PROFILING PREDICTORS OF SPEECH INTELLIGIBILITY IN INDIVIDUALS WITH PARKINSON'S DISEASE

By

CORINA HERNANDEZ

Bachelor of Science in

Communication Sciences and Disorders

Stillwater, Oklahoma

2018

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2020

PROFILING PREDICTORS OF SPEECH

INTELLIGIBILITY IN INDIVIDUALS

WITH PARKINSON'S DISEASE

Thesis Approved:

Dr. Ramesh Kaipa

Thesis Adviser

Dr. Roha Kaipa

Dr. Alex Bishop

Dr. Christopher Dromey

I wish to express my deepest gratitude to my family and friends who supported me on this journey and to all of the individuals who dedicated their time to participate in this study.

Acknowledgements reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

Name: CORINA HERNANDEZ

Date of Degree: MAY, 2020

Title of Study: PROFILING PREDICTORS OF SPEECH INTELLIGIBILITY IN INDIVIDUALS WITH PARKINSON'S DISEASE

Major Field: COMMUNICATION SCIENCES AND DISORDERS

Abstract: The current study investigated the perceptual predictors of speech intelligibility in individuals with Parkinson's disease and the magnitude of each in predicting speech intelligibility as perceived by semi-trained listeners. The outcomes of this study have implications for the treatment protocol for enhancing speech intelligibility in this population.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative movement disorder that can be identified by motor and nonmotor related symptoms and is often developed later in life. Most motor symptoms are caused by a lack of the neurotransmitter, dopamine, primarily within the substantia nigra of the basal ganglia, but also other areas of the brain (Kalia & Lang, 2015; Goberman, Coelho, & Robb, 2001). Three primary motor characteristics of PD include Tremors, bradykinesia and muscle rigidity while non-motor symptoms include, but are not limited to, sleep disorders, cognitive dysfunction, anxiety, dysautonomia, pain and fatigue (Tysnes & Storstein, 2017; Huang et al., 2017; braak, Del, Rub, de Vos, Steur, & Braak, 2003). As the second most common neurodegenerative disorder, following Alzheimer's disease, PD affects between 139-172 men and 81-117 women per 100,000 individuals between the ages of 65-74 years old (Kalia & Lang, 2015; Blin et al., 2015).

Currently the etiology of PD is unknown, and forms of prevention have not yet been identified. However, Kalia and Lang (2015) explain the possibilities of genetic and environmental factors, such as exposure to chemicals and toxins, playing a key role in the cause of PD. Kalia and Lang (2015) also state in many cases PD is often present for years before an official diagnosis is made. Typically, a diagnosis of PD will rely on the manifestation of a combination of motor, speech, emotional, and cognitive deficits (Adams & Fröhlich, 2017). PD can be particularly difficult to accurately and consistently diagnose since many symptoms overlap and are common among other neurodegenerative and non-neurodegenerative diseases.

Hypokinetic dysarthria (HD) is the term used to describe the speech of many individuals with PD, which can often be identified by weak voice, roughness, hoarseness, tremulousness, breathiness, festinating speech rate, and difficulty getting speech started, (Goberman, Coelho, & Robb, 2001; Skodda, 2011). HD is present among nearly 70% of those with PD (Hartelius & Svensson, 1994). Speech changes as a result of HD impact the intelligibility of these individuals (Feenaughty, Tjaden, & Syssman, 2014). Speech intelligibility refers to the degree to which an individual's acoustic signal is understood by the listener (Weismer, 2008). As a result of degraded speech intelligibility, listeners find it challenging to comprehend the speech of individuals with HD. Degraded speech intelligibility in individuals with HD stems from deficits in one or more of the speech dimensions of respiration, phonation, resonance, articulation, prosody, and speech rate (Forrest, Nygaard, Pisoni, & Siemers, 1998; Ramig, Fox, & Sapir, 2004). In order to understand the nature of speech intelligibility in individuals with PD, a brief review of the deficits associated with each of these six speech dimensions is presented below.

CHAPTER II

LITERATURE REVIEW

Speech rate

Speech rate is one of the primary speech deficits discussed in the literature related to HD secondary to PD (HDSPD). Therefore, it is an important measure used to understand speech intelligibility. Studies employing perceptual measures have found abnormal speech rate in individuals with PD, which has a bearing on their speech intelligibility. Tjaden, Sussman, and Wilding (2013) examined the effects of clear, slow, and loud speech in 32 healthy control individuals, 16 with PD, and 30 with Multiple Sclerosis. The researchers found that clear speech had the strongest relationship with the perception of increased speech intelligibility for the PD group in comparison to the other two groups. Canter and Van Lancker (1985) had listeners rate the speech intelligibility of an individual with HDSPD. They observed that listeners judged participants to have higher speech intelligibility when reading than when speaking spontaneously, indicating that reading tasks decreased the participant's speech rate, thus increasing the speech intelligibility as well. Yorkston and Beukelman (1981) found similar results in a study of intelligibility of dysarthric speech. Among 20 dysarthric participants, listeners perceived speakers to have more intelligible speech when reading than when conversing spontaneously. Based on the above studies, it is clear that when individuals with PD speak at a lower speech rate, their speech intelligibility is perceived to be better.

