$ (Figure 9). This suggests that 91.96% of variance in listener effort is explained by VAS intelligibility scores with the addition of 65 dB of multi-talker background noise. Figure 9 shows a strong negative linear relationship between sentence intelligibility (VAS) and listener effort in 65dB multi-talker background noise.

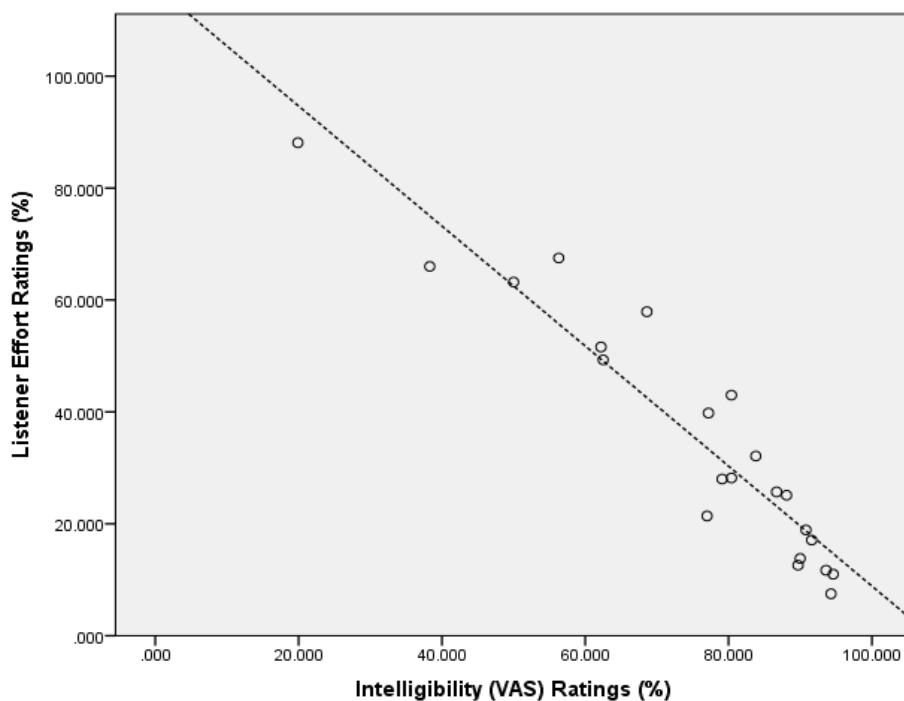


Figure 8. VAS speech intelligibility ratings vs. ratings of listener effort (no added background noise).

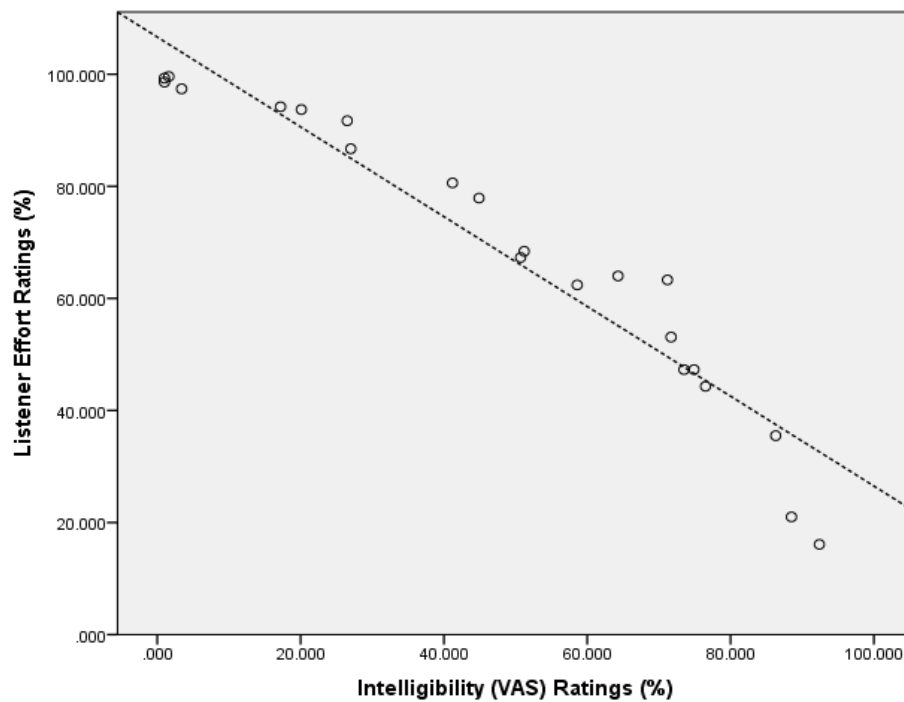


Figure 9. VAS speech intelligibility ratings vs. ratings of listener effort (65dB multi-talker background noise).

These results indicate that ratings of listener effort and transcription based sentence intelligibility scores are highly correlated in both noise conditions (Table 5). The ratings of listener effort and VAS speech intelligibility were also highly correlated in both noise conditions (Table 5). There appear to be steeper slopes in Figures 6 and 8, which represent the relationship between listener effort and intelligibility (transcription based and VAS) in the no added background noise condition. There is also less variance around the line in Figures 7 and 9, which represent the relationship between listener effort and intelligibility (transcription based and VAS) in the 65dB multi-talker background noise condition. In general, these negative correlations show that as intelligibility ratings increase, ratings of listener effort decrease; and as

intelligibility ratings decrease, ratings of listener effort increase in both noise conditions.

Table 5.

Summary of Pearson's correlation scores comparing intelligibility (transcription based & VAS) and ratings of listener effort.

	Transcription vs. Effort (0dB)	Transcription vs. Effort (65dB)	VAS vs. Effort (0dB)	VAS vs. Effort (65dB)
Pearson's correlation	-0.892 <i>p</i> =0.000	-0.963 <i>p</i> =0.000	-0.946 <i>p</i> =0.000	-0.959 <i>p</i> =0.000

3.5 Objective 3: Examine the strength of the relationship between ratings of listener effort and two speech symptoms (articulatory imprecision, reduced loudness) across noise conditions.

The third objective addressed articulatory imprecision, reduced loudness, and listener effort in both noise conditions. In order to determine the degree of correlation, four Pearson's correlations were conducted. More specifically, the following four comparisons were made:

- A) Ratings of listener effort vs. ratings of articulatory imprecision (no added background noise)
- B) Ratings of listener effort vs. ratings of articulatory imprecision (65 dB multi-talker background noise)
- C) Ratings of listener effort vs. reduced loudness ratings (no added background noise)
- D) Ratings of listener effort vs. reduced loudness ratings (65 dB multi-talker background noise)

These analyses were conducted to answer the following research questions:

1. Do ratings of listener effort correlate with ratings of articulatory imprecision?
2. Does the addition of background noise have an effect on this relationship?
3. Do ratings of listener effort correlate with reduced loudness ratings?
4. Does the addition of background noise have an effect on this relationship?

A) A Pearson's correlation coefficient examined the relationship between ratings of listener effort ($M=35.43$, $SD=22.46$) and articulatory imprecision ($M=32.60$, $SD=19.06$) in the no added background noise condition. This correlation was significant: $r(21)= 0.938$, $p=0.000$ (Figure 10). This suggests that 87.98% of variance in listener effort is explained by ratings of articulatory imprecision when no added background noise is present. Figure 10 shows a strong positive linear relationship between listener effort and articulatory imprecision in no added background noise.

B) Pearson's correlation between ratings of listener effort ($M=68.62$, $SD=25.77$) and articulatory imprecision ($M=52.00$, $SD=26.74$) in the 65dB multi-talker background noise condition was $r(21)= 0.934$, $p=0.000$ (Figure 11). This suggests that 87.24% of variance in listener effort is explained by ratings of articulatory imprecision with the addition of 65 dB of multi-talker background noise. Figure 11 shows a strong positive linear relationship between listener effort and articulatory imprecision in 65dB multi-talker background noise.

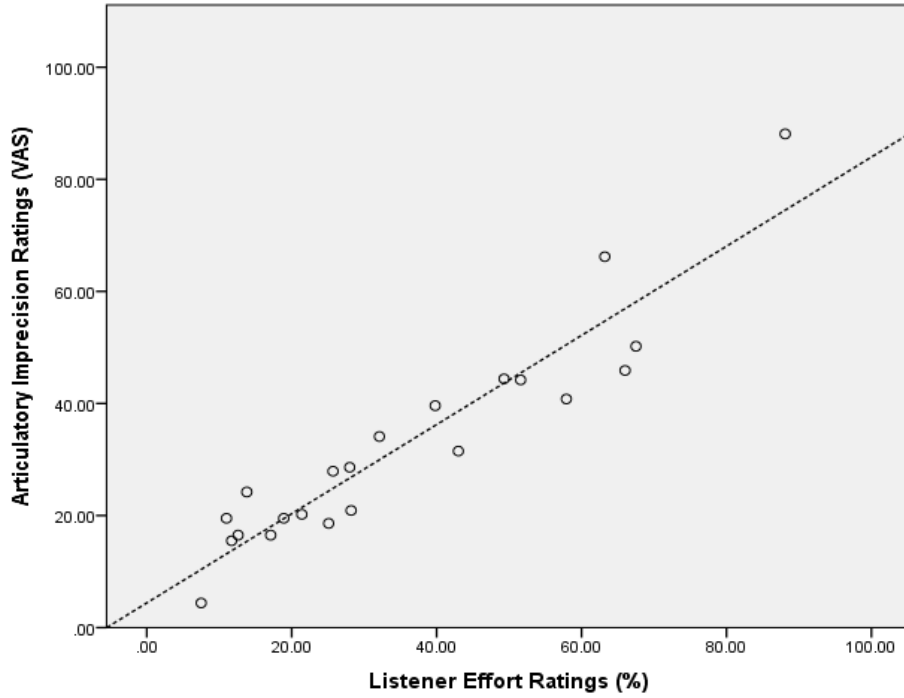


Figure 10. Ratings of listener effort vs. ratings of articulatory imprecision (no added background noise). Articulatory Imprecision Score Scale: 0= most precise, 100= imprecise (severely impaired).

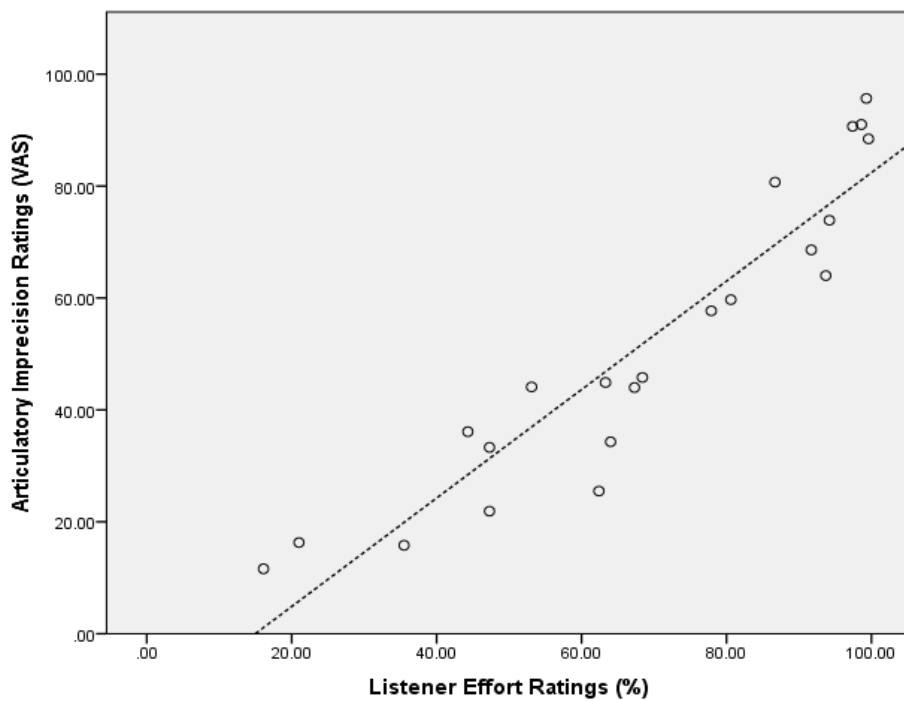


Figure 11. Ratings of listener effort vs. ratings of articulatory imprecision (65dB multi-talker background noise). Articulatory Imprecision Score Scale: 0= most precise, 100= imprecise (severely impaired).

These results indicate that ratings of listener effort and ratings of articulatory imprecision are significantly correlated in both noise conditions (Table 6). Figures 10 and 11 show that there is a steeper slope for the relationship between listener effort and articulatory imprecision in the 65dB multi-talker background noise condition. These positive correlations show that as ratings of listener effort increase, ratings of articulatory imprecision also increase (i.e., articulation is rated to be more imprecise); and as ratings of effort decrease, ratings of articulatory imprecision also decrease (i.e., articulation is rated to be more precise).

Table 6.

Summary of Pearson correlation scores comparing articulatory imprecision and ratings of listener effort.

	0dB	65dB
Pearson's Correlation	0.938 $p=0.000$	0.934 $p=0.000$

C) Pearson's correlation between ratings of listener effort ($M=35.43$, $SD=22.46$) and reduced loudness ratings ($M=32.70$, $SD=24.38$) in the no added background noise condition was $r(21)= 0.843$, $p=0.000$ (Figure 12). This suggests that 71.06% of variance in listener effort is explained by ratings of reduced loudness when no added background noise is present.

Figure 12 shows a moderately strong positive linear relationship between listener effort and reduced loudness in no added background noise.

D) Pearson's correlation between ratings of listener effort ($M=68.62$, $SD=25.77$) and reduced loudness ratings ($M=54.8$, $SD=29.89$) in the 65 dB multi-talker background noise condition was $r(21)= 0.962$, $p=0.000$ (Figure 13). This suggests that 92.54% of variance in listener effort is explained by ratings of reduced loudness with the addition of 65 dB of multi-talker background noise. Figure 13 shows a strong positive linear relationship between listener effort and reduced loudness in 65dB multi-talker background noise.

