PERCIEVED SPEECH SEVERITY ON PROSODIC DISTURBANCE IN SPEAKERS WITH PARKINSON'S DISEASE

by

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THE EFFECT OF PERCIEVED SPEECH SEVERITY ON PROSODIC DISTURBANCE IN SPEAKERS WITH PARKINSON'S DISEASE

A Thesis for the Degree Master of Science

by

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ABSTRACT

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Purpose: To determine if speakers with PD who are perceptually rated as exhibiting moderate-to-severe prosodic impairment exhibit different levels of fundamental frequency variation, as measured using F_o CV, compared to speakers with PD who are perceptually rated as exhibiting less severe prosodic impairment. Also, this study investigated whether male speakers with PD exhibit different levels of F_o CV compared to healthy older male controls.

Method: Recordings from 29 speakers with PD were available for prosodic speech severity ratings which determined group membership (e.g., less severe or more severe) while another three recordings, totaling 32 speakers with PD, were available for acoustic analysis to measure the dependent variable of Fo CV. Existing recordings from 21 HOA speakers were also utilized. The recordings utilized in this study consisted of participants producing two speech tasks: (1) oral reading of the CAPE-V sentences, and (2) oral reading of The Rainbow Passage. The middle sentences (the 2nd, 3rd, and 4th sentences) from the Rainbow Passage were used for data analysis. The third CAPE-V sentence, "We were away a year ago", was used for the sentence analysis.

Results: For the perceptually less severe group the statistical findings indicated greater prosodic variability on the CAPE-V sentences compared to the perceptually more severe group. For the comparison of Fo CV as a function of PD vs. HOA male speakers, results suggested that male speakers with PD exhibited significantly less prosodic variability compared to the HOA male in both CAPE-V sentence and Rainbow passage stimuli speakers. Findings of this study also indicated that perceptual severity had a moderate degree of relationship to acoustic measures of prosodic variability for the CAPE-V sentences in speakers with PD

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Overview of Parkinson's Disease

Parkinson's disease (PD) is defined as a progressive neurological disease which results from a loss of dopamine-producing receptors in the central nervous system (Lew, 2007). PD involves the degeneration of the nigrostriatal pathway, one of the major dopamine pathways in the brain, and a corresponding reduction of dopamine receptors in the striatum (Obeso et al., 2010). Although PD is regularly thought of as a motor disease marked by the cardinal features of resting tremors, hypokinesia, rigidity, and postural instability, many patients will also develop non-motor problems which contribute to a reduced of quality of life (Obeso et al., 2010). Non-motor problems associated with PD include breakdowns in cognitive skills, olfactory dysfunction, sleep abnormalities, and depression (Obeso et al., 2010).

James Parkinson described a syndrome in 1817 that was associated with involuntary tremulous motions and weakened muscle tone, when in action and even with support. He noted that with these motor problems, senses and intellect remained unaffected. His findings led to what we know refer to as PD (Bartkes & Leenders, 2009). Since the first description, knowledge of the pathology and clinical markers of PD have expanded. In addition to Dr. Parkinson's research, Friedrich Heinrich Lewy advanced our knowledge of PD with his discovery of Lewy bodies in 1912. Lewy bodies are abnormal collections of proteins that develop within nerve cells, eventually causing cell death. Lewy bodies are now considered distinctive clinical markers of idiopathic Parkinson's disease (Bartles & Leenders, 2009). They are found within the substantia nigra of the basal ganglia and within peripheral neurons controlling skeletal muscles and autonomic pathways.

PD is the second most common occurring neurological disease after Alzheimer's disease. PD is typically diagnosed in older individuals, occurring in about 1% of individuals aged 60 years or older and then growing to about 4-5% of those aged 85 years or older (Lew, 2007). Patients with PD often report a marked decrease in their quality of life and increased health expenses (Blin et al., 2015). It is estimated that PD affects 3% of the population worldwide (Lew, 2007), which means that 7-10 million people above the age of 50 are living with PD (Mahanjan et al., 2016). In the United States alone, 1 million Americans have PD and 60,000 new cases are diagnosed each year. Studies have concluded that PD diagnoses are on the rise and it is expected that the number of individuals living with PD will double by 2030 (Mahajan et al., 2016). Along with the rise of PD diagnoses comes accompanying increase of heath care costs and a growing demand on physicians, caregivers, and the United States healthcare systems at large (Mahajan et al., 2016).

