PERCEPTION OF PARKINSONIAN SPEECH: RATINGS BY SELF AND LISTENERS VS. ACOUSTIC MEASURES

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A Thesis

Submitted to the Graduate College of Bowling Green State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN COMMUNICATION DISORDERS

May 2009

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Parkinson Disease (PD) has been found to have significant effects on speech production, including deficits in phonation and prosody. Studies of self-perception of speech and voice by individuals with PD suggested that individuals with PD may be unaware of their own speech deficits. It was also hypothesized previously that caregivers (or other non-neurologically impaired listeners) would show awareness of the speech deficits associated with PD. However, neither the claim that individuals with PD are unaware of their deficits, nor the claim that caregivers are aware of deficits have been comprehensively examined. The current study examined ten individuals with PD (speakers) their primary caregivers. Individuals with PD completed a paragraph reading and both those individuals and their caregivers were asked to rate the speech across six perceptual measures. Trained listeners also rated the paragraph reading across the same six perceptual measures. Perceptual measures were correlated with acoustic measures, and perceptual measures were studied for significant differences across listener types. Results showed five correlations between trained perceptions and acoustics, three (one meaningful) correlations between self-perceptions and acoustics, and no correlations between caregiver perceptions and acoustics. Across listener type, trained listener perceptions were found to be significantly higher when compared to self-perceptions on three speech characteristics, and were significantly higher than caregiver perception on one speech characteristic. Although no significant differences were found between self-ratings and caregiver ratings, descriptive analysis of the correlation results may indicate caregivers underestimate the effects of PD on speech and voice. Clinical implications are discussed, including the impact this finding may have
on PD patients and caregivers regarding their abilities to seek and attend treatment for speech and voice.
This thesis is dedicated to all caregivers whose frequently undervalued and selfless work helps improve the lives of so many others.
ACKNOWLEDGMENTS

I would like to acknowledge Drs. Alex Goberman, Elizabeth Burroughs, and Rodney Gabel for their invaluable assistance in assembling the manuscript. In addition, I would like to acknowledge Becky Recker and Melissa Maas, as well as the entire BGSU Communication Disorders Master’s class of 2009 for their assistance with reliability measurements, data calculations, and for serving as trained listeners. Finally, I would like to express heartfelt thanks to all participants and individuals who assisted in the recruitment process.
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INTRODUCTION

Parkinson Disease

More than 1 million people in North America are affected by the degenerative neurological condition Idiopathic Parkinson Disease (PD; Lang & Lozano, 1998). With PD, there is a progressive loss of the neurotransmitter dopamine in the brain, primarily in the basal ganglia area known as the substantia nigra (Brodal, 1998; Goberman & Coelho, 2002; Kent, Kent, Duffy, & Weismer, 1998; Lang & Lozano, 1998). This dopamine loss causes the characteristic signs of PD, including both non-speech movement deficits and deficits related to speech sound production (Goberman & Coelho, 2002; Goberman & Elmer, 2005; Lang & Lozano, 1998).

Symptoms

The non-speech motoric symptoms of PD often include muscular rigidity, slow movement (bradykinesia), problems initiating movement (akinesia), and rest tremors (Brodal, 1998). In addition, patients may present with mask-like facial expressions (Pitcairn, Clemie, Gray, & Pentland, 1990). Cognitive abilities can also be affected, with a higher incidence of dementia in individuals with PD compared to those without PD (Lang & Lozano, 1998). Speech and voice may be affected, and these deficits appear in the course of the disease in an estimated 60-80% of those with PD (De Letter, Santens, & Borsel, 2005). In a number of cases, speech or voice deficits can be among the initial presenting signs of PD (Harel, Cannizzaro, Cohen, Reilly, & Snyder, 2004).

PD Speech Acoustics

The speech and voice deficits inherent to PD are typically classified as hypokinetic dysarthria. Hypokinetic dysarthria can include phonatory, articulatory and prosodic dysfunctions.
Phonation is often the most prominently impaired feature of speech in hypokinetic dysarthria in addition to the intrinsic prosodic deficits in PD (Darkins, Fromkin, & Benson, 1988; Goberman, Coelho, & Robb, 2002; Zwirner & Barnes, 1992).