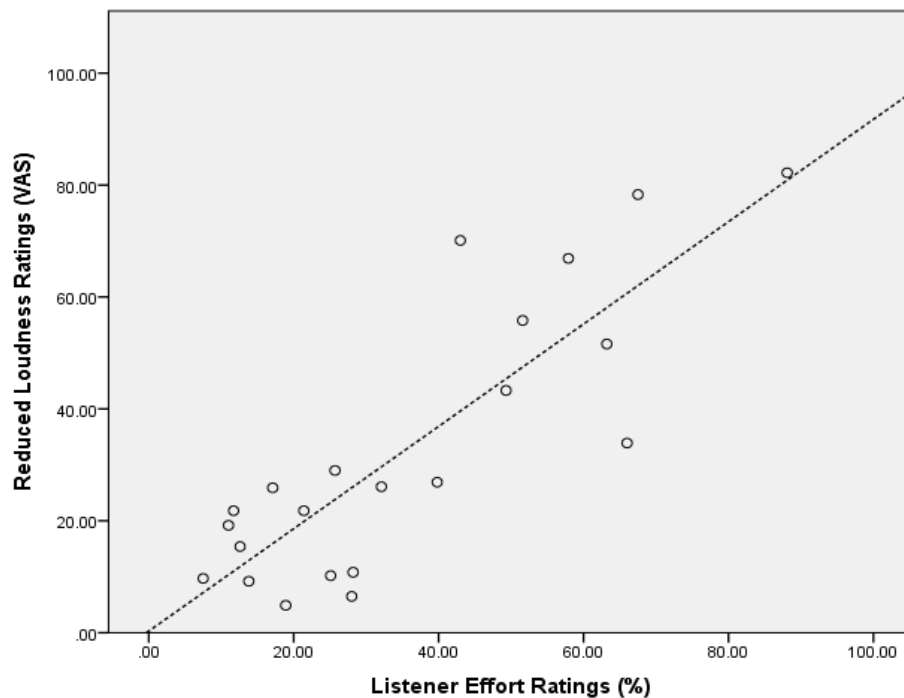


Figure 12. Ratings of listener effort vs. reduced loudness ratings (no added background noise).

Loudness Score Scale: 0=normal loudness/speech intensity, 100=severely impaired loudness/speech intensity.

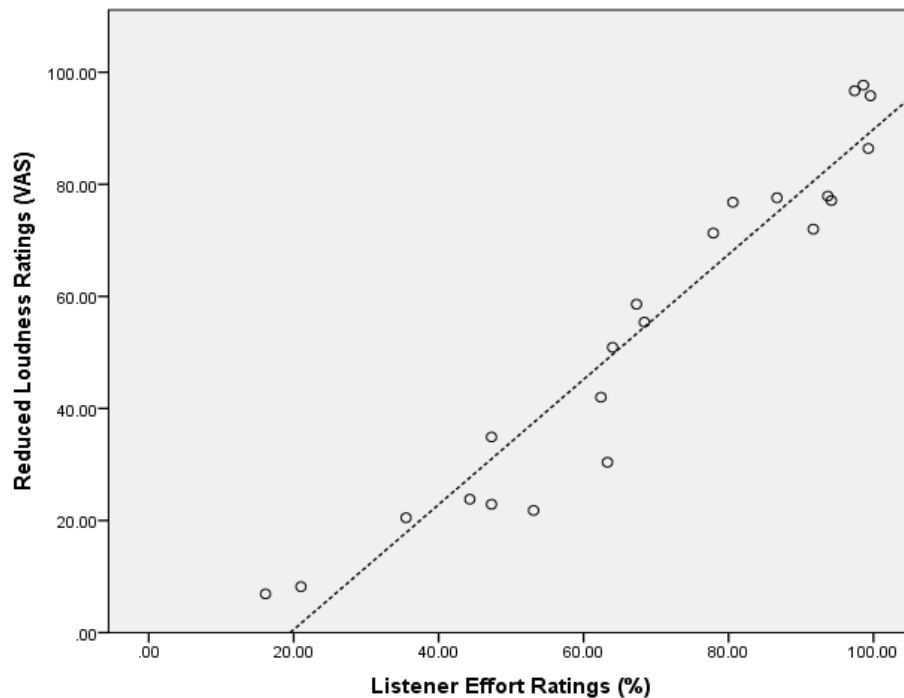


Figure 13. Ratings of listener effort vs. reduced loudness ratings (65dB multi-talker background noise). Loudness Score Scale: 0=normal loudness/speech intensity, 100=severely impaired loudness/speech intensity.

These results indicate that ratings of listener effort are significantly and highly correlated with reduced loudness ratings in both noise conditions (Table 7). Figures 12 and 13 show that there is a steeper slope for the relationship between listener effort and reduced loudness in the 65dB multi-talker background noise condition, as well as that there is less variance around the line in Figure 13. These positive correlations show that as ratings of listener effort increase, reduced loudness ratings also increase (i.e., the speaker with PD is rated as less intense/more quiet); and as ratings of effort decrease, reduced loudness ratings also decrease (i.e., the speaker with PD is rated as more intense/louder).

Table 7.

Summary of Pearson's correlation scores comparing reduced loudness and ratings of listener effort.

	0dB	65dB
Pearson's Correlation	0.843 $p=0.000$	0.962 $p=0.000$

3.6 Objective 4: Examine the strength of the relationship between ratings of speech intelligibility (transcription, VAS) and two speech symptoms (articulatory imprecision, reduced loudness) across noise conditions.

The final objective addressed transcription based sentence intelligibility scores and the relationship to articulatory imprecision and reduced loudness in both noise conditions, as well as VAS speech intelligibility ratings and the relationship to articulatory imprecision and reduced loudness in both noise conditions. In order to determine the degree of correlation amongst these variables, eight Pearson's correlations were conducted. More specifically, the following comparisons were made:

- A) Transcription based sentence intelligibility scores vs. articulatory imprecision ratings (no added background noise)
- B) Transcription based sentence intelligibility scores vs. ratings of articulatory imprecision (65dB of multi-talker background noise)
- C) VAS intelligibility ratings vs. ratings of articulatory imprecision (no added background noise)
- D) VAS intelligibility ratings vs. ratings of articulatory imprecision (65 dB multi-talker background noise)

- E) Transcription based sentence intelligibility scores vs. reduced loudness ratings (no added background noise)
- F) Transcription based sentence intelligibility scores vs. reduced loudness ratings (65 dB multi-talker background noise)
- G) VAS intelligibility ratings vs. reduced loudness ratings (no added background noise)
- H) VAS intelligibility ratings vs. reduced loudness ratings (65 dB multi-talker background noise)

These analyses were conducted to answer the following research questions:

1. Do ratings of articulatory imprecision have a relationship with transcription based speech intelligibility scores and VAS speech intelligibility ratings?
2. Does the addition of background noise have an impact on these relationships?
3. Do reduced loudness ratings have a relationship with transcription based speech intelligibility scores and VAS speech intelligibility ratings?
4. Does the addition of background noise have an impact on these relationships?

A) Pearson's correlation between transcription based sentence intelligibility scores ($M=85.54$, $SD=14.44$) and ratings of articulatory imprecision ($M=32.60$, $SD=19.06$) in the no added background noise condition was $r(21) = -0.865$, $p=0.000$ (Figure 14). This suggests that 74.82% of variance in transcription-based intelligibility scores is explained by ratings of articulatory precision when no added background noise is present. Figure 14 shows a strong negative linear relationship between transcription based sentence intelligibility and articulatory imprecision in no added background noise.

B) Pearson's correlation between transcription based sentence intelligibility scores

($M=46.16, SD=32.36$) and ratings of articulatory imprecision ($M=52.00, SD=26.74$) in the 65 dB of multi-talker background noise condition was $r(21) = -0.957, p=0.00$ (Figure 15). This suggests that 91.58% of variance in transcription-based intelligibility scores is explained by ratings of articulatory imprecision with the addition of 65 dB of multi-talker background noise. Figure 15 shows a strong negative linear relationship between transcription based sentence intelligibility and articulatory imprecision in 65dB multi-talker background noise.

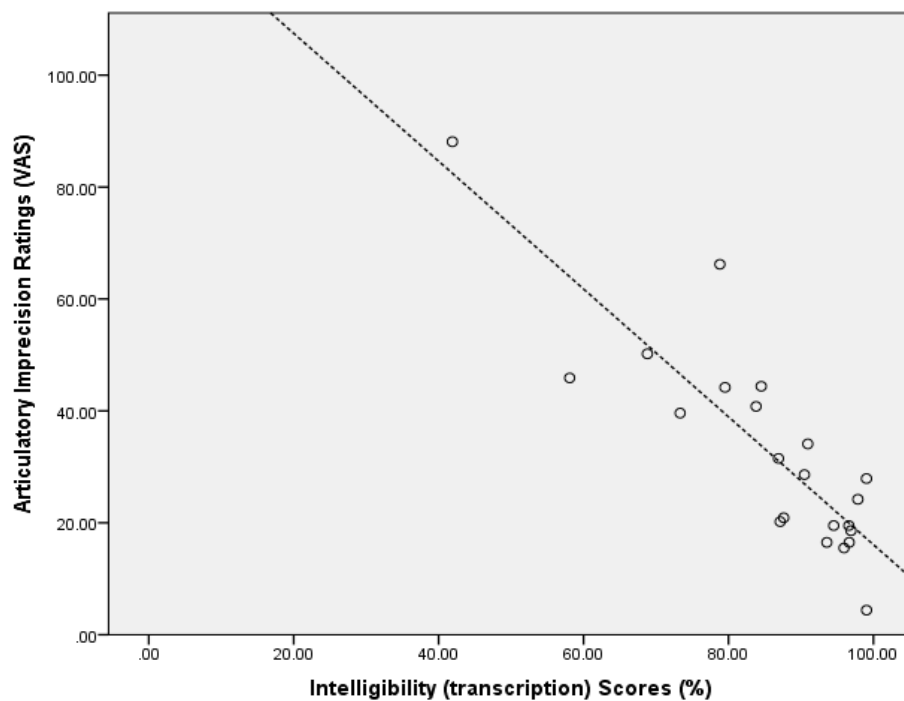


Figure 14. Transcription based intelligibility scores vs. ratings of articulatory imprecision (no added background noise). Articulatory Imprecision Score Scale: 0= most precise, 100=imprecise (severely impaired).

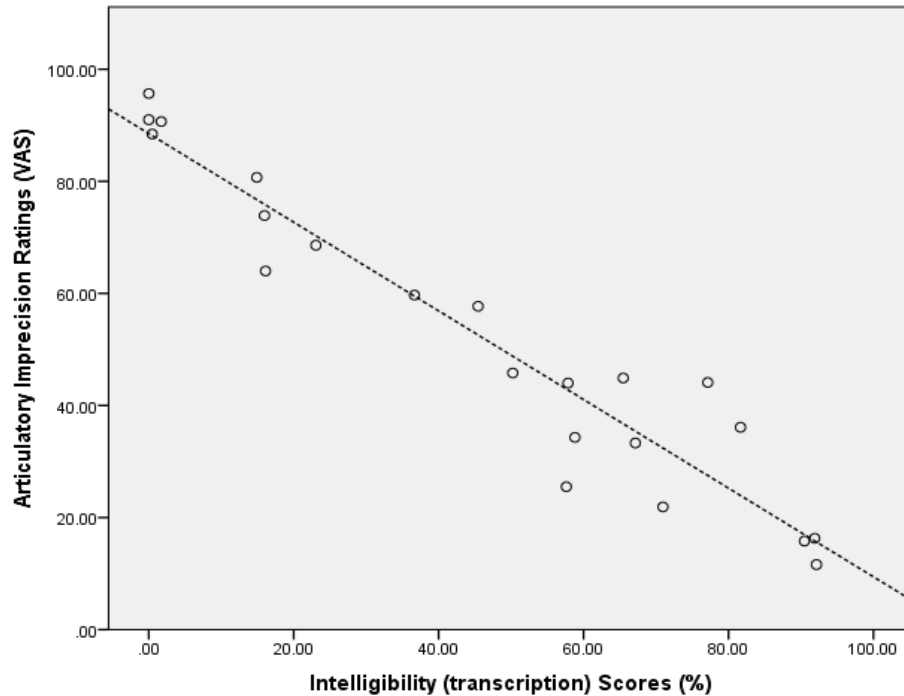


Figure 15. Transcription based intelligibility scores vs. ratings of articulatory imprecision (65dB multi-talker background noise). Articulatory Imprecision Score Scale: 0= most precise, 100=imprecise (severely impaired).

These results indicate that ratings of articulatory imprecision are significantly correlated with transcription based sentence intelligibility scores in both noise conditions (Table 8). Figures 14 and 15 show that there is a steeper slope for the relationship between transcription based sentence intelligibility and articulatory imprecision in the no added background noise condition. The negative correlations demonstrate that as transcription based intelligibility scores increase, the ratings of articulatory imprecision decrease (i.e., articulation is rated to be more precise); and as transcription based intelligibility scores decrease, ratings of articulatory imprecision increase (i.e., articulation is rated to be more imprecise).

Table 8.

Summary of Pearson's correlation values comparing transcription based intelligibility scores and ratings of articulatory imprecision.

	0dB	65dB
Pearson's Correlation	-0.865 $p=0.000$	-0.957 $p=0.000$

C) Pearson's correlation between VAS speech intelligibility ratings ($M=75.23$, $SD=19.82$) and ratings of articulatory imprecision ($M=32.60$, $SD=19.06$) in the no added background noise condition was $r(21) = -0.925$, $p=0.000$ (Figure 16). This suggests that 85.56% of variance in VAS intelligibility scores is explained by ratings of articulatory imprecision when no added background noise is present. Figure 16 shows a strong negative linear relationship between VAS speech intelligibility and articulatory imprecision in no added background noise.

D) Pearson's correlation between VAS speech intelligibility ratings ($M=47.44$, $SD=30.86$) and ratings of articulatory imprecision ($M=52.00$, $SD=26.74$) in the 65dB of multi-talker background noise condition was $r(21) = -0.962$, $p=0.000$ (Figure 17). This suggests that 92.54% of variance in VAS intelligibility scores is explained by ratings of articulatory imprecision with the addition of 65 dB of multi-talker background noise. Figure 17 shows a strong negative linear relationship between VAS speech intelligibility and articulatory imprecision in 65dB multi-talker background noise.