Articulation

With regard to articulation, researchers have focused on the acoustic and kinematic aspects of articulation rather than the perceptual aspects in individuals with HDSPD. Vowel space area has been routinely used to examine articulatory capacity in individuals with HDPSD. This measure is typically used as a measure of vowel production (e.g., Goberman & Elmer, 2005; McRae, Tjaden, & Schoonings, 2002). Relative to PD, prior studies have reported a significantly smaller vowel space area in this population in comparison to healthy control speakers (Tjaden et al., 2013; Tjaden & Wilding, 2004; Whitfield & Goberman, 2014). For example, Whitfield and Goberman (2014) studied habitual and clear speech in 12 individuals with PD in comparison to 10 neurologically healthy adults. The speech samples were acoustically analyzed and perceptually rated for clarity. Results revealed that participants with PD were rated to have decreased speech intelligibility in comparison to controls. Similarly, the vowel space area was significantly lower in participants with PD than the control group. Across the speaking conditions, people with PD were found to have better speech intelligibility and increased vowel space area during the clear speech condition. This suggests that when required, individuals with PD are able to manipulate their articulatory system to improve their speech intelligibility.

Tykalova et al., (2017) investigated the patterns and degree of consonant articulation deficits across different voiceless and voiced stop plosives, as well as the perceptual phonetic contrast between voiceless and voices plosives. All the participants produced a series of speech tokens "CVtka" including the consonants /p/, /t/, /k/, /b/, /d/ and /g/. The vowels were /a/, /ɪ/ and /u/. The results suggested the individuals with PD more poorly produced voiced plosives, /b/, /d/, /g/, as well as voiceless plosives, /p/, /t/, /k/ compared to the healthy control groups.

Phonation

Quality of phonation/vocal intensity is one of the primary measures that has been studied extensively in individuals with PD and commonly presents as decreased, breathy, harsh, and hoarse in this population (Coutinho et al., 2009; Sapri et al., 2007). Reduced volume is one of the primary characteristics of speech discussed in the literature to have an effect on speech intelligibility in PD. Phonation deficits in PD are often clinically observed and in some cases may even be an initial feature of PD (Ramig, Sapir, Countryman, Pawlas, Hoehn, Thompson, 2001). As part of a larger study that compared the phonatory characteristics before and after medications in individuals with PD, Goberman, Coelho, and Robb (2002) described the phonatory characteristics of 9 individuals with PD and compared it to 8 healthy controls. The participants were involved in vowel prolongation, reading, and speaking tasks. These speech samples were recorded for purposes of acoustic analysis. Results of the overall acoustic analyses revealed that fundamental frequency variability in vowels and mean fundamental frequency was higher, and vocal intensity range was lower in PD participants compared to the controls. This indicates the physiological variability of the phonatory system in individuals with PD. From a perceptual perspective, Parveen and Slaten (2019) compared the perception of speech of 5 individuals with PD and 5 healthy controls. The listeners included young, middle, and older-aged adults who were naïve to Parkinsonian speech. The listeners rated the speakers' monologue based on six speech variables including loudness. Results indicated that listeners found it challenging to perceive the speech of individuals with PD based on the perceptual variables including loudness. In summary, the above studies point to the underlying phonatory deficits in individuals with PD and its potential impact on their speech intelligibility.

Prosody

Prosody is described as the emphasis on syllables, changes in tempo or timing, changes in pitch and intonation, tone, loudness, and duration of speech (Pell, Cheang, & Leonard, 2006; Lloyd, 1999). These features combined allow people to express emotions, attitudes, and thoughts to listeners and are crucial across all languages for communicating feelings, such as happiness, anger, sadness, and excitement (Pell et al., 2006). Pitch (fundamental frequency), loudness, duration of speech, phonemic stress, and contrastive stress are vocal parameters typically affected in the early stages of PD causing dysprosody (Pell et al., 2006; Breitenstein et al., 2001). Overall, it is suspected that prosody is one of the many speech characteristics reducing the speech intelligibility among those with PD (Kempler & Van Lancker, 2002).

Anand and Stepp (2015) assessed speech naturalness and monopitch among 16 speakers with PD. Naïve listeners, with no speech language pathology background, were selected to rate the speakers' monoptich, speech naturalness, and speech intelligibility. Results indicated that while monopitch and speech intelligibility were only moderately correlated, monopitch and speech naturalness were highly correlated. Although prosody is seldom targeted as a primary treatment goal for improving speech intelligibility, it should be noted that individuals with PD do find it challenging to express their emotional intent with appropriate prosody markers, which may cause listeners to perceive their communicative intentions inaccurately, and thus have a bearing on their speech intelligibility (Pell et al., 2006).