Gender, Race, and Phonotype in Parkinson's Disease

PD epidemiological studies on gender differences have reported men receiving a diagnosis of PD more often than women. However, there are limited studies on clinical manifestations of PD associated with those gender differences (Song et al., 2014). Studies have identified that women tend to present with later age at onset and are diagnosed with the PD motor subtype of tremor dominant more often than males (Song et al., 2014). A study conducted in 2014 by Members of the Chinese Parkinson Study Group, investigated the demographic information of newly diagnosed PD patients by looking at motor and non-motor symptoms, specifically looking at measurements comparing male and female patients (Song et al., 2014). Differences found on motor subtypes displayed no statistical significance. Non-motor symptoms however, indicated marked differences between males and females. Females were found to be diagnosed at a higher frequency with depression. In addition, typically the female's depression was considered to be "more severe". They also performed worse on cognition assessments when compared to their male counterparts. PD research needs more information on gender differences. Specifically, how disease progression and medication affect males vs. females (Song et al., 2014).

Recently, gender differences have gained increased attention, as they have been noted as important indicators of both the susceptibility to develop some neurodegenerative diseases, such as PD, and the clinical manifestations and therapeutic management of the disease and its manifestations. A recent study in 2017 conducted by Picillo and colleagues examined 253 subjects and found that women were 2 years older than men at time of onset and were more likely to present with a tremor dominant (67%) form than men (48%). Picillo and her colleagues hypothesized that women may have a more benign phenotype of PD, which could be related to the female's estrogen status. Picillo has also identified that age of onset for PD in women correlated positively with age at menopause and fertile life span (Picillo et al., 2017). Yet, once PD has started, evidence supports that there is a shorter time to develop motor fluctuations and dyskinesia in women than in men, arguing against this theory of protective effect of estrogens (Picillo et al., 2017). The Picillo study found that woman have a median time to dyskinesia of 4 years compared to 6 years in men (Picillo et al., 2017). Picillo also reported that gender may be the most important independent predictor of levodopa-induced dyskinesia, with an increased risk for women when compared to men. In a further review of published research, Picillo et al. concluded that a substantial body of evidence supports the notion that non-motor symptoms develop differently in women and men (Picillo et al., 2017).

Picillo et al. also reported that motor symptoms and cognitive disturbances of PD differ between men and women. Women tend to have a more benign phenotype, meaning that the presentation of their PD symptoms are typically less severe than their male counterparts for motor, non-motor symptoms, and cognition. For example, recent data suggest that dementia prevalence in women with PD began to increase steadily after the age of 65 years, and male estimates only after 80 years of age. However, a women's dementia starts off less severe and then steadily progresses as their PD progresses (Picillo et al., 2017). Although, many studies have gathered evidence to demonstrate the existence of gender differences in PD, there is still more work that needs to be done in order for professionals who work with PD patients to understand the interaction between gender and genetics when determining the clinical manifestations of PD progression.

Few studies in the United States have examined the relationship between race and incidence of PD. Those that exist have yielded contradictory findings most likely due to differences in methods and sampling. The scarcity of incidence data in PD in general has been a result of several factors, mainly in the difficulty of establishing an accurate diagnosis of PD in study participants (Van Den Eden et al., 2002). The first study on race and incidence was conducted by Mayeux et al., who developed a registry of patients with PD in NYC and found that the incidence of PD was more than two times greater in African-American men than white men (Mayeux et al., 1992). However, the authors calculated incidence using the United States census data. The numbers obtained from the census underestimated minority populations, which then inflated Mayeux's numbers for observed incidence of PD among African-Americans (Dahodwala et al., 2009).

A second study looking at the racial differences among PD patients was led by Van Den Eden and was conducted in Northern California. This study drew the conclusion that African-Americans were at a decreased risk of PD. The study had the advantage of reduced bias related to healthcare access since all study participants had the same insurance coverage. However, most of the study participants were wealthier and better educated than the general population, which in turn could have affected the reliability of the results (Dahodwala et al., 2009).