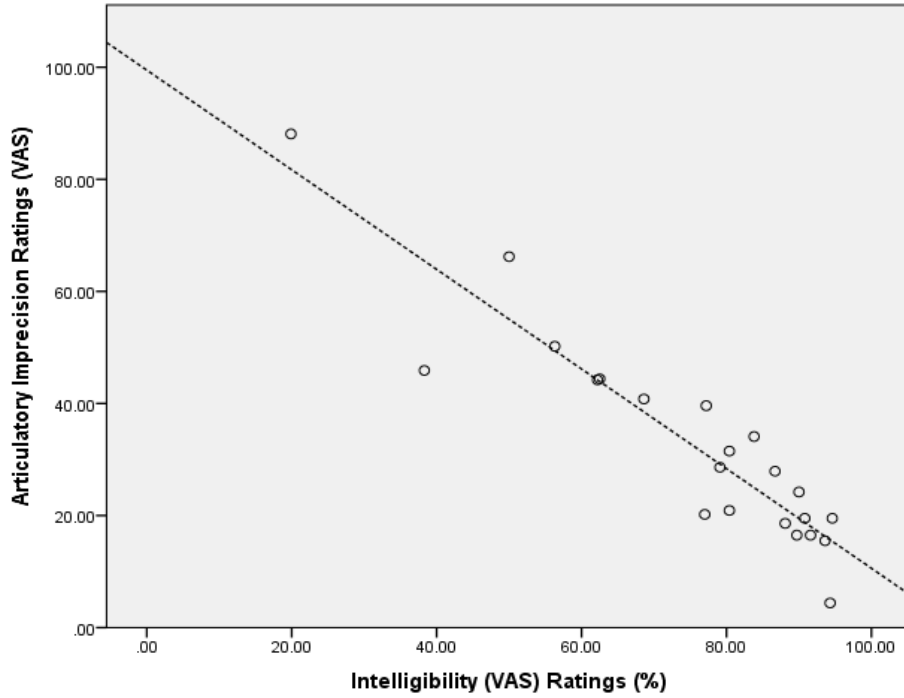


Figure 16. VAS Speech intelligibility ratings vs. ratings of articulatory imprecision (no added background noise). Articulatory Imprecision Score Scale: 0= most precise, 100=imprecise (severely impaired).

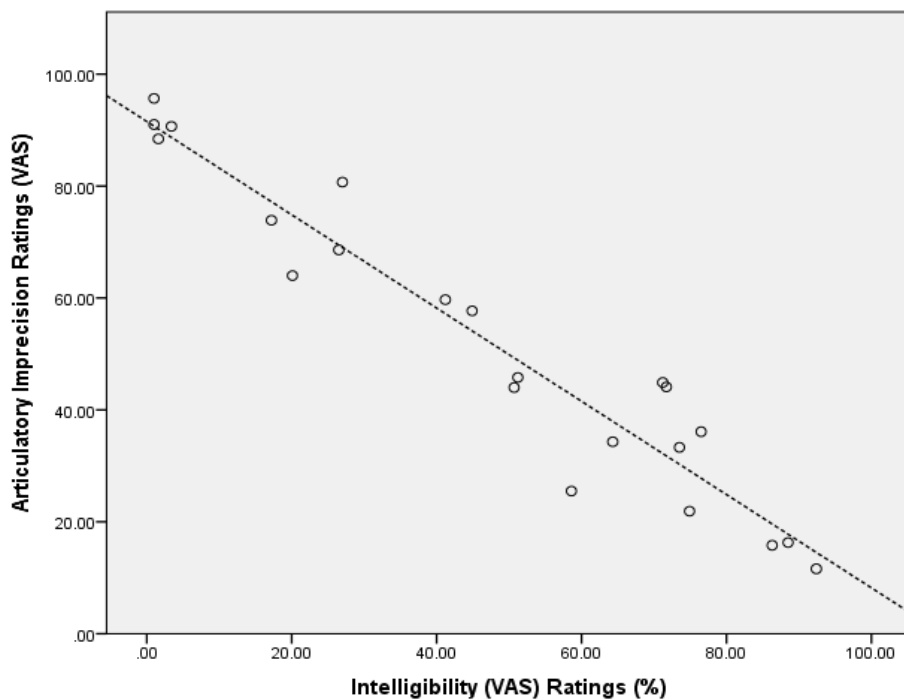


Figure 17. VAS Speech intelligibility ratings vs. ratings of articulatory imprecision (65dB multi-talker background noise). Articulatory Imprecision Score Scale: 0= most precise, 100=imprecise (severely impaired).

These results indicate that ratings of articulatory imprecision are significantly correlated with VAS speech intelligibility ratings in both noise conditions (Table 9). Figures 16 and 17 demonstrate similar slopes. The negative correlations demonstrate that as transcription based intelligibility scores increase, the ratings of articulatory imprecision decrease (i.e., articulation is rated to be more precise); and as transcription based intelligibility scores decrease, ratings of articulatory imprecision increase (i.e., articulation is rated to be more imprecise).

Table 9.

Summary of Pearson's correlation values comparing VAS intelligibility ratings and ratings of articulatory imprecision.

	0dB	65dB
Pearson's Correlations	-0.925 $p=0.000$	-0.962 $p = 0.000$

E) Pearson's correlation between transcription based sentence intelligibility scores ($M=85.54$, $SD=14.44$) and reduced loudness ratings ($M=32.70$, $SD=24.38$) in the no added background noise condition was $r(21)= -0.684$, $p=0.000$ (Figure 18). This suggests that 46.79% of variance in transcription-based intelligibility scores is explained by ratings of reduced loudness when no added background noise is present. Figure 18 shows a moderately strong

negative linear relationship between transcription based sentence intelligibility and reduced loudness in no added background noise.

F) Pearson's correlation between transcription based sentence intelligibility scores

($M=46.16, SD=32.36$) and reduced loudness ratings ($M=54.8, SD=29.89$) in the 65 dB multi-talker background noise condition was $r(21) = -0.966, p=0.000$ (Figure 19). This suggests that 93.32% of variance in transcription-based intelligibility scores is explained by ratings of reduced loudness with the addition of 65 dB of multi-talker background noise. Figure 19 shows a strong negative linear relationship between transcription based sentence intelligibility and reduced loudness in 65dB multi-talker background noise.

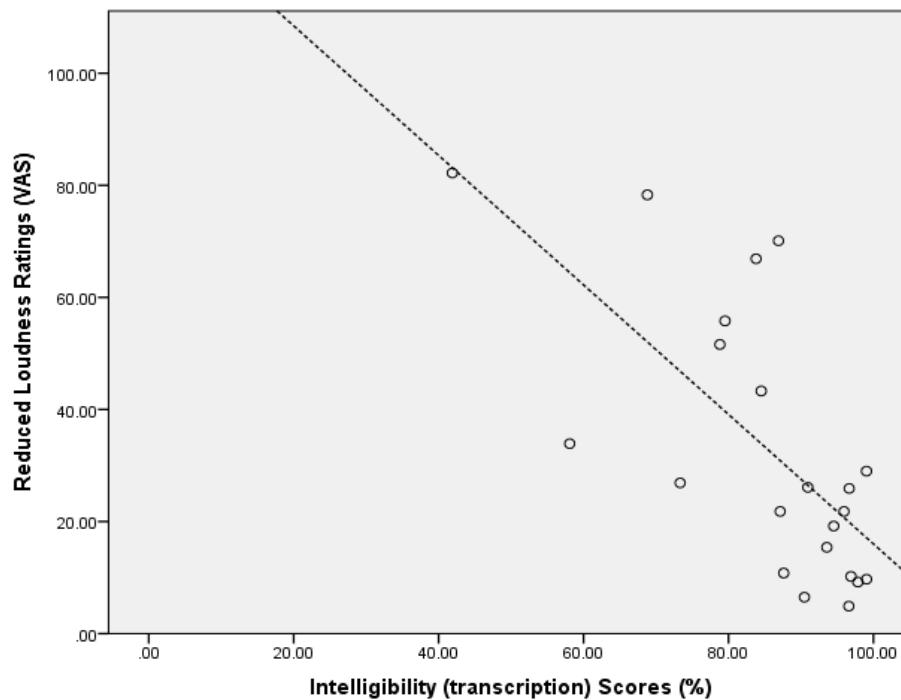


Figure 18. Transcription based intelligibility scores vs. reduced loudness ratings (no added background noise). Loudness Score Scale: 0=normal loudness/speech intensity, 100=severely impaired loudness/speech intensity.

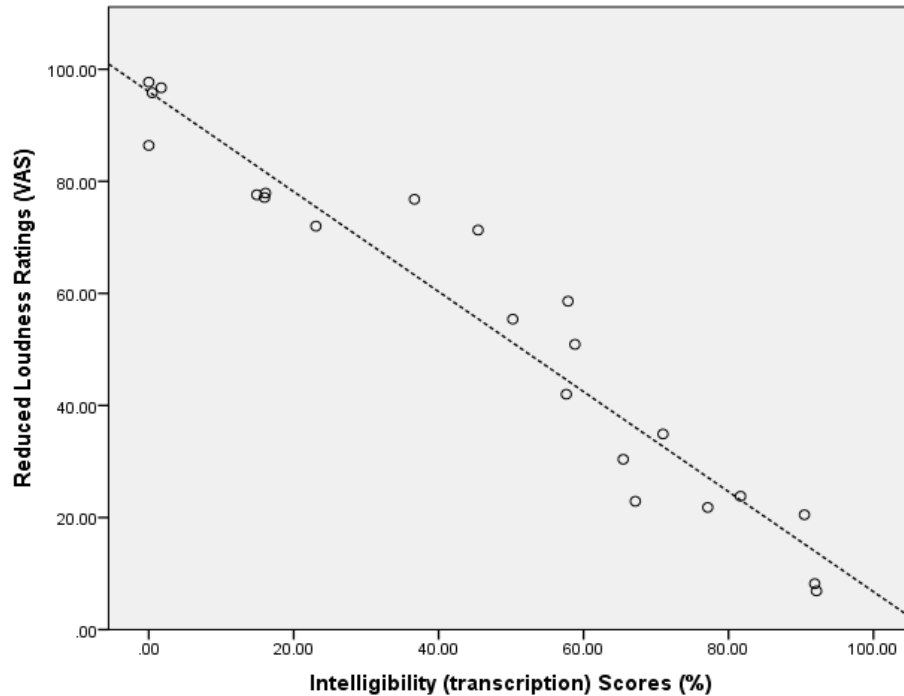


Figure 19. Transcription based intelligibility scores vs. reduced loudness ratings (65dB multi-talker background noise). Loudness Score Scale: 0=normal loudness/speech intensity, 100=severely impaired loudness/speech intensity.

These results indicate that listener ratings of reduced loudness are correlated with transcription based intelligibility scores in both noise conditions (Table 10). Figures 18 and 19 show that there is a steeper slope for the relationship between transcription based intelligibility and reduced loudness, as well as that there is much less variance around the line in Figure 19 which represents the relationship in 65dB of multi-talker background noise. These negative correlations show that as transcription based sentence intelligibility scores increase, reduced loudness ratings decrease (i.e., the speaker with PD is perceived as louder); and as transcription based sentence intelligibility scores decrease, reduced loudness ratings increase (i.e., the speaker

with PD is perceived as less intense).

Table 10.

Summary of Pearson's correlation values comparing transcription based intelligibility scores and reduced loudness ratings.

	0dB	65dB
Pearson's Correlation	-0.684 $p=0.000$	-0.966 $p=0.000$

G) Pearson's correlation between VAS speech intelligibility ratings ($M=75.23$, $SD=19.82$) and reduced loudness ratings ($M=32.70$, $SD=24.38$) in the no added background noise condition was $r(21) = -0.716$, $p=0.000$ (Figure 20). This suggests that 51.27% of variance in VAS intelligibility scores is explained by ratings of reduced loudness when no added background noise is present. Figure 20 shows a moderately strong negative linear relationship between VAS speech intelligibility and reduced loudness in no added background noise.

H) Pearson's correlation between VAS speech intelligibility ratings ($M=47.44$, $SD=30.86$) and reduced loudness ratings ($M=54.8$, $SD=29.89$) in the 65 dB multi-talker background noise condition was $r(21) = -0.968$, $p=0.000$ (Figure 21). This suggests that 93.70% of variance in VAS intelligibility scores is explained by ratings of reduced loudness with the addition of 65 dB of multi-talker background noise. Figure 21 shows a strong negative linear relationship between VAS speech intelligibility and reduced loudness in 65dB multi-talker background noise.

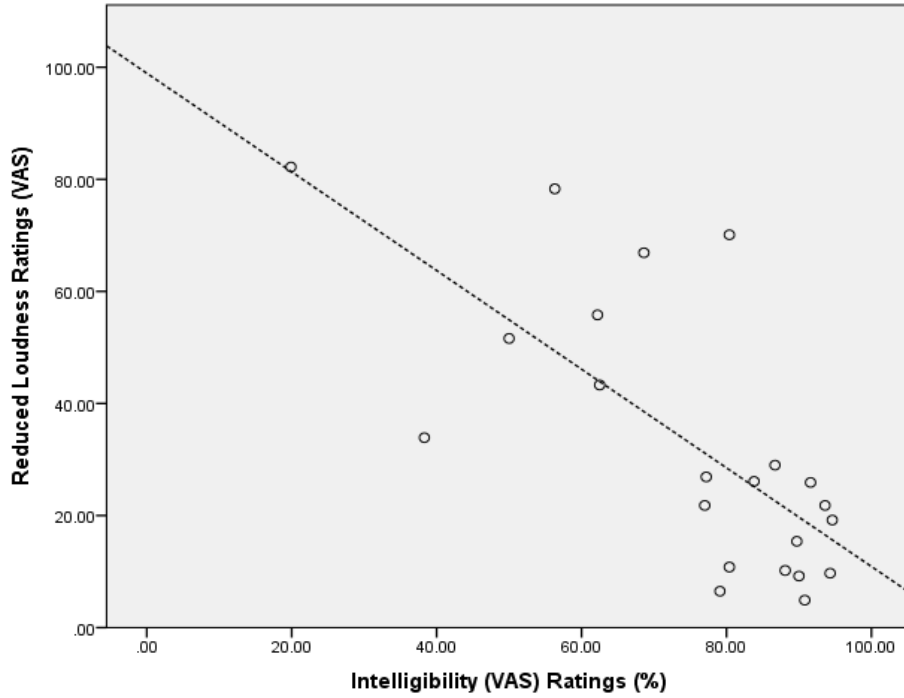


Figure 20. VAS speech intelligibility ratings vs. reduced loudness ratings (no added background noise). Loudness Score Scale: 0=normal loudness/speech intensity,100=severely impaired loudness/speech intensity.