Respiration

There is limited research on respiration patterns in individuals with PD. Most of the studies have used kinematic measures to study the breathing patterns in this population. Studies done thus far suggest that changes in speech breathing within the PD population consist of shorter utterances, higher and/or lower lung volume initiations and terminations, and greater inconsistencies of respiratory movements (Sabaté et al., 1996; Weiner et al., 2002; Haas et al., 2004). Compared to their same aged peers, those with PD usually have smaller vital capacity and weaker inspiratory and expiratory muscles as a result of PD (Huber & Darling-White, 2017). Dyspnea is the term used to describe when an individual experiences shortness of breath and although it is not a complaint among people with PD, it is a common perceptual feature in the speech of people with PD (Weiner et al., 2002). Research investigating the perception of speech intelligibility as a result of respiratory abnormalities in individuals with PD has not received attention thus far. The synchronous relationship between phonatory and respiratory system in speech production may make it difficult for the listeners to isolate the role of respiratory deficits on speech intelligibility, which may explain the limited research in this area.

Resonance

Resonance deficits in individuals with PD are primarily manifested as hypernasality (Duffy, 2013). Research regarding the presence of hypernasality in PD is still at its infancy. Findings vary greatly regarding whether or not hypernasality is actually prevalent in those with PD. Due to the presence of bradykinesia in most people with PD, Rusz et al., (2016) hypothesized that bradykinesia disturbances cause limited soft palate control among those Resonance deficits in individuals with PD are primarily manifested as hypernasality (Duffy, 2013). Research regarding the presence of hypernasality in PD is still at its infancy. Findings vary greatly regarding whether or not hypernasality is actually prevalent in those with PD. Due to the presence of bradykinesia in most people with PD, Rusz et al., (2016) hypothesized that bradykinesia disturbances cause limited soft palate control among those with PD. Decreased control of the soft palate may then result in an incomplete velopharyngeal seal, leading to air leakage when producing oral phonemes, thus causing hypernasality. While some say nasality is one of the main speech subsystems affected in people with PD (Ludlow &

Basich, 1983), others report nasality to have little, if any, change (Logemann et al., 1978). For example, Novotny et al., (2016) performed perceptual analysis of hypernasality among 25 speakers with PD. Each participant completed a freely spoken monologue about their family, work, or interests and was instructed to speak for approximately two minutes. These speech samples were rated by speech-language pathologists for hypernasality on a graded scale (0 = normal nasality to 3 = severe hypernasality). Perceptual analysis revealed increased hypernasality among a majority of the participants. The researchers suggested that although the hypernasality may not be detected acoustically, there is a strong possibility of perceiving hypernasality in individuals with PD. The relationship between hypernasality and speech intelligibility in individuals with PD remains to be thoroughly explored. It remains unknown whether resonance is one of the primary speech subsystems affecting the speech intelligibility among those with PD.

The above studies have furthered our understanding of the effect of the aforementioned six speech dimensions on speech intelligibility in individuals with PD. However, a major shortcoming of these studies is that they did not consider the relative impact of each of these six speech dimensions on speech intelligibility. While it is beyond doubt that speech intelligibility is a byproduct of effective interaction of all the six speech dimensions, it is also important to note that not all of these six dimensions impact speech intelligibility equally in individuals with PD. So, it is critical to investigate the unique contributions of each of these six speech dimensions towards speech intelligibility in individuals with PD. Enhancement of speech intelligibility has been one of the primary goals of speech treatment techniques for individuals with PD (Anand & Stepp, 2015). Currently, practicing speech-language pathologists tend to work on speech intelligibility in individuals with PD based on their speech symptoms (Kalf et al., 2008). However, instead of solely relying on the speech symptoms to decide the treatment approach, an ideal approach to treat speech intelligibility would be to consider the weighted impact of these speech symptoms on speech intelligibility and treat the speech dimension(s) that tend to have a maximum impact of speech intelligibility (Duffy, 2013). This line of research has ramifications for evidence-based practice in Speech-Language Pathology, as it would help practicing speech-language pathologists to decide what speech dimension(s) should be treated first to maximize speech intelligibility in individuals with PD.

There has been limited literature that has sought to explain the magnitude of each of the six speech dimensions on speech intelligibility of individuals with PD. Considering the above limitation, the current study aimed to identify the weighted impact of each of the six speech dimensions (respiration, phonation, resonance, articulation, prosody, and speech rate) on speech intelligibility in individuals with PD. The research question that we intended to answer was: what are the weighted and relative contributions of each of the six speech dimensions, including respiration, phonation, resonance, articulation, prosody, and speech rate on the speech intelligibility of individuals with PD? The outcomes of the current study are likely to offer baseline data on what goals should be considered first when focusing on speech intelligibility in individuals with PD.