Dahodwala and his colleagues suggested that geographic and financial barriers to healthcare access among African-Americans in both studies and within the population at large could lead to undetected PD among the African-American population (Dahodwala et al., 2009). Both studies used initial identification of PD by community clinicians as a criterion of eligibility, which goes back to the difficulty of accurately diagnosing PD for incidence data within the larger population. Therefore, Dahodwala and his colleagues tried to overcome this difficulty by excluding any individuals with at least one claim for conditions that are common causes of secondary parkinsonism (i.e. stork, schizophrenia, and bipolar disorder were excluded from the cohort) (Dahodwala et al., 2009). The study compared both demographic and clinical characteristics among whites, African-Americans, and Latinos. The sample consisted of forty-sixty-five-year-old Medicaid enrolled participants. This study's results showed that the demographic and clinical characteristics did not significantly affect the risk of PD associated with race (Dahodwala et al., 2009). Although racial differences and PD studies have yielded non-significant results, these studies have presented a need for further research as it relates to the diagnosis of PD in minority populations.

Non-Motor and Motor Complications of PD

Since PD is a neurodegenerative disease, it's clinical diagnosis relies on identification of motor impairments that are a direct result of dopamine deficiency. However, non-motor symptoms are sometimes present before a PD diagnosis, and almost always emerge with disease progression (Chaudhuri et al., 2006). The non-motor symptoms associated with PD include, decreased olfactory function, depression, anxiety, sleep disorders, constipation, and a cognitive impairment may be present depending on the progression of the PD (Wu et al., 2016). Non-motor symptoms have recently received increased interest from researchers because, unlike motor symptoms, non-motor symptoms are often poorly recognized both by patients and physicians. In response to poor identification, these non-motor symptoms are often inadequately treated (Chaudhuri et al., 2006). Non-motor symptoms can manifest in different ways depending on the course of the PD.

The Primary motor complications that arise in PD include, resting tremor, bradykinesia, rigidity, and postural instability. Postural instability is categorized by reduced gait speed, shorter stride length, stooped posture, and reduced arm swing (Warlop et al., 2016). The typical gait disorders in PD can lead to patients having a higher fall risk and therefore certain precautions must be put in to place to limit this risk. In PD, a resting tremor occurs when the person’s muscles are relaxed or at rest. The tremor often occurs in the hand or foot on one side of the body. With disease progression, it usually spreads to the other side of the body. However, the tremor tends to remain most apparent on the side of the body that was initially affected. The resting tremor has become one of the most notable symptoms of PD, but it is important to know that not all people with PD will develop a tremor. Bradykinesia, or slow movement, refers to the reduction of spontaneous movement in PD patients. Bradykinesia often appears as stiffness and can accompany a decrease in facial expression. The bradykinesia in PD often contributes to their decrease in daily living skills, impacting daily living tasks such as getting dressed or brushing their teeth. Rigidity in PD causes stiffness and a reduced range of motion in limbs. PD patients often described the rigidity as uncomfortable or even painful (Parkinson's Disease Foundation.)

Swallowing Impairment in Parkinson's Disease

Swallowing concerns for PD patients include impaired laryngeal excursion, palatal elevation, epiglottic movement, CP sphincter opening, and vocal fold adduction (Ellerston, et al., 2016). These deficits than lead to vallecular and pyriform sinus residue, laryngeal penetration, and aspiration. Ellerston and her colleagues identified through a retrospective study using modified barium swallow studies (MBS) that delayed airway protection and reduced pharyngeal constriction were the most prevalent pharyngeal swallowing abnormalities in PD patients (Ellerston et al., 2016).

Dysphagia in PD is a dangerous consequence that can have a negative impact on patient's quality of life. Unfortunately, the prevalence of PD-related aspiration pneumonia because of disease severity is widely unknown (Kalf et al., 2012). Kalf and his colleagues conducted a meta-analysis and identified that at least one third of PD patients presented with oropharyngeal dysphagia. Kalf noted that esophageal dysfunction, as in slowed esophageal transit or dysfunction of lower esophageal sphincter, may also be the cause for swallowing complaints from PD patients. Although studies have reported that 60-70% of PD patients are diagnosed with esophageal dysphagia, Kalf explains that it is important to be cautious of this number because it is unclear how these numbers were gathered. Much of the information gathered was obtained though questionnaires that made it difficult to differentiate between oropharyngeal and esophageal dysphagia (Kalf et al., 2016). Although swallowing risks and associated health outcomes have been identified for PD patients, it is important to note the need for future research in addressing patient treatment outcomes for swallowing impairments.