**Phonation**

Phonation is often impaired in individuals with PD (Darley et al., 1969; Goberman & Coelho, 2002; Goberman & Elmer, 2005). The muscular rigidity inherent to PD can affect the vocal folds, ultimately altering the fundamental frequency (F₀) of most individuals with PD (Goberman & Coelho, 2002; Miller, Noble, Jones, & Burn, 2006). Specifically, researchers have found elevated F₀ when individuals with PD performed reading, monologue and vowel prolongation tasks (e.g., Canter, 1963; Doyle, Raade, St. Pierre, & Desai, 1995; Holmes, Oates, Phyland, & Hughes, 2000; Metter & Hanson, 1986). Canter (1963) examined 17 males with PD in an effort to describe the characteristics of PD speech. From a reading of the Rainbow Passage, 50 ms samples were analyzed with an oscillograph for measures of F₀ central tendency and F₀ variability. Measures of F₀ levels were consistently higher from the 17 males with PD when compared to F₀ levels from control participants. More recently, Holmes et al., (2000) performed an acoustic comparison of the speech of 60 individuals with PD (30 early stage PD and 30 late stage PD) and 30 without PD. Speaking tasks consisted of vowel prolongations, scale singing, and a monologue. Audio recordings were analyzed acoustically on eleven speech sound characteristics. Analysis yielded a higher F₀ specifically in males with PD (Holmes et al., 2000).

The lack of stability of PD speech can also be seen in the increased variability of F₀ during vowel prolongations (e.g., Goberman et al., 2002; Hertrich & Ackerman, 1995; Holmes et al., 2000; Kent, Kim, Weismer, Kent, Rosenbek, Brooks & Workinger, 1994). Goberman et al.,
(2002) examined nine individuals with idiopathic PD during medication on and off states. Multiple vowel prolongations were elicited from each participant, over a series of three sessions (one off- and two on-medication states). During both the off- and on-medication states, acoustic analysis revealed increased $F_o$ variability in individuals with PD compared to age-matched control participants (Goberman et al., 2002).

In addition to $F_o$ changes, individuals with PD often exhibit deficits in the intensity of the voice. Many studies have noted a decrease in speaking intensity for individuals with PD (e.g., Countryman & Ramig, 1993; Holmes et al., 2000). Countryman and Ramig (1993) studied one individual with PD after receiving a bilateral thalamotomy. During this study, acoustic analysis revealed a lowered speaking intensity in the individual during sentence readings and reading of the Rainbow Passage compared to normative intensity values for individuals without PD (Countryman & Ramig, 1993). In their study of 60 individuals with PD, Holmes et al., (2000) also performed acoustic measures of intensity, and found lower than normal intensity values for individuals with PD compared to normal controls (Holmes et al., 2000). One theory on reduced speech volume production was presented by Solomon and Hixon (1993), who indicated muscular rigidity contributed to the problem, since the individual’s respiratory structures do not move as freely and with as much amplitude as before being affected by PD. However, other researchers also indicate that lowered vocal intensity may be attributed to loss of drive to respiratory and laryngeal structures (Fox, Morrison, Ramig, & Sapir, 2002). A third theory suggests that reductions in vocal intensity may result from deficits in volume self-perception of the voice in individuals with PD (Ho, Bradshaw, & Iansek, 2000). Overall, individuals with PD exhibit deficits in speech intensity, and it is unclear whether physiological or psychological factors have a greater degree of influence in lowering vocal intensity.
In summation, current research suggests phonatory characteristics of PD speech are affected in three general ways. First, the $F_o$ is typically increased when compared to control speakers. $F_o$ stability is typically affected, with a decreased stability of $F_o$ than in normal controls. Finally, intensity is decreased in the speech of individuals with PD.

**Prosody**

Prosody can be defined as the normal variations in intensity and rhythm (i.e., rate and pause) of speech, along with normal variations in fundamental frequency. Abnormal prosody (i.e., dysprosody) is a well-known and common effect associated with PD (Caekebeke et al., 1991), and can include deficits in pausing (e.g., Darkins et al., 1988), rate, and $F_o$ variability during speaking tasks (e.g., Goberman et al., 2002; Ludlow, Connor, & Bassich, 1987; Metter & Hanson, 1986).

In individuals with PD, rate has been examined through measurement of both speech rate (syllables/second) and articulation rate (syllables/second after removal of pauses). The speech rate findings have been variable, with some finding individuals with PD exhibiting faster than normal speech rates (e.g., Ackermann, Konczak, & Hertrich, 1997; Flint et al., 1992), some finding slower than normal speech rates (e.g., Ludlow et al., 1987), and others finding no difference in speech rates (e.g., Canter, 1963; Metter & Hanson, 1986). Flint et al. (1992) examined rate of speech in a study comparing individuals with PD to control speakers and speakers with major depression. An acoustic comparison was made between the speech of 30 individuals with PD and 31 control speakers. On one out of four sentence readings, the individuals with PD exhibited faster rates of speech than did controls. However, this difference was not statistically significant.
Ludlow et al., (1987) examined speech rate in 12 PD patients and 12 controls. Individuals in both groups were instructed to produce sentences and syllables at both a regular and fast rate. Both control speakers and individuals with PD were able to change their speaking rate, but the individuals with PD tended to be slower than control speakers. In addition, Goberman, Coelho, & Robb (2005) found slower than normal speech rates in 8 of 9 participants producing a monologue, however this also was not a statistically significant difference. Metter and Hanson (1986) found a wide range of speaking rates in their PD participants, ranging from slow to fast. Further, this variability was not related to disease severity or duration. This variability may serve as a possible explanation for the contrasting speech rate results, with PD speaking rate being a highly variable measure, both across and within participants.