CHAPTER III

METHODOLOGY

Participants

A total of 25 individuals (17 males & 8 females) diagnosed with PD in the age range of 65 - 90 years (*M* = 73.4 years) participated in the current study. The participants were recruited through convenience sampling from the Parkinson's disease Foundation within the state of Oklahoma. The participant inclusion criteria were: (1) a formal diagnosis of PD, (2) over 50 years of age, (3) a score of >25 on the Montreal Cognitive Assessment (MoCA), (4) self-identified concern (or identified by a family member) of degraded speech intelligibility, (5) speech features that warrant a diagnosis of hypokinetic dysarthria secondary to Parkinson's disease or Parkinsonism, (6) ability to sustain attention for about 10-15 min., (7) ability to follow simple 1-2 step verbal commands, (8) native English speaker, and (9) using aided amplification if they were to have hearing loss. Attempts were made to recruit individuals equally across mild, moderate, and severe stages of PD (Tjaden & Wilding, 2011). Thirty-six individuals volunteered to participate in the study, but three were excluded due to other factors and medical diagnosis affecting their speech other than PD, seven were excluded due to achieving a MoCA score below 25, and one was excluded as the participant was a non-native English speaker. For the perceptual listening task, 25 speech- language pathology graduate students at Oklahoma State

University participated as listeners. All graduate students had completed the motor speech disorders course and 19 graduate students had previous experience with a family member or client(s) who had PD. The demographic information of the participants is presented below in Table 1.

Procedure

Speaking Task

The experiment was conducted in a room space that was free of visual and auditory distractions. As part of the experimental task, the participants read the grandfather passage. This passage contains 99 monosyllabic words and 33 multisyllabic words and has a wide combination of phonemes that encourage a variety of articulatory movements from the participant (Tjaden & Wilding, 2011). Caution was exercised to ensure that participants read the passage at their habitual speech rate. Previous research has suggested an effect of the stimulus on speaking outcomes and for this reason the researcher chose to use just the reading task as it represented a minimal cognitive burden for the speakers (McLain, 2018). The passages were recorded using a digital voice recorder with a microphone-to-mouth distance of 12 cm for the purpose of analyses.

Perceptual Task

The recorded speech samples from the participants were presented to semi-trained listeners in a randomized fashion. The listeners were graduate students in a speech-language pathology program. Listeners rated each perceptual dimension using a direct magnitude estimation (DME) scale. Weismer and Laures (2002) described DME as providing a more comprehensive tool for speech intelligibility compared to percentage estimates. Before the perceptual experiment started, all participants underwent a short training session in order to familiarize them with the concept of speech intelligibility and how each speech dimension can affect speech intelligibility. Participants were provided with three perceptual anchors of speech samples of individuals with HDSPD. The severity of these three perceptual anchors ranged from mild to severe. The participants were instructed to focus on how each of the six speech dimensions affected the speech intelligibility in the three speech samples. Following the training session, the participants debriefed their observations with the researcher. Prior to the start of the perceptual experiment, all listeners were instructed to attend to each speech sample and rate the impact of each aspect of speech rate, articulation, prosody, phonation, respiration, and resonance on speech intelligibility. Each of these six speech dimensions were required to be rated with a visual analog scale, which was a number from 0 to 100, to represent the impact of each of the six speech dimensions on speech intelligibility (Weismer & Laures, 2002). A modulus of 0 indicated that the speech dimension impacted the speech intelligibility to a maximum extent. and a modulus of 100 indicated did not compromise the speech intelligibility. The raters completed the listening experiment at their own pace and listened to each speech sample as many times they needed before they indicated their response. Each speech sample was approximately 40 sec. in duration. The specific instruction that was provided to each participant was "You will be hearing 25 speech samples. Your goal is to listen carefully to each speech sample and indicate the extent to which each of the six speech dimensions affects the speech intelligibility by moving the modulus. You can listen to speech samples as many times as you want". At the end of the listening experiment, the responses were entered into an excel spreadsheet by the researcher for data analysis.

Statistical Analysis

All statistical analyses were performed using SPSS v. 26. Both descriptive statistics and parametric statistics were employed. The descriptive statistics yielded mean, range, and standard deviation. For parametric statistics, the perceptual data from all the 25 listeners who rated the six speech dimensions for the 25 participants were subjected to a one-way analysis of variance

(ANOVA). To test the assumption of homogeneity of variance for the current data set, Levene's test for equal variances was performed. The alpha level was set at 0.05 for significance testing.

Reliability measurement

The intra-rater measurement reliability was calculated by randomly remeasuring 15% of the perceptual ratings (i.e. 4 of 25 speakers) (e.g. Anand & Stepp, 2015) and performing an intraclass correlation coefficient (ICC) based on a mean-rating ($k=2$), absolute-agreement, 2-way mixed-effects model. Mean estimation along with 95% confidence intervals was reported. Interpretation was as follows: <0.50, poor; between 0.5 and 0.75, fair; between 0.75 and 0.90, good; above 0.90, excellent (Perinetti, 2018). The average ICC for the inter-rater reliability was excellent at 0.982 (0.923-0.985) ($p < 0.05$).

CHAPTER IV

RESULTS

The results are presented based on the differences in perceptual ratings across the six speech dimensions and the weighted contributions of each of the six speech dimensions towards the participants' speech intelligibility.