Speech Impairment in Parkinson's Disease

Changes in voice and speech affect 70-90% of people with PD. However, the overall impact of PD progression on voice and speech is not well defined. PD's motor symptoms can impair the following subsystems of speech: respiration, phonation, resonance, and prosody (Defazio et al., 2015). Respiratory limitations in PD patients are a result of reduced breath support, affecting a person's ability to produce normal phrases and loudness variations. Phonation is affected when the vocal folds have reduced elongation and unstable or limited adduction, which impacts overall voice quality. At the articulatory level, speech imprecision and resonance imbalance can contribute to lower speech intelligibility.

Prosody is also a feature of speech that is impaired by PD. Skodda and Schlegel conducted a study in 2008 which analyzed speech rate and rhythm in PD (Skodda and Schlegel, 2008). Their analysis included subdividing prosody into the following: speech rhythm and velocity, articulation rate, speech pause ratio, speech intensity, and pitch variation. Speech pauses are reflective of speech velocity which ultimately is regulated by the basal ganglia, therefore PD patients can suffer from abnormalities in speech rate. Skodda and Schlegel identified similarities between disrupted speech rate and difficulties in motor task performance in PD patients. This finding suggests a connection between the impaired time perception and motor planning in PD patients (Skodda and Schlegel, 2008).

"Parkinsonian speech" can result in hypokinetic dysarthria with disease progression. As stated above several subsystems of speech are impacted by PD, including prosody. The dysprosody in PD has been well described and is stated above. Research has indicated that there is a special pattern of speech rate in PD, characterized by an articulatory acceleration in the early stages of the disease, and progressing to a slower rate as the disease severity increases. In addition, Skodda and his colleagues identified that increasing impairments on speech performance tasks were widely varied and seemed to follow an individual basis, indicating, further longitudinal investigation is needed (Skodda et al., 2009).

Not only is dysprosody present in PD patients, but expressive and receptive linguistic prosody is also impaired. Expressive prosody in PD refers to the patient's difficulty in being understood. PD patients often have a difficulty distinguishing between compound nouns and noun phrases, and in producing the rising pitch that distinguishes a statement from a question (Harris et al., 2016). In receptive linguistic prosody, PD patient's fail to recognize prosodically communicated emotion (Harris et al., 2016). It is a known medical phenomenon that music can positively influence the motor patterns and movements of PD patients. Robert Harris and his colleagues hypothesized that positive effects of music on a PD patient's gait was not specific to locomotion, but that it extended to vocal behavior too. Harris and his colleagues investigated whether PD patient's signing would have the same effect as music on movement patterns. They noted that PD patients signing did not seem to suffer from the same prosodic impairments that they experience while speaking (Harris et al., 2016).

STATEMENT OF THE PROBLEM

Despite the identification through research that dysprosody is a negative and persistent feature of PD, evidence is lacking on the ability of PD patients to modulate prosodic attributes to convey linguistic meaning. A study out of McGill University by Marc Pell and his colleagues investigated how dysprosody affected a PD patients' overall communicative intent and reported that dysprosody in PD patients can lead to negative social relationships, since unfamiliar listeners had greater trouble identifying the intended meaning of the PD patients' speech (Pell et al., 2006). Harris noted that although all his study participants with PD were identified as having high levels of intelligibility, the negative effects of dysprosody on successful communication were detectable to unfamiliar listeners (Harris et al., 2016).

The repercussions of impaired communication in PD, specifically what is occurring at the prosodic level, is an area of research in PD that needs further investigation, considering the early overall impact that prosodic abnormalities can have on PD patient's quality of life. The purpose of this study was twofold: (1) to determine if speakers with PD who are perceptually rated as exhibiting moderate-to-severe prosodic impairment also exhibit different levels of fundamental frequency variation as measured in acoustic recordings than speakers with PD who are perceptually rated as exhibiting mild-to-moderate prosodic impairment; and (2) to determine if male speakers with PD exhibit different levels of fundamental frequency variation compared to healthy older male controls