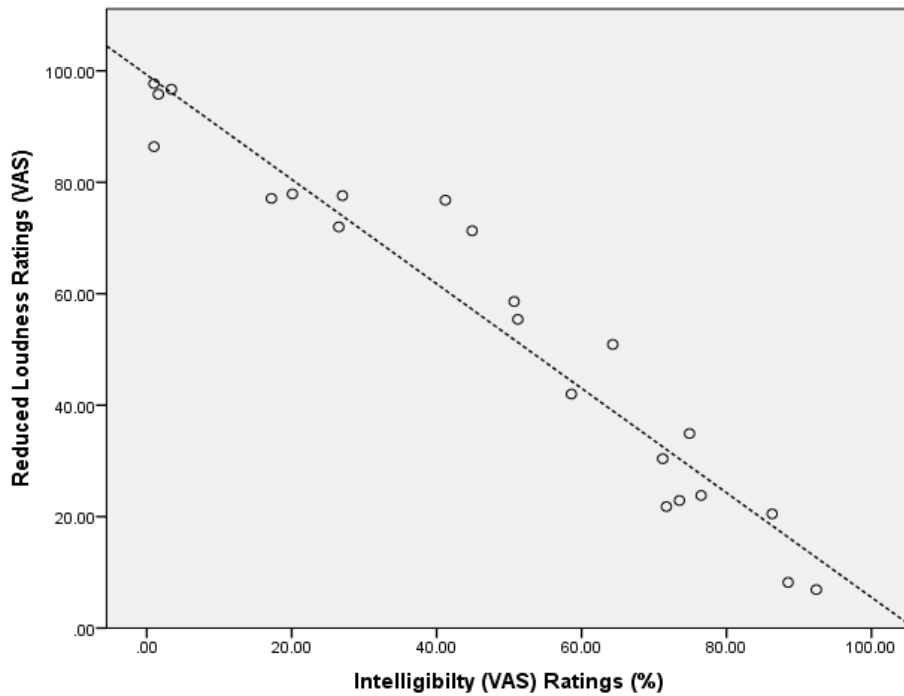


Figure 21. VAS speech intelligibility ratings vs. reduced loudness ratings (65dB multi-talker background noise). Loudness Score Scale: 0=normal loudness/speech intensity, 100=severely impaired loudness/speech intensity.

These results indicate that reduced loudness and VAS speech intelligibility ratings are significantly and highly correlated in both noise conditions (Table 11). Figures 20 and 21 show that there are similar slopes for the relationship between transcription based intelligibility and reduced loudness, as well as that there is much less variance around the line in Figure 21 which represents the relationship in 65dB of multi-talker background noise. These negative correlations show that as VAS speech intelligibility ratings increase, reduced loudness ratings decrease (i.e., the speaker is perceived as louder); and as VAS speech intelligibility ratings decrease, reduced loudness ratings increase (i.e., as the speaker is perceived as less intense).

Table 11.

Summary of Pearson's correlation values comparing VAS intelligibility ratings and reduced loudness ratings.

	0dB	65dB
Pearson's Correlations	-0.716 <i>p</i> =0.000	-0.968 <i>p</i> =0.000

Chapter 4

4 Discussion

4.1 Overview

This study examined the relationships among listener ratings of speech intelligibility (both transcription based scores and VAS ratings), perceived listener effort, as well as articulatory imprecision and reduced loudness in speakers with PD demonstrating hypophonia as their primary dysarthric feature. This study also examined the impact of background noise on ratings of speech intelligibility, perceived listener effort, articulatory imprecision, and reduced loudness ratings. The first objective of this study addressed the impact of background noise on speech intelligibility (transcription and VAS), listener effort, and the perception of articulatory imprecision and reduced loudness. The second objective addressed the relationship between listener effort and speech intelligibility (transcription and VAS). The third objective addressed the relationships among the two speech symptoms (articulatory imprecision and reduced loudness) and listener effort. The final objective addressed the relationships among the two speech symptoms (articulatory imprecision and reduced loudness) and speech intelligibility (transcription and VAS).

The following sections in this chapter will discuss the primary findings of the present study and relate these findings to those of previous research. Ensuing sections will discuss the limitations of the current study, recommendations for future research, and clinical and research implications.

The overarching goal of this study was to examine two of the common speech symptoms associated with hypokinetic dysarthria (i.e., articulatory imprecision and reduced loudness) and

how they contribute to judgements of listener effort and speech intelligibility, as well as the impact of background noise. In order to examine speech intelligibility, the SIT by Yorkston and colleagues (2011) served as the primary method of measuring sentence intelligibility. The use of visual analog scaling served as a secondary method of measuring intelligibility, as well as the primary method of measuring listener effort, articulatory imprecision, and reduced loudness.

4.2 Objective 1: Evaluate and compare transcription based intelligibility scores, VAS ratings of speech intelligibility, ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness across two noise conditions.

The first objective of this study examined transcription based intelligibility scores, VAS speech intelligibility ratings, ratings of listener effort, ratings of articulatory imprecision, and ratings of reduced loudness in a no added background noise condition and in a 65dB of multi-talker background noise condition.

Speech Intelligibility. The comparison of transcription based sentence intelligibility scores revealed significantly higher intelligibility scores in the no added background noise condition ($M=85.54$, $SD= 14.44$) compared to the 65dB multi-talker background noise condition ($M= 46.17$, $SD= 32.37$) ($t(21)= 7.192$, $p=0.000$). This result suggests that listeners had more difficulty accurately transcribing the sentences presented in the 65 dB multi-talker background noise condition. The comparison of ratings of VAS speech intelligibility also revealed significantly higher intelligibility ratings in the no added background noise condition ($M= 75.23$, $SD=19.83$) compared to the 65dB multi-talker background noise condition ($M= 47.44$, $SD=30.86$) ($t(21)= 5.355$, $p=0.000$). This result suggests that listeners consistently assigned a higher rating of speech intelligibility to speakers in the no added background noise condition as

compared to the 65dB multi-talker background noise condition. Therefore, listeners had more difficulty understanding what was being spoken by speakers with PD in the 65 dB background noise condition as compared to the no added background noise condition.

The motor speech disorder associated with PD, hypokinetic dysarthria, is primarily associated with reduced overall movement in the orofacial regions. This can present as speech related movements that are abnormally reduced in size and force (Duffy, 2013; Adams & Dykstra, 2009; Rusz et al., 2013), which can impair speech production. As a result, articulatory imprecision, rate of speech, prosodic factors (i.e., monopitch and monoloudness), voice quality, and speech intensity can all be affected (Darley et al., 1969). This reduced clarity and quality of the speech signal can cause listeners to report difficulty understanding speakers with dysarthria (Beukelman, et al., 2011). Although the speakers with PD in the current study presented with hypophonia as their primary dysarthric feature, our results may be capturing some of the other speech impairments associated with hypokinetic dysarthria in the overall ratings of speech intelligibility. When considering the transcription based and VAS intelligibility scores in the present study, the VAS scores were lower than transcription based scores in the no added background noise condition, but almost equal in 65dB of multi-talker background noise. Therefore, it appears that transcription based measures of speech intelligibility are not equal to VAS measures of speech intelligibility in the no added background noise condition. It could be that there is a ceiling effect of the transcription based scores in no noise that is not present for the VAS ratings. It is also possible that VAS ratings of speech intelligibility may be including or capturing other aspects of speech production such as, but not limited to, rate of speech, prosody, and voice quality. In the 65 dB noise condition some of the other aspects of speech production

may not be as salient in the ratings because the addition of noise may be exacerbating the hypophonia in our speakers with PD, which could explain why the VAS ratings are closer to the transcription scores in the noise condition. The aspects of speech production mentioned above may, therefore, factor into a global impression of speech intelligibility making VAS ratings a more holistic measure of impaired speech production, whereas transcription based intelligibility measures are based solely on the percentage of words correctly understood and transcribed by a listener. This interpretation is supported by Beukelman and colleagues (2011) who indicate that measuring transcription based speech intelligibility does not provide information on the perceptual load experienced by a listener when transcribing a disordered speech signal. Furthermore, previous research has indicated that listeners have more difficulty understanding disordered speech in comparison to normal speech (Dykstra et al., 2007).

In the current study, we chose longer SIT sentences of 13-15 words in length because longer sentences are considered more complex to produce (Altmann & Troche, 2011). These longer, more complex sentences may have been more taxing on the speech production mechanism of our speakers with PD, making it more challenging for these individuals with hypokinetic dysarthria to produce intelligible sentences in either of the noise conditions. More complex sentences can also make it more difficult for listeners to predict and fill in content when the speech signal is already distorted, and therefore may be more representative of everyday speech demands (Yorkston, Strand, & Kennedy, 1996; Yorkston & Beukelman, 1981).

When comparing speech intelligibility scores across noise conditions, both comparisons were significant regardless of the measurement technique used for generating the intelligibility score. The intelligibility results are consistent with the findings of Adams and colleagues (2008)

and Dykstra and colleagues (2013) who also found that the introduction of background noise significantly reduced speech intelligibility scores. Our analysis shows the dramatic and significant effect that moderate intensity levels of multi-talker background noise have on a listeners ability to understand what was being spoken by speakers with PD. Although most of the individuals with PD in the current study were judged to have mild-moderately impaired speech intelligibility in no added background noise, these results demonstrate that the introduction of moderate intensity multi-talker background noise significantly degraded the speech intelligibility of our sample of speakers with PD and hypophonia.

Listener Effort. The comparison of ratings of listener effort across noise conditions revealed significantly lower ratings of listener effort in the no added background noise condition ($M= 35.43, SD= 22.46$) compared to the 65dB multi-talker background noise condition ($M= 68.62, SD= 25.77$) ($t(21)= -7.997, p=0.000$). This result suggests that listeners required an increased amount of effort to understand speakers with PD in the 65 dB multi-talker background noise condition, but also used some effort in the no added background noise condition. Therefore moderate intensity levels of background noise create a more effortful listening environment for individuals listening to the speech of individuals with PD.

A study by Beukelman and colleagues (2011) measured attention allocation and concluded that speech with relatively high intelligibility that is distorted by dysarthria results in an increased perceptual load for listeners. This finding is similarly demonstrated in the current study by the ratings of listener effort. Even the no added background noise condition revealed that listeners were using some effort ($M=35.43, SD=22.46$), and in the 65dB multi-talker background noise condition our results demonstrated that considerably more effort ($M=68.62,$

$SD=25.77$) was being expended by our listeners with the introduction of background noise. In Dykstra's (2007) study, using the same VAS anchors for assigning ratings of listener effort, she demonstrated that even with no background noise, listeners consistently assigned higher effort ratings for participants with PD (Effort: $M= 22.90$, $SD= 18.89$) than control participants (Effort: $M= 8.83$, $SD= 8.76$) in a conversational intelligibility task (Dykstra, 2007). When noise was introduced this pattern was exacerbated across a variety of multi-talker background noise conditions. For example, in 65 dB of multi-talker background noise, listeners assigned a mean effort rating of 42.53 ($SD=25.38$) for the PD group, and a mean effort rating of 21.00 ($SD=8.99$) for the control group (Dykstra, 2007). Although the listener effort ratings were slightly lower for speakers with PD in Dykstra's study compared to the current study, and although we did not use control participants, her results support the findings of the current study. Dykstra's findings suggest that even in ideal listening conditions (i.e., no added background noise) the communication partners of speakers with PD still are using some extra effort when listening to PD speech as compared to how very little effort is expended when listening to control participants. In noise, the ratings of listener effort levels increase dramatically suggesting that communication partners would need to exert very high levels of effort when listening to PD speech. The difficulty experienced by a listener may be attributed to the extra effort he or she is required to exert in order to understand a distorted speech signal. Specifically, there is an empirical literature suggesting that listeners need to exert an increased amount of effort when listening to dysarthric speech (e.g., Whitehill & Wong, 2006; Dykstra et al., 2007; Landa et al., 2014). The current study demonstrates that this is even more relevant with the addition of background noise. When background noise was introduced, both VAS and transcription based

intelligibility scores decreased to severely impaired levels, and ratings of listener effort increased. Therefore the addition of background noise made it even more difficult for listeners to understand the speech signal that was already distorted by dysarthria. This suggests that listeners would have had to use information processing strategies relying on context and sentence structure in addition to the speech signal to determine what was being spoken (Beukelman et al., 2011). This additional effort and reallocation of resources by the listeners could be considered cognitive overload with time, and may cause a barrier to communication and reduce opportunities for individuals with PD to communicate (Beukelman et al., 2011; Dykstra et al., 2007).

Articulatory Imprecision. The comparison of ratings of articulatory imprecision across noise conditions revealed significant differences between listener ratings in the no added background noise condition ($M = 32.60$, $SD = 19.07$) and the 65 dB multi-talker background noise condition ($M = 52.00$, $SD = 26.74$) ($t(21) = -4.822$, $p = 0.000$). These results suggest that listeners consistently assigned a rating indicative of more precise articulation to speakers in the no added background noise condition as compared to the 65 dB multi-talker background noise condition.

Previous studies have indicated that articulatory imprecision is the speech feature that contributes the most to ratings of intelligibility (Darley et al, 1969; de Bodt et al., 2002; Whitehill & Wong, 2006). The current study demonstrated that the introduction of background noise significantly impacts a listeners perception of how precise the articulation is, and that noise potentially exacerbates the difficulties individuals with PD have with articulation. It seems that it is possible our speakers with PD may have the same deficits in articulatory precision that have

been observed in other studies, even with hypophonia as the primary dysarthric feature.

Reduced Loudness. The comparison of reduced loudness ratings across noise conditions revealed that listeners perceived speakers with PD to be significantly louder in the no added background noise condition ($M = 32.70$, $SD = 24.38$) compared to the 65 dB multi-talker background noise condition ($M = 54.80$, $SD = 29.90$) ($t(21) = -4.185$, $p = 0.000$). These results suggest that listeners consistently assigned a rating indicative of more intense speech to speakers in the no added background noise condition as compared to the 65 dB multi-talker background noise condition. The results of this objective also demonstrate that a listener's perception and ratings of the severity of hypophonia are exacerbated in noise.