Results of the Levene's test for equality of variance revealed that the assumption of homogeneity of variance was not violated, $F(5,144) = 0.658$, $p = 0.656$. The results of the one-way ANOVA indicated that there was a statistically significant difference between the perceptual ratings across the six speech dimensions, $F(5,144) = 3.495$, $p < 0.05$. Post hoc analysis using Tukey's HSD test revealed that the perceptual ratings for prosody ($M = 55.01$, $SD = 15.05$) and speech rate ($M = 51.08$, $SD = 18.65$) were significantly more impaired than articulation ($M = 68.56$, $SD = 19.62$). There were no significant differences across the other speech dimensions. The perceptual ratings for all the six speech dimensions across 25 participants with PD are visually illustrated in Figure 1.

CHAPTER V

DISCUSSION

It is well known that speech intelligibility is a multi-dimensional construct and is influenced by the synchronous interaction of many speech dimensions. Some of the common speech dimensions that are referenced in the literature that contribute to speech intelligibility include respiration, phonation, resonance, prosody, speech rate, and articulation (Ramig, Fox, & Sapir, 2004). Despite this, the weighted impact of each of these speech dimensions on speech intelligibility has not received attention from researchers. Interestingly, the current findings provide information on how semi-trained listeners perceive the speech of individuals with PD. The current study aimed to investigate the magnitude of each of the six dimensions of respiration, phonation, resonance, articulation, prosody, and speech rate on speech intelligibility in individuals with PD. The results indicated that articulation received statistically higher perceptual ratings in comparison to speech rate and prosody. These findings suggest that listeners perceived speech rate and prosody to negatively impact the speech intelligibility in comparison to the other four speech dimensions.

De Bodt, Hernández-Díaz Huici, and Van De Heyning (2002) mentioned that intelligibility is expressed by a linear combination of weighted single speech dimensions that indicated the relative impact of each of these dimensions. To test this assumption, the researchers played 79 dysarthric speech samples to two experienced listeners.

These listeners perceptually evaluated the speech dimensions of vocal quality, articulation, nasality, and prosody using a 4-point rating and the overall speech intelligibility using GRBAS 3-point rating scale (0-being normal; 3-clear and severe disorder in articulation, nasality, voice, and prosody). A multiple regression analysis was carried out to evaluate the relationship between the speech dimensions as well as to the speech intelligibility. The results indicated that articulation was highly correlated with overall speech intelligibility (0.82) and prosody was not correlated (0.55). With regard to weighted ratings for each speech dimension, the listener ratings suggested that articulation (47%) was considered to be the most dominant dimension, followed by the voice quality (27%), prosody (19%), and nasality (5%). The findings of the current study are in partial agreement with the findings of De Bodt et al. In the current study, the listeners weighed articulation to positively impact the speakers' speech intelligibility. However, unlike De Bodt's findings, prosody (and speech rate) were weighed to influence speech intelligibility in a negative direction.

Anand and Stepp (2015) investigated the effect of listeners' perception of monopitch on speech naturalness and speech intelligibility. The results revealed that monopitch was moderately correlated with speech intelligibility. While the researchers did not ask the participants to weigh the isolated contributions, they did find that monopitch, impacts the speech intelligibility, which corresponds to the findings of the current study to some extent. The discrepancy between De Bodt et al. and the current study in weighing the impact of prosody can be attributed to the languages spoken by the participants of both the studies. Participants in De Bodt et al.'s study spoke Dutch as their primary language, whereas participants in the current study were native English speakers. It is possible that the Dutch speakers weigh the magnitude of prosody on speech intelligibility differently than English speakers.

Interestingly, there were no statistical differences between other speech dimensions. However, on a descriptive note, resonance and phonation were weighed to be enhance speech intelligibility behind articulation. These findings shed light on how semi-trained listeners perceive the speech of individuals with PD. Although the acoustic literature on speech deficits in PD indicates a preponderance of evidence on articulatory and phonatory deficits (Rusz, Cmejla, & Tykalova, 2013; Ho, Iansek, Mariglia, Bradshaw, & Gates, 1999), surprisingly, these were not perceived to impact the speech intelligibility in the current study. So, this begs the question: why did the listeners in the current study rate prosody and speech rate to negatively impact speech intelligibility over other speech dimensions? Before answering this question, it worthwhile to point out that there is minimal to no relation between acoustic and perceptual measures of speech of individuals with PD. Lowit, Dobinson, Timmins, Howell, & Kröger (2010) found that improvements in speech rate of individuals with PD as indicated by acoustic measurements do not translate to the perceptual domain.

Although there is a plethora of research on articulatory and phonatory deficits in individuals with PD using acoustic measures, it is possible that they do not transfer over to the perceptual environment. In the current study, as listeners were exposed to dysarthric speech prior to the experiment, it is plausible that they were comfortable to perceive the segmental speech characteristics more clearly over suprasegmental characteristics. This could explain the reason that why listeners considered the suprasegmental aspects (prosody and speech rate) to be negative markers of speech intelligibility over the other segmental speech aspects. In summary, the findings of this study present some novel information on how the speech dimensions are perceived by the listeners, and this can have a bearing on clinical practice in speech-language pathology.

Limitations

While the current study does present some interesting findings, it is not without limitations. First, the sample size was relatively small and was drawn through convenience sampling. This affects the generalization of current findings. Second, not all the listeners had interacted with individuals with dysarthria. This could have affected the perceptual ratings of the six speech dimensions. Finally, the current study did not consider the differences in speech patterns between male and female speakers. The socio-phonetic differences between male and female participants in experiments are well established (Robb, Gilbert, & Lerman, 2005). This could have had a bearing on the results.