METHODS

Participants

This study utilized existing speech recordings of speakers with Parkinson's disease and healthy older adult (HOA) controls. Recordings from 53 speakers who participated in a previous study were analyzed. Participants with PD were recruited via regional support groups and advertisements. To be eligible, they were required to have a diagnosis of idiopathic PD by a neurologist, and be free of other neurological diagnoses not related to PD. All participants with PD were scheduled for testing at a time during the day when medication was self-reported as most effective. Recordings from 29 speakers with PD were available for prosodic speech severity rating (see below), while another three recordings, totaling 32 speakers with PD, were available for acoustic analysis to measure the dependent variables (see below). Existing recordings from 21 HOA speakers were also utilized. In the previous study, these speakers were recruited from the community and were required to be free of diagnosed neurological disease and speech or voice disorder.

Procedures

<u>Prosodic Severity Ratings:</u> Perceptual speech prosody severity was assessed for recordings of 29 speakers with PD using a magnitude estimation procedure following the protocol of Weismer et al., 2001. Three second-year graduate students were recruited as perceptual judges. Perceptual judges considered their ratings in the context of a definition of prosody provided to them. This definition aligned with that of McNeil, 1997. Specifically, the judges were asked to focus their ratings on "*the suprasegmental aspects of speech, including stress, rhythm, melody intonation, juncture, and rate*". For the magnitude estimation procedure, a perceptual anchor was used

consisting of a speaker with PD manifesting a moderate degree of prosodic impairment. The severity of the perceptual anchor was assigned a rating of 100 by the experimenters, and reflected their perception of a moderate degree of prosodic impairment severity. The perceptual judges used this anchor to rate the rest of the speakers based on the magnitude estimation scale. They were instructed to rate a speaker whom they perceived as twice as severe as the anchor with a rating of 200; one-half severe with a rating of 50; or any number below or above 100 which reflected their perceived severity. The stimulus used for perceptual ratings was recordings of The Rainbow Passage**,** which were obtained from a previous study. For perceptual ratings, the recordings were played free field via a speaker at a comfortable listening level. All recordings were presented in a randomized order with the anchor played approximately every 5 samples for perceptual calibration. Inter-rater reliability was assessed by comparing the strength of relationship between the three scores of each rater for individual speaker recordings.

Speaking Tasks: The recordings utilized in this study consisted of participants producing two speech tasks: (1) oral reading of the CAPE-V sentences, and (2) oral reading of The Rainbow Passage. The middle sentences (the 2^{nd}, 3^{rd}, and 4^{th} sentences) from the Rainbow Passage were used for data analysis. The third CAPE-V sentence, "We were away a year ago", was used for the sentence analysis. This sentence consisted of all-voiced phonemes, whereas the three sentences of the Rainbow Passage consisted of a mix of voiced and unvoiced phonemes, along with intonation and stress markers throughout the various phrases within the Rainbow passage sentences. The CAPE-V sentence was produced three separate times, while the Rainbow Passage was produced once. Recordings were obtained in a quiet room using commercial software associated with the Pentax Computerized Speech Lab (CSL) and a head mounted microphone (AKG Acoustics SM-15). All recordings were obtained using a sample rate of 44,100 Hz.

Analyses: The dependent variable for this study was the F_o coefficient of variation (F_o CV), which reflected the variability of F_o adjustments during speech and thus represented a critical component of prosodic intonation. The F_o CV of variation measure is useful for prosodic analyses because it converts variability in F_o to a percentage of the mean, which helps to "normalize" variability to compare different voice types (e.g., males and females, who have naturally divergent fundamental frequencies). The mean of the three CAPE-V measurements and the mean Rainbow passage measurements were used as the data point for each participant recording. F_o CV was calculated as follows:

- The Real Time Pitch software of the CSL was used to measure mean F_o and the standard deviation of F_o across (a) the entire duration of the CAPE-V sentence, for all three sentences and (2) the entire duration of the middle three Rainbow passage sentences.
- For each CAPE-V sentence (x3) and the Rainbow Passage sentences (these were analyzed together, not separately), F_o CV was then calculated as follows:
  - F_o CV = (F_0 standard deviation)/(mean $F\underline{0}$)×100).