Previous studies have demonstrated that in background noise control participants regulated their speech intensity, duration, and frequency in order to be heard over the noise; this is referred to as the Lombard effect (Lane & Tranel, 1971; Patel & Schell, 2008; Adams et al., 2005; Adams et al., 2006). The current study demonstrated that in 65dB of multi-talker background noise, individuals with PD were rated as less intense than in the no noise condition (see Objective 1). Adams and colleagues have previously demonstrated the relationship between background noise and speech intensity regulation in individuals with PD and hypophonia (Adams et al., 2005; Adams et al., 2006; Adams et al., 2008). In the Adams and colleagues (2005) study, the authors demonstrated that individuals with PD demonstrated a Lombard effect, with participants with PD demonstrating consistently lower levels of speech intensity in comparison to control participants. The speech intensity of individuals with PD has also been found to be more variable than that of control participants (Dysktra et al., 2013). However, it is also important to consider speech-to-noise ratios. Speech-to-noise ratios compare the noise level

of speech to the noise level of background noise. Although participants perceived the speech of individuals with PD to be reduced in loudness in the noise condition, they were actually more intense (louder) in order to be heard over the noise. Therefore, our listener ratings of reduced loudness are affected by the level of background noise (in this case 65dB), as well as the speech-to-noise ratio.

The comparison of reduced loudness ratings across noise conditions demonstrated that reduced loudness is a salient speech feature contributing to reductions in speech intelligibility and increased listener effort in our speaker population. This result is not entirely unexpected because our speakers with PD presented with hypophonia as their primary dysarthric feature. However, since hypophonia was the primary dysarthric speech feature for the speakers in this study, it should be considered that our speaker group likely represents a subgroup of individuals with PD that is not representative of all speakers with hypokinetic dysarthria. Future studies may wish to examine and consider a more heterogenous group of speakers with PD to ascertain the variety of speech symptoms that impact both speech intelligibility and ratings of listener effort.

4.3 Objective 2: Determine the relationship between speech intelligibility (transcription, VAS) and ratings of listener effort across noise conditions.

The second objective of this study examined the relationship between perceived ratings of listener effort and speech intelligibility (both transcription based scores and VAS ratings) in the no added background noise and 65dB of multi-talker background noise conditions.

Transcription based sentence intelligibility was determined using the SIT. Individuals with PD read aloud three unique sentences ranging from 13-15 words in length while being audio-recorded, once in no added background noise and once with 65dB of multi-talker background

noise. Listeners then transcribed the sentences in both noise conditions. VAS speech intelligibility was determined by having listeners rate three sentences spoken by each speaker with PD on a 100mm line with the anchors “0%” and “100%”. Ratings of listener effort were determined by using a VAS, with the anchors “no effort required” and “maximum effort required”.

The following significant correlations demonstrate that as intelligibility was rated as less impaired, lower ratings of listener effort were assigned; and as intelligibility was rated as more impaired, higher ratings of listener effort were assigned. More specifically, in the no added background noise condition, the correlations between speech intelligibility (transcription, VAS) and listener effort were: Transcription: $r(21) = -0.892, p = 0.000$; VAS: $r(21) = -0.946, p = 0.000$ and in 65dB multi-talker background noise the correlations were: Transcription: $r(21) = -0.963, p = 0.000$; VAS: $r(21) = -0.959, p = 0.000$. Therefore, all of the correlations examining the strength of the relationships between speech intelligibility and listener effort were significant regardless of the noise condition or measurement technique used for rating intelligibility. These results suggest a very strong correlation between speech intelligibility and listener effort. All of the graphs (Figures 6, 7, 8, 9) show strong linear relationships. The slopes of the graphs representing the no added background noise condition are somewhat steeper than those representing the 65dB multi-talker background noise condition. There is also less variance around the line in the graphs representing the 65dB multi-talker background noise condition, which suggests a stronger relationship in noise.

When examining speech intelligibility and perceived listener effort based on the speech samples of individuals with hypophonia and PD, there were significant correlations in both noise

conditions. This is consistent with the previous findings of Whitehill and Wong (2006) who observed a strong correlation between speech intelligibility scores and listener effort in various dysarthria types. As well, Landa and colleagues (2014) demonstrated that when listeners rated ‘ease of listening’ for dysarthric speech, poorer intelligibility scores were associated with increased listening effort. Dykstra (2007) also reported similar correlations for conversational intelligibility and perceived listener effort in hypokinetic dysarthria that support the results of this study.

4.4 Objective 3: Examine the strength of the relationship between ratings of listener effort and two speech symptoms (articulatory imprecision, reduced loudness) across noise conditions.

The third objective of this study examined the relationship between articulatory imprecision and ratings of listener effort and the relationship between reduced loudness and ratings of listener effort in no added background noise and in 65dB multi-talker background noise. Articulatory imprecision was rated using a VAS with the anchors “normal articulatory precision” and “severely impaired articulatory precision”. Reduced loudness was determined using a VAS with the anchors “normal loudness” and “severely impaired loudness”.

Articulatory Imprecision. In the current study articulatory imprecision was defined as “precise, clear, and crisp sounding speech”. The following significant correlations demonstrate that as ratings of listener effort increased, articulation was rated as more imprecise; and as ratings of listener effort decreased, articulation was rated as more precise. Articulatory imprecision was correlated significantly with listener effort across both noise conditions (No noise: $r(21)= 0.938$, $p=0.000$); 65 dB noise: $r(21)= 0.934$, $p=0.000$). These results suggest that articulatory

imprecision is related to listener effort regardless of noise condition.

This finding is consistent with the previous findings of Whitehill and Wong (2006) who discerned that listener effort and articulation errors were highly related, suggesting that articulation plays an important role in the understandability of speech. However it is important to note that the study by Whitehill and Wong included various dysarthria types, while the current study only examined hypokinetic dysarthria. As well, their study only considered effort and articulation in quiet listening conditions. Considering the current study, the correlation between articulatory imprecision and listener effort is similar in both noise conditions, however Figures 10 and 11 show that there is a steeper slope for the relationship between listener effort and articulatory imprecision in the 65dB multi-talker background noise condition. There is also a more even spread of data along the line in the 65dB multi-talker background noise condition. This suggests that for our speakers with PD, articulatory imprecision is a dominant dimension that impacts listener effort in both noise conditions. However, it is important to consider that the current study is one of the initial studies to examine articulatory imprecision and ratings of listener effort in two different noise conditions. Future research should explore these results further, perhaps by considering taking a more in-depth look at the impact that vowels and consonants have on speech intelligibility and listener effort.

Reduced Loudness. One of the most prevalent and distinctive speech symptoms of hypokinetic dysarthria is hypophonia, also referred to as low speech intensity. In the current study we examined the perceived 'reduced loudness' of our speakers with PD. The following significant correlations demonstrated that as ratings of listener effort increased, the speaker with PD was rated as less intense; and as ratings of listener effort decreased, the speaker with PD was

rated as more intense. Reduced loudness was correlated significantly with listener effort across both noise conditions (No noise: $r(21)= 0.843, p=0.000$; 65 dB noise: $r(21)= 0.962, p=0.000$). These results suggest that reduced loudness is related to listener effort regardless of noise condition.

When examining the relationship between ratings of reduced loudness and listener effort, there were significant correlations in both noise conditions. Figures 12 and 13 show that there is a steeper slope for the relationship between listener effort and reduced loudness in the 65dB multi-talker background noise condition, as well as that there is less variance around the line in the 65dB multi-talker background noise condition. These results suggest that speakers with PD and hypophonia may be increasing the cognitive load of listeners. Listeners may have to use extra effort to understand what is being spoken. In turn, the extra attention allocation required to understand the speech signal in noise would increase the amount of effort the listener would need to expend in order to carry on a conversation. This amount of effort would further increase in demand in communication situations involving background noise, which would not only increase the listener's cognitive load and therefore effort expenditure, but could also distort or completely overwhelm the speech signal. The current study demonstrates this finding. More specifically, in no added background noise ratings of listener effort were relatively low while reduced loudness was rated as more intense, and in 65 dB of background noise ratings of listener effort were relatively higher while reduced loudness was rated as less intense. Since our speakers with PD presented with hypophonia as their primary dysarthric feature, it is not unexpected that our results show a strong correlation between reduced loudness and perceived listener effort. These results suggest that reduced loudness is a salient dimension impacting perceived ratings of

listener effort in noise.

4.5 Objective 4: Examine the strength of the relationship between ratings of speech intelligibility (transcription, VAS) and two speech symptoms (articulatory imprecision, reduced loudness) across noise conditions.

The final objective of this study first examined the relationship between ratings of articulatory imprecision and speech intelligibility (both transcription based scores and VAS ratings) in both noise conditions. This objective also examined the relationships between ratings of reduced loudness and speech intelligibility (both transcription based scores and VAS ratings) in both noise conditions.

Articulatory Imprecision. The following correlations demonstrate that as transcription based intelligibility scores increased, articulation was rated as more precise; and as transcription based intelligibility scores decreased, articulation was rated as more imprecise across noise conditions. More specifically, in the no added background noise condition, the correlations between speech intelligibility (transcription, VAS) and articulatory imprecision were: Transcription: $r(21) = -0.865, p = 0.000$; VAS: $r(21) = -0.925, p = 0.000$ and in 65dB multi-talker background noise the correlations were: Transcription: $r(21) = -0.957, p = 0.000$; VAS: $r(21) = -0.962, p = 0.000$. These results suggest that reduced loudness is related to intelligibility regardless of noise condition or measurement technique used for speech intelligibility.

When comparing ratings of articulatory imprecision to speech intelligibility, the observed correlations demonstrated a linear relationship between articulatory imprecision and speech intelligibility. This result is consistent with Adams and Dykstra (2009) who suggested that individuals with hypokinetic dysarthria can have difficulty with the accurate production of

vowels and consonants, which could have an impact on articulatory imprecision and speech intelligibility. Other research (Darley et al., 1969; De Bodt et al., 2002; Duffy, 2013) has indicated that articulatory imprecision is a dominant factor that has a clear impact on speech intelligibility, and that articulatory imprecision may even be considered the greatest contributor to speech intelligibility in comparison to other speech dimensions. The results of the current study demonstrate that, for our speakers with PD, articulatory imprecision is a dominant dimension that impacts intelligibility in both noise conditions. As well, it has been suggested that VAS ratings of speech intelligibility may be encompassing more aspects of speech production beyond the number of words accurately understood and transcribed, typical of transcription based measures of speech intelligibility (i.e., SIT). This could explain why Figures 14 and 16 depicting the no noise condition look different, whereas Figures 15 and 17 depicting the 65dB multi-talker background noise condition are more similar. The speech-to-noise ratio in the no added background noise condition would have been better than in the 65dB multi-talker background condition, therefore allowing listeners to rate VAS with a full representation of all of the aspects of speech production, some of which may have been disrupted in the 65dB multi-talker background noise condition.

Reduced Loudness. The following significant correlations demonstrate that as speech intelligibility scores increased, speakers with PD were rated as louder/more intense; and as speech intelligibility scores decreased, speakers with PD are rated as quieter/less intense, regardless of the noise condition. More specifically, in the no added background noise condition, the correlations between speech intelligibility (transcription, VAS) and reduced loudness were: Transcription: $r(21) = -0.684, p = 0.000$; VAS: $r(21) = -0.716, p < 0.01, p = 0.000$ and in 65dB multi-

talker background noise the correlations were: Transcription: $r(21) = -0.966, p = 0.000$; VAS: $r(21) = -0.968, p = 0.000$. These results suggest that reduced loudness is related to intelligibility regardless of noise condition or measurement technique used for speech intelligibility. This is consistent with previous research that has suggested that reduced loudness can decrease speech intelligibility and hinder verbal communication in a multitude of social contexts. For example, in a study by McAuliffe and colleagues (2014) five individuals with PD completed the SIT with their normal speech loudness as well as at a level they felt was two times louder than their normal speech. This resulted in intelligibility scores increasing from an average of 45.23% to 60.45%, and suggests that intensity has a direct impact on intelligibility (McAuliffe et al., 2014). Studies that have considered speech-to-noise ratios indicate that individuals with PD have lower speech-to-noise ratios than controls in background noise (Adams et al., 2008). As well, with an increase in background noise comes a decrease in speech-to-noise ratios, which was found to have a negative impact on intelligibility (Adams et al., 2008). This suggests that a similar phenomenon is occurring in the current study, as the presentation of background noise also resulted in ratings of both reduced intelligibility and reduced loudness.

Although we found significant correlations regardless of noise condition, it remains important to assess speech intelligibility in both optimal and sub-optimal communication environments. For example, in clinical settings, where most assessments of individuals with PD are completed, speakers may seem appropriately loud due to the lack of background noise, or individuals with PD might increase their speech intensity because they know what is expected of them in a treatment setting (Dykstra et al., 2007; Dykstra et al., 2013). Interestingly, Tjaden and Wilding (2011) suggest that intelligibility scores derived from validated intelligibility tests, such

as the SIT, when administered in a quiet environment are not indicative of actual intelligibility in an ecologically valid context or in spontaneous speech. The study by Adams and colleagues (2008) demonstrated that individuals with hypophonia had overall significantly lower conversational intelligibility scores in noise when compared to control participants, despite relatively unimpaired speech intelligibility when tested in quiet conditions. The results of the current study (based on Objective 1) also reflect this result, as the intelligibility ratings are considered in the mildly impaired range and reduced loudness was rated as more intense in the no added background noise condition, but when 65dB of multi-talker background noise is introduced intelligibility scores decreased to severe impairment and reduced loudness was rated as relatively less intense. This finding was also demonstrated by Dykstra and colleagues (2013) when studying the conversational intelligibility of individuals with hypophonia in noise. Their study found that without added background noise there was no significant difference in the intelligibility scores of individuals with PD versus control participants. However, the speech intensity of the PD group was lower and had more variability than the control participants and when background noise was introduced participants with PD had lower conversational intelligibility scores (Dykstra et al., 2013). The results of previous studies, as well as the current study, all demonstrate the importance of assessing the speech intelligibility of hypophonic speakers in a variety of contexts including noise, even if they are quite intelligible in a quiet environment.