Conclusion

The findings of the current study suggest that prosody and speech rate should be considered as one of the primary treatment goals to improve speech intelligibility in individuals with PD. Anecdotal as well as experimental reports have shown that prosody and speech rate-based approaches hold promise to improve speech intelligibility in individuals with PD (Liss, 2007, McLain, 2018). Practicing speech-language pathologists should document the outcomes of treatment approaches that focus on speech rate and prosody. Such practice-based evidence is likely to strengthen the treatment approaches for suprasegmental features in individuals with PD.

REFERENCES

Adams, W., & Fröhlich, H. (2017). High-accuracy detection of early Parkinson's Disease multiple characteristics of finger movement while multiple characteristics of finger movement while typing. *PLoS ONE, 12*(11), E0188226.

Anand, S. & Stepp, C. E. (2015). Listener perception of monopitch naturalness, and intelligibility for speakers with Parkinson's disease. Journal of Speech, Language, and Hearing Research, 58, 1134-1144.

Braak, H., Del Tredici, K., Rub, U., de Vos, R. A., Jansen Steur, E. N., & Braak, E. (2003). Staging of brain pathology related to sporadic parkinson's disease. *NeurobiolAging*, 24, 197-211.

Blin, P., Dureau-Pournin, C., Foubert-Samer, A., Grolleau, A., Corbillon, E., Jove, J., Lassalle, R., Robinson, P., Poutignat, N., Droz-Perroteau, C. and Moore, N. (2015). Parkinson's disease incidence and prevalence assessment in France using the national healthcare insurance database. *European Journal of Neurology*, 22: 464-471.

Breitenstein, C., Van Lancker, D., Daum, I., & Waters, C. (2001). Impaired perception o vocal emotions in Parkinson's disease: Influence of speech time processing and executive functioning. *Brain and Cognition*, 45, 277-314.

Canter, G. J., & Van Lancker, D. (1985). Disturbances of the temporal organization of speech following bilateral thalamic surgery in a patient with Parkinson's disease. *Journal of Communication Disorders*, 18, 329-349.

Coutinho, S. B., Diaferia, G., Oliveira, G., & Behlau, M. (2009). Voice and speech of individuals with parkinson's disease during amplification, delay and masking situations. PRO-FONO: *Revista De Actualizacao Cientifica, 21*(3), 219-225.

Duffy, J. (2012). Motor Speech Disorders. 3rd rev. ed. St. Louis: MO; Elsevier Mosby.

Feenaughty, L., Tjaden, K. & Sussman, J. (2014). Relationship between acoustic measures and judgments of intelligibility in Parkinson’s disease: A within-speaker approach. *National Center for Biotechnology Information, 28*(11), 857-878.

Forrest, K., Nygaard, L., Pisoni, D. B., & Siemers, E. (1998). Effects of speaking rate on word recognition in parkinson's disease and normal aging. *Journal of Medical Speech-Language Pathology, 6*(1), 1-12.

Goberman, A., Coelho, C., & Robb, M. (2001). Phonatory characteristics of Parkinsonian speech before and after morning medication: The on and off states. *Journal of Communication Disorders*, *35*(2002), 217-239.

Goberman, A. & Elmer, L. W. (2005). Acoustic analysis of clear versus conversational speech in individuals with Parkinson disease. Journal of Communication Disorders, 38(3), 215-230.

Haas, B. M., Trew, M., & Castle, P. C. (2004). Effeccts of respiratory muscle weakness on daily living function, quality of life, activity levels, and exercise capacity in mild to moderate Parkinson’s disease. *American Journal of Physical Medicine and Rehabilitation*, *83*(8), 601-607.

Hartelius, L. & Svensson, P. (1994). Speech and swallowing symptoms associated with parkinson’s disease and multiple sclerosis: A survey. *Folia Phoniatr,* 46, 9-17

Ho, A. K., Iansek, R., Marigliani, C., Bradshaw, J. L., & Gates, S. (1999). Speech impairment in a large sample of patients with Parkinson’s disease. *Behavioural neurology*, *11*(3), 131-137.

Huber, J. E., & Darling-White, M. (2017). Longitudinal changes in speech breathing in older adults with and without parkinson's disease. *Seminars in Speech and Language*, *38*(3), 200.

Huang, J., Zhuo, W., Zhang, Y., Sun, H., Chen, H., Zhu, P., Pna, X., Yang, J., & Wang, L. (2017). Cognitive function characteristics of Parkinson's disease with sleep disorders. *Parkinson's Disease*, vol. 2017, no.

Kalia, L. V. & Lang, A. E. (2015). Parkinson's disease. *The Lancet, 386*(9996), 896-912.

Kalf, H., Swart, B., Bonnier-Baars, M., Kanters, J., Hofman, M., Kocken, J., Miltenburg, M., Bloem, B., Munneke, M. (2011). Guidelines for speech-language therapy in Parkinson's disease. ParkinsonNet/National Parkinson Foundation.