To answer the first research question, two independent sample t-tests were applied to the F_o CV data for the CAPE-V sentence and the Rainbow passage, respectively. In both t-tests, Group membership (less severe PD vs. more severe PD) was the independent variable. As an ad-hoc analysis, the relationship between perceived prosodic impairment severity and acoustic measures of F_o CV in speakers with PD was assessed using a Pearson product-moment correlation. To answer the second research question, a third and fourth independent samples t-test was applied to the F_o CV data for the CAPE-V sentence and the Rainbow passage, respectively, but with PD versus Control as the independent variable. Since this was a pilot study in this line of investigation, the alpha level was set at 0.05 to maintain a reasonable level of statistical power.

RESULTS

Table 1 illustrates demographic information for the speakers with PD speakers utilized in group comparison of less severe vs. more severe based on perceived prosodic severity. Three additional male speakers with PD were included in the group comparison of PD versus HOA control. Demographic information for those speakers is illustrated in Table 2.

Table 1. Demographic information for speakers with PD used in the study for comparisons of prosodic severity. Data indicates means and standard deviations (in parentheses) in years (e.g., years.months).

Group	Sex	Age	Dx Age	Dis. Duration
PD overall	Male n = 16	72.1 (6.4)	68.3 (7.1)	3.7 (2.2)
	Female n = 13	69.8 (10.3)	62.7 (11.2)	6.4 (4.3)
Less Severe	Male n = 8	72.5 (5.8)	68.5 (7.3)	3.9 (2.5)
	Female n = 5	72.5 (8.7)	65.8 (9.2)	3.9 (2.5)
More Severe	Male n = 8	71.6 (7.2)	68.1 (7.3)	3.4 (2.0)
	Female n = 8	65.4 (12.2)	57.8 (13.4)	7.4 (4.9)

Table 2. Demographic information for the speakers used in the comparison of PD male versus HOA control male. Data indicates means and standard deviations (in parentheses) in years (e.g., years.months).

Group	Age	Dx Age	Dis. Duration
PD Male n = 21	72.4 (6.5)	68.2 (7.3)	4.0 (2.4)
HOA Male n = 21	68.6 (7.2)		

As previously discussed, the more severe and less severe groups were based on perceptual severity ratings assigned by judges. The two groups were divided based on mean severity rating scores across the three judges. We used a score of 100 as a dividing line between less severe and more severe. This resulted in 16 speakers with PD assigned to the more severe group, and 13 speakers with PD assigned to the less severe group. Table 3 displays descriptive statistics of the dependent variable for both stimulus contexts. As can be seen, the less severe group manifested greater F_o CV compared to the more severe group in both the CAPE-V sentence and Rainbow passage.

Table 3 also displays means and standard deviations for F_o CV as a function of the PD males and HOA males. The speakers with PD manifested a much smaller F_o CV in the CAPE-V sentence compared to the HOA speakers. The same trend was evident in the Rainbow passage sentences. Smaller measures of F_o CV would indicate less prosodic variability. As such, the descriptive statistics indicated that speakers with PD manifested reduced prosodic variability compared to the HOA speakers. This same interpretation could be applied to the more severe PD speakers, who manifested less prosodic variability compared to the less severe PD speakers.

Table 3. Means and standard deviations (in parentheses) of F_o CV for less severe and more severe prosodic impairment groups, and for PD male and HOA male groups, in both measurement conditions (CAPE-V sentence and Rainbow Passage).

Group	CAPE-V	Rainbow
PD less severe	15% (4.2)	19% (6.9)
PD more severe	11% (4.7)	20% (6.8)
PD male	12% (4.4)	22% (7.5)
HOA male	17% (7.6)	28% (6.1)

Table 4. Means and standard deviations (in parentheses) of effect size, interpretation, and percent differences, in both measurement conditions (CAPE-V and Rainbow Passage) and across group membership (PD Less, PD More, HOA).