4.6 Limitations of the Current Study

Although this study revealed many interesting findings, it is also important to acknowledge some of the methodological limitations that were present. The first methodological

limitation relates to the sample of listener participants of the current study. With only 10 listeners the sample size is considered fairly small, however all of our statistical comparisons were statistically significant. The second limitation relates to the age of the listeners, as well as listener familiarity. Our eligibility criteria limited our listener pool to a young, unfamiliar, and naïve population that is not representative of all listeners. In some cases, younger listeners have been found to provide higher intelligibility scores than older listeners (Jones, Mathy, Azuma & Liss, 2004). This could be due to a natural cognitive decline that occurs with age, or in some cases (in particular older men) hearing loss (Pennington & Miller, 2007). Various studies (Liss, Spitzer, Caviness, & Adler, 2002; Tjaden & Liss, 1995a; Tjaden & Liss, 1995b) have demonstrated that familiar non-naïve listeners are better able to recognize speech than unfamiliar naïve listeners, and therefore give higher intelligibility scores. Spouses have also been shown to be better able to understand dysarthric speech than other listeners (DePaul & Kent, 2000). This may also impact ratings of listener effort, as being more familiar with a distorted speech signal may also make it easier to understand. Listener familiarity could also be applied to expert listeners such as SLPs. Some studies show that SLPs assign higher ratings of intelligibility than untrained listeners, perhaps because they are used to listening to disordered speech (Dagenais, Garcia, & Watts, 1998; Dagenais, Watts, Turnage & Kennedy, 1999). However, Pennington and Miller (2007) suggest that with standardized listening conditions, factors such as age, gender and familiarity may not have a significant impact on intelligibility results. A potential third limitation is listener fatigue, which refers to listeners becoming fatigued from listening to and transcribing disordered speech (especially speech in noise). Although the study was split into two listening sessions, it still took approximately 1.5 to 2 hours per session to listen to all of the speech samples and make

the ratings. In some cases participants may have felt bored or become tired from writing, which may have made some of the ratings less accurate.

The next set of limitations relate to the speech samples that were used in this listening study. All of the speech samples came from individuals with PD that presented with hypophonia as their primary dysarthric feature. It is possible that these speech samples represent a specific subgroup of individuals with PD, and so the results may not be generalizable to the general PD population that may be experiencing different elements of hypokinetic dysarthria such as prosodic abnormalities or impairments in speech rate. The continued study of factors related to speech intelligibility and listener effort in individuals with PD and hypophonia warrant future investigation since this clinical population may represent a unique presentation of hypokinetic dysarthria that remains relatively unexplored. In the future, it would be ideal to have equalization of male and female speakers with PD, as well as to control for the severity of hypophonia, and the medication cycle. It would also be interesting to collect acoustic data for intensity to support the perceptual reduced loudness ratings. As well, the speech samples in this study were presented through loud speakers, and so it is possible that the samples were distorted in loudness, although every effort was made to avoid this by calibrating with a diagnostic audiometer before each listening session.

The final limitation of this study relates to the content and artificial nature of the speech samples. Unfortunately the sentences used in this study do not represent natural conversation, although Dykstra (2007) suggests that sentence intelligibility and conversational intelligibility are comparable in validity. We chose the longer sentences from the SIT in an attempt to make our stimuli more ecologically valid than shorter sentences.

4.7 Future Directions

As this was a pilot study, the results of this research provide preliminary information from which a larger scale study can be developed. The areas of interest brought to light in this study can be further explored by replicating the study, adapting the research design, and examining the results and key findings in greater depth.

As discussed previously, it would be relevant to replicate this study with different types of listener participants for example, using older naïve listeners, expert listeners (e.g. SLPs), and/or familiar conversation partners (e.g. spouses). Evaluating speech intelligibility and ratings of listener effort across various listener types could provide more information of potential similarities or differences in ratings of these variables based on type of listener. It has been suggested previously that speaker experience and listener familiarity impacts intelligibility scores (Tjaden & Liss, 1995a & 1995b). It could also provide further evidence as to whether SLPs rate individuals with dysarthria differently because of a trained ear, and if familiar conversation partners are better at interpreting what is being said (DePaul & Kent, 2000; Liss, Spitzer, Caviness, & Adler, 2002). Including conversational tasks could also be beneficial as it would provide a more ecologically valid and generalizable study, especially if the recordings were made in the speakers natural environment. It may be pertinent to provide visual information, such as a video recording of individuals with PD speaking, to determine if visual information improves ratings of intelligibility or ratings of effort in noise in comparison to ratings in noise without visual information. It would also be ideal to include and rate speech samples of control participants. Especially for research that is focused on gaining more knowledge about listener effort, it would be interesting to consider ratings of listener effort in no noise and background

noise from a control population and compare those to ratings from the PD population.

Another possible future direction would be to examine additional speech symptoms. This study only evaluated reduced loudness and articulatory imprecision, however, it would be pertinent to examine other speech features relevant in PD such as rate of speech, voice quality, pitch, or prosody. This is especially relevant because each speech subsystem (i.e., articulatory, respiratory, laryngeal, velopharyngeal) likely contributes to speech intelligibility and listener effort in a cumulative, but differential way (Dykstra, 2007). It has been suggested that this information could help to provide clinicians with a better idea of what speech symptoms have a greater impact on speech intelligibility, as well as provide information on the underlying physiological mechanisms of hypokinetic dysarthria in PD (Yahalom, Simon, Thorne, Peretz & Giladi, 2004). This information could also aid in the creation of “profiles” for various subgroups of PD, especially if a study controlled for equal numbers of males and females and was able to determine severity levels for the different speech symptoms (Lewis et al., 2005). It could also provide a base upon which to build treatment approaches based on an individual’s response pattern (i.e., LSVT for individuals with hypophonia). As well, having listeners rate attention allocation and provide confidence ratings could add a better understanding of the cognitive load involved with listening to individuals with PD in both quiet and noise conditions with various speech profiles (Beukelman et al, 2011).

4.8 Research and Clinical Implications

The results of this study provide potentially important implications for clinical and research applications. Since this preliminary study examined how listeners rate the speech intelligibility, articulatory imprecision, and reduced loudness of speakers with PD and

hypophonia in noise and no noise, as well as the perceived amount of effort expended, the clinical implications are fairly broad in nature. The first consideration relates to furthering our knowledge and understanding of listener effort and the impact it has on communicative participation. This study identified that even in no added background noise, individuals listening to speakers with PD found it somewhat effortful. Developing a more in depth understanding of how articulatory imprecision, reduced loudness, and other variables impact speech intelligibility in no noise and noise is essential to target the salient speech symptoms with tailored interventions. This knowledge can also help to inform novel therapy techniques, such as guided conversation which can help to stimulate conversation and help individuals to relay important information. With continued study in this area, future research could better inform assessment and treatment protocols for the reduction of listener effort and improvement of speech intelligibility.

Another consideration relates to the evaluation of speech intelligibility in multi-talker background noise. The results of the current study demonstrated that the individuals with PD were all rated as more quiet, and less intelligible in the 65dB background noise condition compared to the no added noise condition. Therefore, only assessing speech intelligibility in a room with no added background noise has the potential to underestimate the negative impact of hypophonia on speech intelligibility and listener effort in noise (Adams et al., 2008; Dykstra et al., 2007; Dykstra et al., 2013). Introducing background noise to individuals in therapy might allow for a transfer of treatment to communicative situations that require increased loudness, such as a busy restaurant.

4.9 Summary and Conclusions

The present study was designed to examine the relationships among listener ratings of speech intelligibility (both transcription based scores and VAS ratings), ratings of listener effort, and the two speech symptoms of articulatory imprecision and reduced loudness, in the speech of individuals with PD and hypophonia. This study also examined the impact of background noise on these listener ratings. The overarching goal of this study was to determine how these two speech symptoms associated with hypokinetic dysarthria contribute to judgements of listener effort, as well as to determine the strength of the relationship between listener ratings of intelligibility and effort, and the effect of background noise on these relationships.

The first objective of this study revealed significant differences when comparing transcription based intelligibility scores across noise conditions. These results suggest that listeners had more difficulty accurately transcribing the sentences presented in the 65 dB multi-talker background noise condition than in no noise. The comparison of VAS speech intelligibility scores also revealed significant differences across noise conditions. This result suggests that listeners consistently assigned a higher rating of speech intelligibility to speakers with PD in the no added background noise condition as compared to the 65dB multi-talker background noise condition. In the comparison of ratings of listener effort in no added background noise and 65dB of multi-talker background noise, significant results were revealed. These results suggest that listeners required an increased amount of effort to understand the speakers with PD in the 65 dB multi-talker background noise condition as compared to the no noise condition. The comparison of articulatory imprecision ratings revealed a significant difference across noise conditions. This result suggests that listeners perceived a difference in the articulatory imprecision of speakers in

the different noise conditions. When comparing ratings of reduced loudness a significant difference was revealed across noise conditions. This suggests that background noise had an impact on listener's perception of the speaker's reduced loudness.

The second objective revealed significant correlations between speech intelligibility (both transcription based scores and VAS ratings) and ratings of listener effort, in both noise conditions. These results suggest that speech intelligibility and listener effort are highly correlated in both noise and no noise conditions, regardless of measurement technique (transcription vs. VAS).

The third objective revealed significant correlations between ratings of articulatory imprecision and ratings of listener effort in both noise conditions. Additionally, significant correlations were revealed between reduced loudness ratings and ratings of listener effort in both noise conditions. Overall, these results demonstrate that articulatory imprecision and reduced loudness ratings are related significantly to listener effort ratings regardless of noise condition. Furthermore, these results suggest that these speech parameters contribute to the increased effort listeners expend when listening to speakers with hypokinetic dysarthria.

Finally, the fourth objective of this study revealed significant correlations among articulatory imprecision ratings with both transcription based intelligibility and VAS intelligibility in both noise conditions. The fourth objective also revealed significant correlations among reduced loudness ratings with both transcription based speech intelligibility and VAS intelligibility in both noise conditions.

This study has revealed novel and potentially valuable information concerning the impact of hypophonia on ratings of listener effort and speech intelligibility in background noise. The

results and implications of this research have contributed to the knowledge of speech intelligibility and listener effort in Parkinson's disease. The findings from this line of research will contribute to the growing body of literature regarding speech intelligibility and listener effort in Parkinson's disease. This study could also inform the development of novel assessment and research protocols designed to reduce listener effort, and improve the speech intelligibility of individuals with hypokinetic dysarthria associated with PD.

References

- Abbruzzese, G., & Berardelli, A. (2003). Sensorimotor integration in movement disorders. *Movement Disorders, 18*(3), 231–240.
- Adams, S. & Dykstra, A.D. (2009). *Hypokinetic dysarthria* (pp.166-186). In *Clinical Management of Sensorimotor Speech Disorders*, Second Edition, Malcolm R. McNeil (ed.), New York: Thieme.
- Adams, S., Dykstra, A., Abrams, K., Winnell, J., Jenkins, M., & Jog, M. (2006). Conversational speech intensity under different noise conditions in hypophonia and Parkinson's Disease. *Canadian Acoustics, 34*(3), 96-97.
- Adams, S.G., Dykstra, A., Jenkins, M., & Jog, M. (2008). Speech-to-noise levels and conversational intelligibility in hypophonia and Parkinson's Disease. *Journal of Medical Speech-Language Pathology, 16*(4), 165-172.
- Adams, S., Haralabous, O., Dykstra, A., Abrams, K. & Jog, M. (2005). Effects of multi talker background noise on the intensity of spoken sentences in Parkinson's Disease. *Canadian Acoustics, 33*(3), 94-95.
- Adams, S. & Jog, M. (2009). *Parkinson's disease* (pp.365-368). In *Clinical Management of Sensorimotor Speech Disorders*, Second Edition, Malcolm R. McNeil (ed.), New York: Thieme.
- Altmann, L.J.P. & Troche, M.S. (2011). High-level language production in Parkinson's disease: A review. *Parkinson's Disease, 1*-12.
- Beukelman, D.R., Childes, J., Carrell, T., Funk, T., Ball, L.J., & Pattee, G.L. (2011). Perceived attention allocation of listeners who transcribe the speech of speakers

- with amyotrophic lateral sclerosis. *Speech Communication*, 53, 801-806.
- Boersma, P. & Weenink, D. (2011). Praat, software for speech analysis and synthesis.
- Boersma, P. & Weenink, D. (2013). Praat, software for speech analysis and synthesis.
- Campbell, N.A., Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., & Jackson, R.B. (2008). *Biology*, 8th Ed. San Francisco, CA: Pearson Benjamin Cummings.
- Clark, J.P., Adams, S.G., Dykstra, A.D., Moodie, S., & Jog, M. (2014). Loudness perception and speech intensity control in Parkinson's Disease. *Journal of Communication Disorders*, 51, 1-12.
- Dagenais, P. A., Garcia, J. M., & Watts, C.R. (1998). Acceptability and intelligibility of mildly dysarthric speech by different listeners. In M. P. Cannito, K. M. Yorkston, & D. R. Beukelman (Eds.), *Neuromotor speech disorders: Nature, assessment and treatment* (pp. 229-239). Baltimore, MD: Brookes.
- Dagenais, P. A., Watts, C. R., Turnage, L., & Kennedy, S. (1999). Intelligibility and acceptability of moderately dysarthric speech by three types of listeners. *Journal of Medical Speech Language Pathology*, 7(2), 91-96.
- Darley, F.L., Aronson A.E., & Brown, J.R. (1975). *Motor Speech Disorders*, Philadelphia, PA: W.B. Saunders
- Darley, F.L., Aronson, A.E., & Brown, J.R. (1969). Differential diagnostic patterns of dysarthria. *Journal of Speech, Language, and Hearing Research*, 12, 246-269.
- De Bodt, M.S., Hernandez-Diaz Huici, H.M., & Van de Heyning, P.H. (2002). Intelligibility as a linear combination of dimensions in dysarthric speech. *Journal*

of Communication Disorders, 35(3), 283-292.

DePaul, R. & Kent, R.D. (2000). A longitudinal case study of ALS effects of listener familiarity and proficiency on intelligibility judgments. *American Journal of Speech Language Pathology*, 9(3), 230-240.

Duffy, J. R. (2013). *Motor speech disorders: Substrates, differential diagnosis, and management* (third ed.). St. Louis, MO Mosby.