Specific to the articulation rate (rate with pauses removed) of individuals with PD, findings are also mixed, with reports of either no change in articulation rate (Goberman et al., 2005; Nishio & Nimii, 2001), or an increased articulation rate (McRae, Tjaden, & Schoonings, 2002; Solomon & Hixon, 1993). Nishio and Nimii (2001) examined 72 speakers with varying types of dysarthria. Japanese speakers were recorded using a standard passage known as “The north wind and the sun.” Eight participants with hypokinetic dysarthria exhibited no significant change in articulation rate compared to control subjects. In addition, Goberman et al. (2005) found articulation rate to be no different than control speakers in both medication on-states and medication off-states. Regarding increased articulation rate, McRae et al., (2002) examined 13 individuals with PD who were reading a standard passage. Analysis revealed generally faster articulation rates for males with PD when compared to healthy controls. However, there was a slight increase in articulation rate for female controls when compared to the rate of females with PD (McRae et al., 2002). The cause of this gender difference is unknown.
Although pausing can be considered a component of speech rate, pausing has also been examined alone, with mixed results. Flint et al., (1992) examined pausing in a study of 30 individuals with PD and 31 controls. During speaking tasks including sentence readings, paragraph reading, and readings of emotionally-loaded content passages, pausing was found to be no different in individuals with and without PD (Flint et al., 1992). Conversely, others have found an increased pause time in individuals with PD compared to control speakers (Goberman et al., 2005; Torp & Hammen, 2000). Torp and Hammen (2000) studied 14 individuals with PD, and 14 controls completing a reading task. An across group comparison showed individuals with PD exhibiting not only a greater number of pauses, but also a greater percent pause time. A possible explanation for timing deficits in PD (including rate and pausing) is that individuals with PD may have deficits in their internal time-keeping device (Graber, Hertrich, Daum, Spieker & Ackermann, 2002). This time-keeping deficit could lead to changes in syllable length and pause durations.

Along with speech rate, articulation rate, and pausing changes, reduced $F_o$ variability in speaking tasks can be another aspect of dysprosody in PD. Because $F_o$ variability is typically used to signal semantic meaning, emotional content, and word stress (Pell, Cheang, & Leonard, 2006), reductions in $F_o$ variability may contribute to decreased intelligibility. In general, individuals with PD exhibit a decreased prosodic $F_o$ variability (Goberman et al., 2005; Holmes et al., 2000; Metter & Hanson, 1986). Metter and Hanson (1986) examined 8 males with PD during a reading task, and completed comparisons between these individuals with PD and matched controls. They reported a significant decrease in $F_o$ variability for the individuals with PD. Interestingly, they also reported that there were a number of cases where mean $F_o$ values were normal in comparison to those of controls; however, there were abnormal $F_o$ variations
Based on reading and monologue tasks, Goberman et al. (2005) found that 9 of 9 participants produced decreases in $F_o$ variation compared to controls. The variation in $F_o$ has also been examined in a speaker’s ability to produce the semantic distinction between questions and statements. A rising intonation contour (i.e., rising $F_o$) typically signals a question, and several reports have demonstrated that PD speakers are impaired in the production of these contours (Kegl, Cohen, & Poizner, 1999; Le Dorze et al., 1992; Penner et al., 2001). Penner et al., (2001) instructed individuals with PD to read sentences in angry, questioning, and descriptive manners. Flatter intonation peaks were found in the speech of PD subjects when compared to the speech of controls across the semantically varied sentences.

Studies of intensity variation in PD speech do not appear to be as comprehensive or conclusive as those of other PD speech characteristics. Metter and Hanson (1986) studied seven males with PD during a reading of the Grandfather Passage. Results indicated individuals with severe dysarthria exhibit decreased intensity variation when compared to controls. However, individuals not in the “severe” category produced intensity variation comparable to controls (Metter & Hanson, 1986).