CAPE-V				
	M ± SD	Effect size	Interpret	% difference
PD Less (n = 13)	15 ± 4.2	0.92	Large	36.7%
PD More (n = 16)	11 ± 4.7			
Males (n = 21)	12 ± 4.4	0.83	Large	29%
HOA (n = 21)	17 ± 7.6			

Rainbow				
	M ± SD	Effect size	Interpret	% difference
PD Less (n = 13)	19 ± 6.9	0.15	Small	5%
PD More (n = 16)	20 ± 6.8			
Males (n = 21)	22 ± 7.5	0.90	Large	21%
HOA (n = 21)	28 ± 6.1			

To answer the first research question, two independent samples t-tests were conducted to compare the more severe PD group to the less severe PD group. One t-test was applied to the CAPE-V F_o CV data, and the second to the Rainbow passage F_o CV data. For the CAPE-V F_o CV, there was a significant difference between the more severe and less severe groups of participants with PD ($t[1,27] = -2.46$, $p = .020$). There was not a significant difference between the more severe and less severe PD groups on measures of F_o CV in the Rainbow passage ($t[1,27] = 0.034$, $p = .0.74$).

Using the data obtained from the first research questions, a correlational analysis was conducted to compare the relationship between perceptual severity and the CAPE-V F_o CV and

Rainbow Passage F_o CV. The resulting correlation coefficient for CAPE-V F_o CV and perceptual severity was $r = -0.507$, which was statistically significant ($p = 0.005$). The resulting correlation coefficient for Rainbow F_o CV and perceptual severity was $r = -0.13$, which was not statistically significant ($p = 0.49$). Collectively, these findings indicated a significant negative correlation between perceived speech severity and measures of F_o CV from the CAPE-V sentence, but no relationship between perceived speech severity and F_o CV from the Rainbow passage.

To answer the second research question, two independent samples t-tests were conducted to compare the male PD group to the male HOA group. One t-test was applied to the CAPE-V F_o CV data, and the second to the Rainbow passage F_o CV data. For the CAPE-V F_o CV, there was a significant difference between the PD males and HOA males ($t[1,40] = -2.70$, $p= 0.01$). For the Rainbow F_o CV, there was also significant difference between the PD males and HOA males ($t[1,40] = -2.81$, $p= 0.008$). Collectively, these results suggested that male speakers with PD exhibited significantly less prosodic variability compared to the HOA male speakers.

Inter-judge reliability for the perceptual severity scores was calculated by researchers, using the Intraclass Correlation Coefficient. During the severity ratings procedures, the perceptual judges listened to and scored five participant's samples from the Rainbow Passage twice. These five-participant's speech severity rating scores were then used to calculate inter-judge reliability. However, for the final calculation, inter-judge reliability was only computed using the ratings from four of the five participants, ($r= .832$, $p=.003$). The Intraclass Correlation Coefficient reveled a significant positive correlation for inter-judge reliability.

DISCUSSION

The purpose of this study was to determine if speakers with PD who are perceptually rated as exhibiting moderate-to-severe prosodic impairment exhibit different levels of fundamental frequency variation, as measured using F_o CV, compared to speakers with PD who are perceptually rated as exhibiting less severe prosodic impairment. Also, this study investigated whether male speakers with PD exhibit different levels of F_o CV compared to healthy older male controls. For the perceptually less severe group the statistical findings indicated greater prosodic variability on the CAPE-V sentences compared to the perceptually more severe group. Perceptual severity in the speakers with PD did not affect Fo CV in the Rainbow passage. Regarding the comparison of Fo CV as a function of PD vs. HOA male speakers, results suggested that male speakers with PD exhibited significantly less prosodic variability compared to the HOA male in both CAPE-V sentence and Rainbow passage stimuli speakers. Findings of this study also indicated that perceptual severity had a moderate degree of relationship to acoustic measures of prosodic variability for the CAPE-V sentences in speakers with PD.

Acoustically, previous research has shown that decreased Fo and intensity variability are characteristic of prosodic impairments in speakers with PD (Jones 2009, Pell et al., 2016). Previous perceptual studies have also described how the negative effects of dysprosody were detectable to listeners, even though speakers with PD were deemed highly intelligible (Pell et al., 2016). These findings relate to the current study, which found that reduced F_o CV variability was a hallmark of speakers with PD who are perceived to be more severe. That is, the more perceptually noticeable the dysprosody, then the less F_o CV variability in the speech patterns of those with PD. This decreased F_o CV variability aligns with perceptual descriptions of PD speech as mono-pitch. To our knowledge, the present study is the first to study prosodic perceptual severity as a factor correlated to acoustic measures of prosodic variability.