Kempler, D., & Van Lancker, D. (2002). Effect of speech task on intelligibility in dysarthria: A case study of Parkinson's disease. Brain and Language, 80, 449–464.

Liss, J. M. (2007). Perception of dysarthric speech. Motor speech disorders: Essays for Ray Kent, 187-219.

Lloyd, A. J. (1999). Comprehension of prosody in Parkinson's disease. *Cortex*, 35, 389-402.

Logemann, J. A., Fisher, H. B., Boshes, B., Blonsky, E. R., (1978). Frequency and co-occurrence of vocal tract dysfunctions in the speech of a large sample of Parkinson patients. *Journal of Speech and Hearing Disorders,* 43:47–57

Lowit, A., Dobinson, C., Timmins, C., Howell, P., & Kröger, B. (2010). The effectiveness of traditional methods and altered auditory feedback in improving speech rate and intelligibility in speakers with Parkinson's disease. *International Journal of Speech-Language Pathology*, *12*(5), 426-436.

Ludlow, C. L. & Basich, C. J., (1983). The results of acoustic and perceptual assessment of two types of dysarthria. In: Berry WR, ed. Clinical dysarthria. San Diego: College-Hill Press, 121–154.

McLain, N. (2018). Perceptual evaluation of speech intelligibility of individuals with Parkinson's disease following speech rate modification through altered auditory feedback. Thesis, (M.S.). Oklahoma State University.

Novotny, M., Rusz, J., Čmejla, R., Růžičková, H., Klempíř, J., & Růžička, E. (2016). Hypernasality associated with basal ganglia dysfunction: Evidence from Parkinson's disease and Huntington's disease. PeerJ, 4, e2530.

Parveen, S. & Slaten, A. (2019). Effects of aging on speech perception of individuals with and without Parkinson disease. Clin Arch Communication Disorders, *4*(2), 72-82.

Pell, M. D., Cheang, H. S., & Leonard, C. L. (2006). The impact of Parkinson's disease on vocal-prosodic communication from the perspective listeners. *Brain and Language*, *97*(2), 123-134.

Perinetti, G. (2018). Sta Tips Part V: The adjustment of the P value in the context of multiple comparisons. South European Journal of Orthodontic Dentofacial Research, *5*(2), 20-21.

Ramig, L. O., Sapir, S., Countryman, S., Pawlas, A. A., O'Brien, C., Hoehn, M., & Thompson, L. L. (2001). Intensive voice treatment (LSVT ®) for patients with Parkinson's disease: A 2 year follow up. *Journal of Neurol Neurosurg Psychiatry,* 71, 493-498.

Robb, M., Gilbert, H., & Lerman, J. (2005). Influence of gender and environmental setting on voice onset time. Folia Phoniatrica et Logopaedica, 57(3), 125-133.

Rusz, J., Cmejla, R., Tykalova, T., Ruzickova, H., Klempir, J., Majerova, V., ... & Ruzicka, E. (2013). Imprecise vowel articulation as a potential early marker of Parkinson's disease: Effect of speaking task. *The Journal of the Acoustical Society of America*, *134*(3), 2171-2181.

Rusz, J., Tykalova, T., Klempir, J., Cmejla, R., & Ruzicka, E. (2016). Effects of dopaminergic replacement therapy on motor speech disorders in Parkinson's disease: Longitudinal follow-up study on previously untreated patients. *Journal of Neural Transmission,* 123, 379–387.

Sabaté, M., González, I., Ruperez, F., & Rodríguez, M. (1996). Obstructive and restrictive pulmonary dysfunctions in Parkinson's disease. *Journal of Neurological Sciences*, *138*(1-2), 114-119.

Skodda, S. (2011). Aspects of speech rate and regularity in Parkinson's disease. Journal of Neurological Sciences, 310, 231-236.

Tjaden, K., Sussman, J. E., & Wilding, G. E. (2013). Impact of clear, loud, and slow speech on scaled intelligibility and speech severity in Parkinson's disease and Multiple Sclerosis. *Journal of Speech, Language, and Hearing Research*, 57, 779-792.

Tjaden, K. & Wilding, G. E. (2004). Rate and loudness manipulations in dysarthria: Acoustic and perceptual findings. *Journal of Speech, Language, and Hearing Research, 47*(4), 766-783.

Tjaden, K. & Wilding, G. E. (2011). Speech and pause characteristics associated with voluntary rate reduction in Parkinson's disease and Multiple Sclerosis. *Journal of Communication Disorders*, *44(*2011), 655-665.

Tykalova, T., Rusz, J., Klempir, J., Cmejla, R., & Ruzicka, E. (2017). Distinct patterns of imprecise consonant articulation among Parkinson's disease, progressive supranuclear palsy, and multiple system atrophy. *Brain & Language*, *165*(2017), 1-9.

Tysnes, O. B. & Storstein, A. J. (2017). Epidemiology of Parkinson's disease. *Journal of Neural Transmission*, *124*(8), 901-905.