Dykstra, A.D. (2007). *The Effects of Hypophonia on Speech Intelligibility, Communication Effectiveness and Communication-Related Quality of Life in Parkinson's disease* (Doctoral dissertation). (Order No. NR30802). Available from ProQuest Dissertations & Theses Global. (304759731). Retrieved from <https://www.lib.uwo.ca/cgi-bin/ezpauthn.cgi?url=http://search.proquest.com/docview/304759731?accountid=15115>

Dykstra, A.D., Adams, S.G., & Jog, M. (2012). The effect of background noise on the speech intensity of individuals with hypophonia associated with Parkinson's disease. *Journal of Medical Speech-Language Pathology*, 20(3), 19-30.

Dykstra, A.D., Adams, S.G., & Jog, M. (2013). Examining the conversational speech intelligibility of individuals with Hypophonia associated with Parkinson's Disease. *Journal of Medical Speech-Language Pathology*, 20(4), 53-57.

Dykstra, A.D., Hakel, M.E., & Adams, S.G. (2007). Application of the ICF in reduced speech intelligibility in dysarthria. *Seminars in Speech and Language*, 28(4), 301-311.

Fox, C.M., & Ramig, L.O. (1997). Vocal sound pressure level and self-perception of speech and voice in men and women with idiopathic Parkinson's Disease.

- American Journal of Speech-Language Pathology*, 6(2), 85-94.
- Gamboa, J., Jimenez-Jimenez, F.J., Nieto, A., Montojo, J., Orti-Pareja, M., Molina, J.A., Garcia-Albea, E., & Cobeta, I. (1997) Acoustic voice analysis in patients with Parkinsons disease treated with dopaminergic drugs. *Journal of Voice*, 11(3), 314-20.
- Ho, A. K., Bradshaw, J. L., & Ianseck, R. (2000). Volume perception in Parkinsonian speech. *Movement Disorders*, 15, 1125–1131.
- Ho, A.K., Inseam R., Marigliani, C., Bradshaw, J.L., & Gates, S. (1999). Speech impairment in a large sample of patients with Parkinson’s disease. *Behavioural Neurology*, 11, 131-137.
- Hustad, K.C. (2007). Effects of speech stimuli and dysarthria severity on intelligibility scores and listener confidence ratings for speakers with cerebral palsy. *Folia Phoniatr Logop*, 59, 306-317.
- Hustad, K.C. (2008). The relationship between listener comprehension and intelligibility scores for speakers with dysarthria. *Journal of Speech Language and Hearing Science*, 51, 562-573
- Jones, W., Mathy, P., Azuma, T, & Liss, J. (2004). The effect of aging and synthetic topic cues on the intelligibility of dysarthric speech. *Augmentative and Alternative Communication*, 20(1), 22-29.
- Kent, R.D., Weismer, G., Kent, J.F., & Rosenbek, J.C. (1989). Toward phonetic intelligibility testing in dysarthria. *Journal of Speech and Hearing Disorders*, 54, 482-499.

Keppel, G. (1991). *Design and analysis: a researcher's handbook (3rd ed.)*. Englewood Cliffs, NJ: Prentice Hall.

Landa, S., Pennington, L., Miller, N., Robson, S. Thompson, V. & Steen, N. (2014). Association between objective measurement of the speech intelligibility of young people with dysarthria and listener ratings of ease of understanding. *International Journal of Speech-Language Pathology, 16*(4), 408-416.

Lane, H., & Tranel, B. (1971). The Lombard sign and the role of hearing in speech. *Journal of Speech and Hearing Research, 14*, 677-709.

Latorre, A., Bloise, M.C., Colosimo, C., Di Biasio, F., Defazio, G., Berardelli, A., & Fabbrini, G. (2014). Dyskinesias and motor symptoms onset in Parkinson disease. *Parkinsonism and Related Disorders, 20*, 1427-1429.

Lewis, S.J.D., Foltynie, T., Blackwell, A.D., Robbins, T.W., Owen, A.M., Barker, R.A. (2005). Heterogeneity of Parkinson's disease in the early clinical stages using a data driven approach. *Journal of Neurology, Neurosurgery and Psychiatry, 76*, 343-348.

Liss, J. M., Spitzer, S. M., Caviness, J. N., & Adler, C. (2002). The effects of familiarization on intelligibility and lexical segmentation in hypokinetic and ataxic dysarthria. *Journal of the Acoustical Society of America, 112*, 3022-3030.

Logemann, J.A., & Fisher, H.B. (1981). Vocal tract control in Parkinson's disease: Phonetic feature analysis of misarticulations. *Journal of Speech and Hearing Disorders, 46*, 348-352.

Logemann, J.A., Fisher, H.B., Boshes, B., & Blonsky, E.R. (1978). Frequency and cooccurrence of vocal tract dysfunctions in the speech of a large sample of

- Parkinson patients. *Journal of Speech and Hearing Disorders*, 43(1), 47-57.
- Ludlow, C.L. & Bassich, C.J. (1984). Relationships between perceptual ratings and acoustic measures of hypokinetic speech. In: McNeil, M.R., Rosenbek, J.C., Aronson, A.E. *Dysarthria of speech: Physiology-acoustics-linguistics-management*. (163-196) (Eds). College-Hill Press, San Diego, CA, USA.
- McAuliffe, M.J., Kerr, S.E., Gibson, E.M.R., Anderson, T., & LaShell, J. (2014). Cognitive-perceptual examination of remediation approaches to hypokinetic dysarthria. *Journal of Speech, Language and Hearing Research*, 57, 1268-1283.
- McKim, W.A. (2007). *Drugs and behaviour: An introduction to behavioural pharmacology*, 6th Ed. USA: Pearson Prentice Hall.
- Miller, N. (2013). Measuring up to speech intelligibility. *International Journal of Language and Communication Disorders*, 48(6), 601-612.
- Nagle, K.F., & Eadie, T.L. (2012). Listener effort for highly intelligible tracheoesophageal speech. *Journal of Communication Disorders*, 45, 235-245.
- Pal, P., Samii, A., & Calne, D. (2002). *Cardinal features of early Parkinson's disease* (pp.41-56). In *Parkinson's disease: Diagnosis and clinical management*, S. Factor and W. Weiner (eds.), New York, NY: Demos Medical Publishing.
- Parkinson, J. (1817). An essay on the shaking palsy. *Neuropsychiatry Classics*, 14 (2), 223-236.
- Parkinson Society Canada. (2015). Retrieved March 4, 2015, from <http://www.parkinson.ca/>
- Patel, R. & Schell, K.W. (2008). The influence of linguistic content on the Lombard Effect. *Journal of Speech, Language, and Hearing Research*, 51, 209-220.
- Pell, M.D., Cheang, H.S., & Leonard, C.L. (2006). The impact of Parkinson's disease on

- vocal-prosodic communication from the perspective of listeners. *Brain and Language*, 97, 123-134.
- Pennington, L. & Miller, N. (2007) Influence of listening conditions and listener characteristics on intelligibility of dysarthric speech. *Clinical Linguistics & Phonetics*, 21(5), 393-403.
- Portney, L. & Watkins, M.P (2000). *Foundations of clinical research applications to practice, 2nd edition*. New Jersey: Prentice Hall.
- Rusz, J., Cmejla, R., & Tykalova, T. (2013). Imprecise vowel articulation as a potential early marker of Parkinson's disease: Effect of speaking task. *Journal of the Acoustic Society of America*, 134(3), 2171-2181.
- Schneider, S.A., & Obeso, J.A. (2014). Clinical and pathological features of Parkinson's disease. *Current Topics in Behavioural Neuroscience*.
- Sethi, K.D. (2002). Clinical aspects of Parkinson's disease. *Current Opinion in Neurology*, 15(4), 457-60.
- Skodda, S. (2011). Aspects of speech rate and regularity in Parkinson's disease. *Journal of the Neurological Sciences*, 310, 231-236.
- Skodda, S., Gronheit, W., Mancinelli, N., & Schlegel, U. (2013). Progression on voice and speech impairment in the course of Parkinson's Disease: A longitudinal study. *Hindawi Publishing Corporation*, 1-8.
- Skodda, S., & Schlegel, U. (2008). Speech rate and rhythm in Parkinson's disease. *Movement Disorders*, 23, 985-92.
- Tanner C. M. & Goldman S. M. (1996). Epidemiology of Parkinson's disease. *Neurologic Clinics*, 14, 317-335.

- Tjaden, K.K., & Liss, J.M. (1995a). The role of listener familiarity in the perception of dysarthric speech. *Clinical Linguistics & Phonetics*, 9(2), 139-154.
- Tjaden, K.K. & Liss, J. M. (1995b). The Influence of Familiarity on Judgments of Treated Speech. *American Journal of Speech Language Pathology*, 4(1), 39-48.
- Tjaden, K. & Wilding, G. (2011). Effects of speaking task on intelligibility in Parkinson's disease. *Clinical Linguistics & Phonetics*, 25(2), 155–68.
- Twelves, D., Perkins, K.S.M., & Counsell, C. (2003). Systematic review of incidence studies of Parkinson's disease. *Movement Disorders*, 18(1), 19-31.
- Whitehill, T.L., Ciocca, V., & Yiu, E.M-L. (2004). Perceptual and acoustic predictors of intelligibility and acceptability in Cantonese speakers with dysarthria. *Journal of Medical Speech-Language Pathology*, 12(4), 229-233.
- Whitehill, T.L. & Wong, C.C-Y. (2006). Contributing factors to listener effort for dysarthric speech. *Journal of Medical Speech-Language Pathology*, 14(4), 335-341.
- Wirdefeldt, K., Adami, H-O., Cole, P., Trichopoulos, D. & Mandel, J. (2011). Epidemiology and etiology of Parkinson's Disease: A review of the evidence. *European Journal of Epidemiology*, 26(1), 1-58.
- Yahalom, G., Simon, E.S., Thorne, R., Peretz, C., & Giladi, N. (2004). Hand rhythmic tapping and timing in PD. *Parkinsonism and Related Disorders*, 10, 143-148.
- Yorkston, K.M. & Beukelman, D.R. (1981). Communication efficiency of dysarthric speakers as measured by sentence intelligibility and speaking rate. *Journal of Speech and Hearing Disorders*, 46, 296-301.

Yorkston, K.M., Beukelman, D.R., & Bell, K. (1988). *Clinical management of dysarthric speakers*. Boston, MA: College Hill Press.

Yorkston, K.M., Beukelman, D.R., & Tice, R. (2011). *Speech Intelligibility Test*. Lincoln, NE: Institute for Rehabilitation Science and Engineering at Madonna Rehabilitation Hospital.

Yorkston, K.M., Beukelman, D.R., & Traynor, C. (1984). *Computerized assessment of intelligibility of dysarthric speech*. Tigard, Oregon : C.C. Publications.

Yorkston, K.M., Strand, E.A., & Kennedy, M.R.T. (1996). Comprehensibility of dysarthric speech. *American Journal of Speech-Language Pathology*, 5, 55-66.

APPENDIX A

Letter of Information**Project Title:**

Examining factors contributing to listener effort in speakers with Parkinson's disease

Principal Investigator:

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School of Communication Sciences and Disorders; Health and Rehabilitation Sciences

Western University

**Co-Investigators:**

Carlee Wilson

MSc Candidate, Speech and Language Science

Health and Rehabilitation Sciences

Western University

Dr. Mandar Jog, MD, FRCPC

Director

Movement Disorders Program; Clinical Neurological Sciences

London Health Sciences Centre, University Campus, and Western University

Letter of Information for Listener Participants**1. Invitation to Participate**

You are invited to participate in this research study investigating factors that contribute to listener judgements of effort in the speech of individuals with Parkinson's disease (PD) and dysarthria (a speech impairment). You have been invited to participate because you have normal hearing ability and English is your first language.

2. Purpose of the Letter

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research.

3. Purpose of this Study

The purpose of this study is to investigate factors that may contribute to listener judgements effort in speakers with a speech impairment resulting from Parkinson's disease. This study also aims to determine potential relationships among ratings of listener effort, and speech intelligibility.

4. Inclusion Criteria

To be eligible to participate as a listener in this study, individuals must be between 18 and 30 years old, have normal hearing ability, and speak English as their first language.

5. Exclusion Criteria

Individuals who have a history of hearing, language, or cognitive impairment or who are unable to pass a 20 dB hearing screening test are not eligible to participate in this study. Additionally, individuals will be excluded from the study if they have extensive research or clinical experience with individuals with PD.

6. Study Procedures

If you agree to participate, you will first be asked to take a basic hearing screening test and to provide your age as well as general information about your medical, speech and hearing, and neurological history. The study involves listening to pre-recorded speech samples of individuals with PD. You will be asked to rate the audio samples heard in terms of speech intelligibility, effort, articulatory precision, voice quality, etc. It is anticipated that the entire experiment will take approximately 2-3 hours to complete over two 1-1.5 hour sessions. The tasks will be conducted in Dr. Allyson Dykstra's lab, [REDACTED]. There will be a total of 10 naïve listeners participating in this study.

7. Possible Risks and Harms

There are no known or anticipated risks or discomforts associated with participation in this study. The experiment will be conducted in a safe, hygienic, university lab with adequate lighting and ventilation. The experimental procedures will require very minimal physical effort, and you will be seated in a comfortable chair and given rest breaks at approximately ten-minute intervals or more frequently if requested.

8. Possible Benefits

There is no direct benefit to participation in this study. The potential benefits to society include an improved understanding of the speech production and perception and disordered speech associated with PD.

9. Compensation

You will not be compensated for your participation in this study. However, on-site parking will be complimentary on the days of participation regardless of whether you

complete the study. A free daily visitor's parking pass will be provided to you upon your arrival to the Elborn College parking lot.

10. Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your academic status, course evaluation, or grades in any way.

11. Confidentiality

All data collected will remain confidential. Your name and any identifying information will be collected separately from the data. All data collected with no personal identifiers will be retained indefinitely. If you choose to withdraw from this study, your data will be immediately removed and destroyed from our database. Our research records will be locked in a cabinet in the principal investigator's secure lab in Elborn College, Western University. Listener participants will make perceptual ratings from de-identified audio recordings. All other data collected will remain accessible only to the investigators of this study. Representatives of Western University's Research Ethics Board may contact you or require access to your study-related records to monitor the conduct of the research.

12. Contacts for Further Information

If you require any further information regarding this research project or your participation in the study, you may contact Dr. Allyson Dykstra at [REDACTED] and [REDACTED].

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

13. Publication

If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published. If you would like to receive a copy of any potential study results, please contact Dr. Allyson Dykstra.

This letter is yours to keep for future reference.