In this study, males with PD and healthy age-matched peers were compared when producing both CAPE-V and Rainbow passage stimuli. The findings suggested that the healthy age-matched peers produced more F_0 CV variability in both measurement conditions compared to male participants with PD. We chose to compare males in this study for several reasons. First, a majority of our existing normal control voice-recordings were males. Secondly, PD may affect males and females differently (Pringsheim et al., 2014). Historically, females experience a lower prevalence of PD than males and often a more benign phenotype characterized by a slower disease progression than males (Haaxma et al., 2007). The differing phenotypes and prevalence of PD suggested that sex was a variable in need of control. Therefore, this study chose to focus on comparing males.

This study looked at prosodic severity using measurements of F_0 CV variability in two different conditions (e.g. the CAPE-V sentences and Rainbow Passage). However, only statistical significance was found on the CAPE-V measurement condition. Interestingly, the perceptual severity ratings were only assigned based on recordings of the Rainbow Passage sample and not on recordings of the CAPE-V sentences. Future studies should consider obtaining perceptual severity ratings from both connected speech stimuli (e.g. CAPE-V and Rainbow Passage). Additionally, adding more participants to the PD sample size could prove further statistical significance to strengthen the results from this study.

Differences in statistical results were observed between the two measurement conditions. However, statistical significance was only observed on the CAPE-V and not on the Rainbow Passage. This finding may have been due to the differences in the contextual makeup of the

CAPE-V vs. the Rainbow Passage. The CAPE-V sentences were constructed using only voiced consonants. However, the sentences making up the Rainbow Passage are phonetically balanced, thus allowing for manipulation of the F_o Co as the speakers moved from voice to unvoiced consonants. This manipulation of F_o Co may have created more variability in the mean F_o Co, the marker for prosody. The large variability in the F_o Co for the Rainbow Passage did not allow for statistical significance, however the trend of the data indicates a potential relationship for prosodic severity and the Rainbow Passage. Future studies with larger sample sizes may be needed to further test this phenomenon.

The implications of this study on clinical practice are exciting. The results of this research demonstrate a statistically significant relationship between perceived prosodic impairment and acoustic measures of prosody in a commonly used clinical stimulus, the CAPE-V sentence "We were away a year ago". When using the CAPE-V sentences, clinicians and professionals working with patient with PD who have a perceived prosodic impairment can measure this dysprosody quantitatively. Professionals and clinicians can use the CAPE-V sentence as a way to gauge the perceived prosodic impairment and its comparison to quantitative measures. This finding offers a potential new way to quantitatively assess gains made during therapeutic techniques like LSVT which is noted to improve a PD speaker's prosody (Ramig et al. 2001). Future studies should continue to look at other measurement conditions in which perceived prosodic severity can be quantitatively measured, which would continue to add to this body of research.

STUDY LIMITATIONS

A number of methodological limitations warrant guarded conclusions from this study. The participant's recordings for this study were obtained from a previous study. This created a limitation in the number and the variety of the participants. Using previously recorded participant samples also created difficulties in controlling for certain personal and health factors. While participants were required to have a diagnosis of PD confirmed by a physician, previous history of speech therapy or enrollment in speech therapy was not controlled for. Prosodic severity ratings were obtained by graduate students who were required to have completed graduate level voice course. However, since prosodic severity was subjectively assessed, it was difficult to control for any additional variables which could have affected the graduate students' knowledge or understanding of prosody. Prosodic severity ratings were also only assigned and given for the Rainbow Passage, therefore the researchers did not control for or assign prosodic severity for both measurement conditions.

CONCLUSION

The findings of this research study indicated a greater prosodic variability on the CAPE-V sentences for the perceptually less severe group. The comparison of Fo CV as a function of PD vs. HOA male speakers indicated male speakers with PD exhibited significantly less prosodic variability compared to the HOA male in both measurement conditions. Overall, the statistical results indicate that perceptual severity had a moderate degree of relationship to acoustic measures of prosodic variability for the CAPE-V sentences in speakers with PD. Having identified this moderate degree of a relationship creates potential for a procedural protocol to be used in clinical practice to assess a listener's perceptual severity rating to quantitative measures, such as Fo CV in the CAPE-V sentences. This procedure could allow clinicians to assess variable change and progress in the dysprosody of PD patients.

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