Weiner, P., Inzelberg, R. Davidovich, A. Nisipeanu, P., Magadle, R., Berar-Yanay, N., & Carasso, R. L. (2002). Respiratory muscle performance and the perception of dyspnea in Parkinson's disease. *Canadian Journal of Neurological Sciences*, *29*(1), 68-72.

Weismer, G. & Laures, J. S. (2002). Direct magnitude estimates of speech intelligibility in dysarthria: Effects of a chosen standard. *Journal of Speech, Language,and Hearing Research*, 45, 421-433.

Weismer, G. (2008). Speech intelligibility. In M.J. Ball, M. Perkins, N. Müller, & S. Howard (Ed.), The Handbook of Clinical Linguistics (pp.568-582).Oxford, UK: Blackwell Publishers.

Whitfield, J. A. & Goberman, A. M. (2014). Articulatory-acoustic vowel space: Application to clear speech in individuals with Parkinson's disease. *Journal of Communication Disorders*, 51, 19-28.

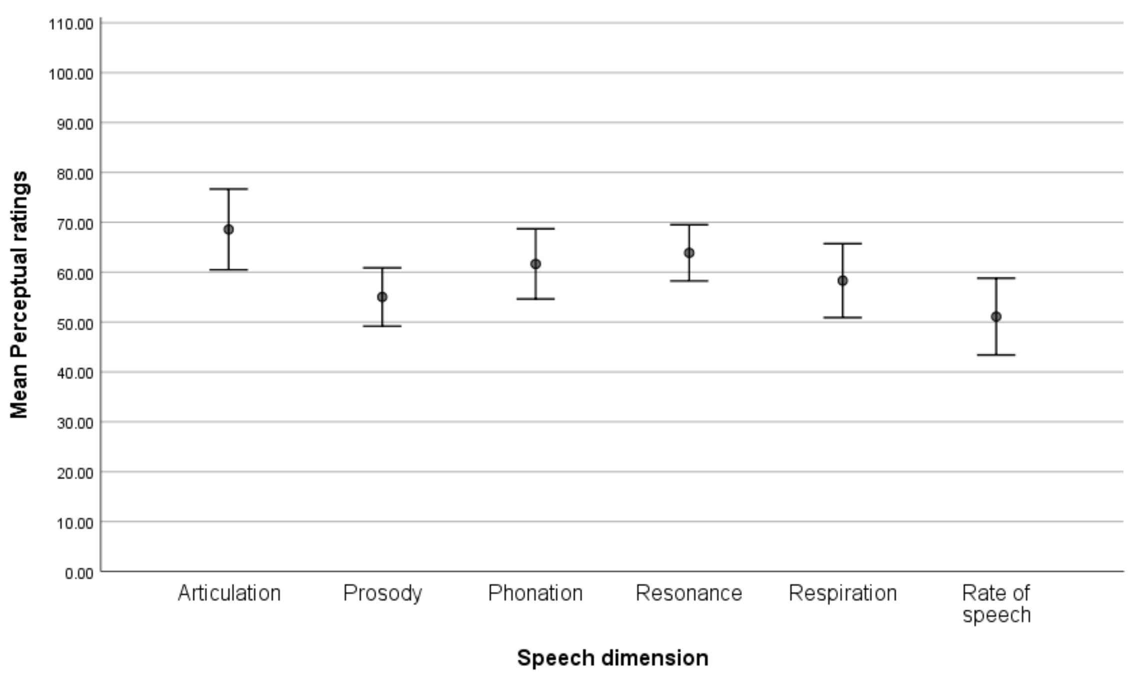
Yorkston, K. M. & Beukelman, D. R. (1981). *Assessment of intelligibility of dysarthric speech*. Tigard, OR: C.C. Publications

Table 1: Demographic information of the participants

Parameter	Mean (range)
Number of participants	*N* = 25 (17 men, 8 women)
Age (years)	73.4 (65 - 90 years)
Age at onset of PD	65.72 (46 – 88 years)
Mean duration of disease since diagnosis	7.8 years (1-21 years)
UPDRS III Motor Section	26.56 (7 – 46)
MoCA	27.52 (25 – 30)
Self-assessment of PD severity	2.34 (1; mild -4; severe)

PD, Parkinson's disease; UPDRS, unified Parkinson's disease rating scale; MoCA, Montreal cognitive assessment.

Figure 1. Mean perceptual ratings across six speech dimensions for the 25 participants with PD. Error bars indicate 95% confidence intervals. Lower scores indicate more impact while higher scores indicate minimal impairment.



VITA

Corina Theresa Hernandez

Candidate for the Degree of

Master of Science

Thesis: PROFILING PREDICTORS OF SPEECH INTELLIGIBILITY IN INDIVIDUALS WITH PARKINSON'S DISEASE

Major Field: Communication Sciences and Disorders

Biographical:

Education:

Completed the requirements for the Master of Science in Communication Sciences and Disorders at Oklahoma State University, Stillwater, Oklahoma in May, 2020.

Completed the requirements for the Bachelor of Science in Communication Sciences and Disorders at Oklahoma State University, Stillwater, OK in 2018.