APPENDIX B

Consent Form**Project Title:**

Examining factors contributing to listener effort in speakers with Parkinson's disease

Principal Investigator:

Allyson Dykstra, PhD

Assistant Professor

School of Communication Sciences and Disorders; Health and Rehabilitation Sciences

Western University

**Co-Investigators:**

Carlee Wilson

MSc Candidate, Speech and Language Science

Health and Rehabilitation Sciences

Western University

Dr. Mandar Jog, MD, FRCPC

Director

Movement Disorders Program; Clinical Neurological Sciences

London Health Sciences Centre, University Campus, and Western University

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

Signature of Research Participant

Printed Name

Date

Signature of Person Obtaining Consent

Printed Name

Date

APPENDIX C

Intake Form***Section 1: Demographic Information***Unique ID: _____ Gender: M F Language: _____

Age: _____ Occupation: _____

Section 2: Hearing Screening Results

Hearing Threshold:

Threshold	Right Ear	Left Ear
500 Hz		
1000 Hz		
2000 Hz		
4000 Hz		

Section 3: History of Speech, Language, Hearing, and Neurological ImpairmentHave you ever been diagnosed with a speech impairment? Yes No

If yes, please indicate the diagnosis:

Have you ever been diagnosed with a language impairment? Yes No

If yes, please indicate the diagnosis:

Have you ever been diagnosed with a hearing impairment? Yes No

If yes, please indicate the diagnosis:

Have you ever been diagnosed with a neurological impairment? Yes No

If yes, please indicate the diagnosis:

APPENDIX D

Ethics Approval Notice



Western
Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Allyson Dykstra
Department & Institution: Health Sciences/Communication Sciences & Disorders, Western University

HSREB File Number: 106423
Study Title: Examining factors contributing to listener effort in speakers with Parkinson's disease
Sponsor:

HSREB Initial Approval Date: April 17, 2015
HSREB Expiry Date: April 17, 2016

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Letter of Information & Consent		2015/04/15
Recruitment Items	Recruitment Flyer (received April 16, 2015)	
Western University Protocol	Received April 16, 2015	
Data Collection Form/Case Report Form	Listener protocol - data collection form (65 dB noise condition)	2015/02/23
Data Collection Form/Case Report Form	Listener protocol - data collection form (no noise condition)	2015/02/23
Instruments	Sample sentences that listeners will rate across various speech dimensions (received Feb.24, 2015)	
Data Collection Form/Case Report Form	Intake form for listener participants (received Feb.24, 2015)	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

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

[Redacted]
Ethics Officer, on behalf of Dr. Marcelo Kremenichutzky, HSREB Vice Chair

Ethics Officer to Contact for Further Information

Erika Basile	Grace Kelly	Mina Mekhail	Vikki Tran
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This is an official document. Please retain the original in your files.

APPENDIX E

Speech Intelligibility Test (SIT) – Sentence Examples

Sample sentences from the Speech Intelligibility Test (Yorkston, Beukelman & Tice, 2011)

13. After you've finished answering all the questions, please mail the card to us.
14. The sun never reaches the ground through the overhead canopy of trees and vines.
15. It was the exact same feeling you get when your knee gives out on you.

APPENDIX F

Listener ID: _____ PD ID: _____ Stimuli version: _____ Date: _____

Condition: 0 dB

A. Orthographic Transcription of Sentences

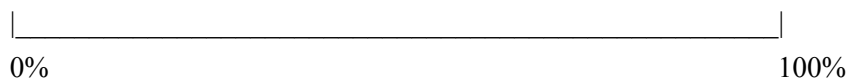
13. _____

14. _____

15. _____

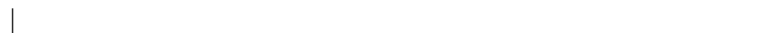
B. VAS Rating of Intelligibility

Please rate your perception of how intelligible the sentences were, based on all three sentences.



C. Ratings of Effort

Please rate the amount of effort you used when listening these sentences



No effort required

Maximum effort required

D. Please rate the severity of each of the following 2 speech variables.

1. **Articulatory Precision** (i.e., the precision in the articulation of sounds)



Normal articulatory precision

Severely impaired articulatory precision

2. **Loudness** (i.e., reduced loudness)



Normal loudness

Severely impaired loudness

APPENDIX G

Listener ID: _____ PD ID: _____ Stimuli version: _____ Date: _____
 Condition: 65 dB

A. Orthographic Transcription of Sentences

13. _____

14. _____

15. _____

B. VAS Rating of Intelligibility

Please rate your perception of how intelligible the sentences were, based on all three sentences.

|_____|
 0% 100%

C. Ratings of Effort

Please rate the amount of effort you used when listening these sentences

|_____|
 No effort required Maximum effort required

D. Please rate the severity of each of the following 2 speech variables.

1. **Articulatory Precision** (i.e., the precision in the articulation of sounds)

|_____|
 Normal articulatory precision Severely impaired articulatory precision unable to rate

2. **Loudness** (i.e., reduced loudness)

|_____|
 Normal loudness Severely impaired loudness

APPENDIX H
Inter-rater Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
0.963	10

Intraclass Correlation Coefficient							
	Intraclass Correlation ^b	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig.
Single Measures	0.705 ^a	0.500	0.893	27.373	9	81	0.000
Average Measures	0.960	0.909	0.988	27.373	9	81	0.000

Two-way random effects model where both people effects and measures effects are random

a. The estimator is the same, whether the interaction is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

APPENDIX I
Intra-rater Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
0.891	2

Intraclass Correlation Coefficient							
	Intraclass Correlation ^b	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig.
Single Measures	0.815 ^a	0.419	0.951	9.146	9	9	0.001
Average Measures	0.898	0.590	0.975	9.146	9	9	0.001

Two-way random effects model where both people effects and measures effects are random

a. The estimator is the same, whether the interaction is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

APPENDIX J

Paired Samples T-test Analyses

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SIT ¹ 0dB	85.54418	22	14.441345	3.078905
	SIT ¹ 65dB	46.16945	22	32.367537	6.900782
Pair 2	VAS ² 0dB	75.23182	22	19.828152	4.227376
	VAS ² 65dB	47.44091	22	30.860294	6.579437
Pair 3	Effort ³ 0dB	35.43182	22	22.465389	4.789637
	Effort ³ 65dB	68.62273	22	25.778506	5.495996
Pair 4	Artic ⁴ 0dB	32.60455	22	19.066237	4.064935
	Artic ⁴ 65dB	51.9978	22	26.74437	5.70192
Pair 5	Loud ⁵ 0dB	32.70455	22	24.383161	5.198507
	Loud ⁵ 65dB	54.80000	22	29.899594	6.374615

Paired Samples Correlations			
	N	Correlation	Sig.
SIT ¹ 0dB & SIT ¹ 65dB	22	0.638	0.001
VAS ² 0dB & VAS ² 65dB	22	0.615	0.002
Effort ³ 0dB & Effort ³ 65dB	22	0.682	0.000
Artic ⁴ 0dB & Artic ⁴ 65dB	22	0.709	0.000
Loud ⁵ 0dB & Loud ⁵ 65dB	22	0.600	0.003

¹ Sentence intelligibility measured by orthographic transcription

² Speech intelligibility measured by visual analog

³ Overall listener effort measured by visual analog scale

⁴ Articulatory imprecision measured by visual analog scale

⁵ Reduced loudness measured by visual analog scale

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	Difference				
				Upper	Lower			
SIT¹ 0dB & SIT¹ 65dB	39.374727	25.679636	5.474917	27.989015	50.760440	7.192	21	0.000
VAS² 0dB & VAS² 65dB	27.790909	24.343884	5.190133	16.997436	38.584382	5.355	21	0.000
Effort³ 0dB & Effort³ 65dB	-33.190909	19.467871	4.150564	-41.822480	-24.559339	-7.997	21	0.000
Artic⁴ 0dB & Artic⁴ 65dB	-19.39322	18.86336	4.02168	-27.75676	-11.02967	-4.822	21	0.000
Loud⁵ 0dB & Loud⁵ 65dB	-22.095455	24.762808	5.279448	-33.074668	-11.116241	-4.185	21	0.000

¹ Sentence intelligibility measured by orthographic transcription

² Speech intelligibility measured by visual analog

³ Overall listener effort measured by visual analog scale

⁴ Articulatory imprecision measured by visual analog scale

⁵ Reduced loudness measured by visual analog scale

¹ Sentence intelligibility measured by orthographic transcription

² Speech intelligibility measured by visual analog

³ Overall listener effort measured by visual analog scale

⁴ Articulatory imprecision measured by visual analog scale

⁵ Reduced loudness measured by visual analog scale

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Curriculum Vitae

Carlee Wilson, BSc., MSc Candidate

EDUCATION

Western University (London, Ontario) September 2014-Present

- Master of Science Health and Rehabilitation Sciences, Speech Language Science Field
- Thesis: Variables contributing to listener effort in hypokinetic dysarthria.

Algoma University (Sault Ste. Marie, Ontario) Conferred June 2014**Murdoch University** (Perth, Australia - Study Abroad Program, Fall 2011 Semester)

- Bachelor of Science (Honours) Psychology, minor in French
- Thesis: Perceptions of Intelligence of Stuttering Individuals.

TEACHING EXPERIENCE

Graduate Teaching Assistant September 2015-April 2016*Western University, School of Communication Sciences and Disorders*

- Counselling for Speech-Language Pathologists (CSD 9635), Introduction to Speech and Language Disorders (CSD 4411)

Teaching Assistant September 2013-April 2014*Algoma University, Psychology Department*

- Introductory Psychology (PSYC1106 & PSYC1107), Sensory Processes (PSYC2906), Scientific Methods and Analysis (PSYC2127), Human Neuropsychology (PSYC2617), Perception (PSYC2907)

Tutor November 2013-April 2014*Algoma University, Learning Centre*

- Introductory French (FREN1021 & FREN1022), Brain and Behaviour (PSYC2606)

RESEARCH EXPERIENCE

Research Assistant September 2014-December 2014*Speech Movement Disorders Lab, Western University*

- Acoustic analysis of speech samples using Praat software

Summer Student Analyst

May 2014-August 2014

Western Ivey International Centre for Health Innovation

- Completed a broad literature search and review
- Data collection and entry

Research Assistant

January 2014-August 2014

DeCode

- Conducted and transcribed interviews with students about government student loans
- Provided perspectives on the user-friendliness of a student loan website

Research Assistant

April 2013-August 2013

Algoma University, Psychology Department

- Gathered information for a literature review
- Helped to set up and conduct various experiments

Research Assistant

April 2012 - August 2012

Health Informatics Institute

- Authored a literature review
- Translated a mental health consumer survey into French
- Conducted and transcribed interviews, aided in focus group data collection
- Aided in the completion of qualitative and quantitative analyses of data

PRESENTATIONS & PUBLICATIONS

Poster Presentations

- Dykstra, A.D., Siegel, L., **Wilson, C.**, & Jog, M. "Examining speech intelligibility and self-rated communication related quality of life in individuals with oromandibular dystonia receiving botulinum toxin therapy." Madonna Rehabilitation Hospital Motor Speech Conference March, 2016.
- Dykstra, A.D., Siegel, L., **Wilson, C.**, & Jog, M. "Examining speech intelligibility and self-rated communication related quality of life in individuals with oromandibular dystonia receiving botulinum toxin therapy." Western University FHS Annual

Research Day, March 2016.

- **Wilson, C.**, Dykstra, A., Siegel, L., Mancinelli, C., Jog, M. “Exploring self-perceived communication competence in speakers with oromandibular dystonia.” Queen’s University 17th Annual Research Rehabilitation Colloquium, May 1, 2015.
- **Wilson, C.**, Dykstra, A., Siegel, L., Mancinelli, C., Jog, M. “An exploration of the perception of communication competence in speakers with OMD receiving botulinum toxin injections.” Western University FHS Annual Research Day, March 25, 2015.
- Siegel, L., Dykstra, A., Mancinelli, C., **Wilson, C.**, Jog, M. “Examining ratings of communication-related quality of life in speakers with oromandibular dystonia receiving botulinum toxin therapy.” Western University FHS Annual Research Day, March 25, 2015.
- **Wilson, C.**, Dykstra, A., Siegel, L., Mancinelli, C., Jog, M. “Examining ratings of self-perceived communication competence in speakers with oromandibular dystonia receiving botulinum toxin therapy.” Western University HRS 8th Annual Graduate Research Conference, February 4, 2015.
- Mancinelli, C., Dykstra, A., **Wilson, C.**, Siegel, L., Dworschak-Stokan, A., & Husein, M. “Communication-related quality of life and speech intelligibility in adults with velopharyngeal insufficiency.” Western University HRS 8th Annual Graduate Research Conference, February 4, 2015.
- Siegel, L., Dykstra, A., Mancinelli, C., **Wilson, C.**, Jog, M. “Examining ratings of communication-related quality of life in speakers with oromandibular dystonia receiving botulinum toxin therapy.” Western University HRS 8th Annual Graduate Research Conference, February 4, 2015.

Oral Presentations

- **Wilson, C.**, Dykstra, A.D., Adams, S.G., & Jog, M. “Hypophonia and other variables contributing to listener effort in Parkinson’s disease” Speech and Language Science Seminar Presentation, March 30, 2016.
- **Wilson, C.**, Dykstra, A.D., Adams, S.G., & Jog, M. “Examining variables contributing to listener effort in Parkinson's disease.” Western University HRS 9th Annual Graduate Research

Conference, February 3, 2016.

- **Wilson, C.** “Perceptions of Intelligence of Stuttering Individuals.” Algoma University 27th Annual Psychology Thesis Conference, March 21, 2014.

Reports

- Shaw, N.T., Aceti, V., **Wilson, C.**, Woolner, K., Secondi, S., Robson, J., Mental Health and Addiction Support in Algoma District: A Consumer Needs Assessment for the Algoma Anchor Agency, November 30, 2012.

SCHOLARSHIPS & AWARDS

- AlgomaU Gold Award of Excellence (2010)
- Richard M. Haynes Bursary Award (2011)
- William M. Hogg Scholarship (2012)
- Edward & Frank McGrath Award (2012)
- Soo Mill & Lumber Company Scholarship (2013)
- Dean’s List (2011, 2012, 2013, 2014)
- Best MSc Poster at the Queen’s University 17th Annual Research Rehabilitation Colloquium (2015)
- Western Graduate Research Scholarship (2015, 2016)