Overall, prosodic features of PD speech are less clearly defined than phonatory characteristics. Speech rate of individuals with PD has been found to be increased, decreased, and not changed when compared to speech rate of control speakers. Articulation rate and percent pause time of PD speakers has been found to be increased or not changed when compared to those measured in control speakers. A reduced $F_o$ variability has been noted in individuals with PD, while studies of intensity variability have been less conclusive.
PD Speech Listener Perception

Darley et al., (1969) rated 32 individuals with PD on 38 different perceptual speech characteristics. This study is regarded in the field as one of the classic studies of perceptual characteristics of dysarthric speech. To examine their perceptions of Parkinsonian (i.e., hypokinetic) speech, Darley et al. (1969) listened for a series of phonatory characteristics including both pitch and intensity levels, along with the prosodic characteristics of rate, pausing, and pitch and intensity variation. More recently, Bunton, Kent, Duffy, Rosenbek, and Kent (2007) carried out a similar study by having two groups of listeners (experienced and inexperienced) rate the speech of 10 individuals hypokinetic dysarthria due to PD. The same 38 speech characteristics were examined, and results from both listener groups yielded agreement with the findings of Darley et al. (1969). Both studies found that the defining perceptual characteristics of PD included both phonatory and prosodic deficits.

Phonation

Although acoustic studies have found that \( F_o \) levels are increased in individuals with PD (Canter, 1963; Holmes et al., 2000), the perceptual analysis by Darley et al. (1969) found a lower pitch associated with hypokinetic dysarthria. In addition, Pell et al. (2006) noted the speech of individuals with PD is often perceived as “sad,” due to a perceived lower pitch. Along with a perception of decreased pitch, individuals with PD can also be perceived by others as having decreased loudness. A case study of an individual with PD receiving a bilateral thalamotomy included perceptual ratings by speech-language pathologists (Countryman & Ramig, 1993). The perceptual ratings characterized the individual as having a lower speaking volume compared to normative control data. Similarly, a perceptual study by Holmes et al. (2000) showed that listeners perceived a lower speaking loudness in PD participants, with a greater impairment in
loudness during the later stages of the disease. A report of one individual with PD, noted by Miller et al. (2006), addresses listeners’ perception of vocal loudness in PD, by saying “I feel as if I am shouting, but you can see it on peoples’ faces, they haven’t heard what you’re saying,” (Miller et al., 2006, p.237). This supports the notion that listeners perceive a decreased speaking intensity for individuals with PD. In short, when listening to PD speech, individuals appear to perceive a lower pitch and decreased loudness when compared to non-disordered speakers.

Prosody

Although acoustic findings have indicated that rate is either increased or decreased for individuals with PD, findings of perceptual studies have generally reported increased rate in PD. Relative to perceptual changes in rate associated with PD, Darley et al. (1969) noted that short rushes of speech and an overall increase of rate were distinctive features of hypokinetic dysarthria. The perceptual component of the study by Flint et al. (1992) also found increased rate in individuals with PD. In addition to rate, Darley et al. (1969) also examined pausing in individuals with hypokinetic dysarthria, and listeners perceived inappropriate silences to be a distinctive feature of hypokinetic dysarthria.

Studies have shown that non-disordered listeners find the linguistic-prosodic features of PD speech (i.e., linguistic pitch variation) to be deviant (e.g., Blonder, Gur, & Gur, 1989; Caektebeke et al., 1991; Cheang & Pell, 2004). Darley et al. (1969) also found monopitch to be a commonly perceived characteristic of PD speech. The absence of the pitch variation to signal word-stress and semantic meaning may leave the listener with faulty perceptions of the speaker’s message. Pell et al., (2006) noted that emotionally loaded productions (anger, disgust, and happiness) by PD patients were difficult to interpret, and were said to be “neutral” by listeners, with the speech lacking vocal inflection. This demonstrates how dysprosody and abnormal pitch
contours may lead the listener to falsely interpret the emotional content of the PD speaker’s message.

Along with the reduction in pitch variation, intensity variation has been perceived as decreased or narrowed (Darley et al., 1969; Holmes et al., 2000). The study by Holmes et al., (2000) had listeners rate the speech of individuals with early- and late-stage PD. Perception of loudness variability for the early-stage group showed a more decreased or narrowed intensity range than for the late-stage group. However, acoustically it was shown the late-stage group had a lower mean intensity standard deviation. Data for controls was not provided for these measurements in this study, making it difficult to determine how these findings relate to the perception of normal speech. Darley et al., (1969) also indicated that when listeners perceived parkinsonian speech, monoloudness was one of the most prominent characteristics identified.

To summarize, research suggests listeners of PD speech perceive an increased speech rate to that of non-disordered speech. Inappropriate silences or increased pauses are also perceived by listeners. In addition, listeners often perceive decreased pitch variation and intensity/loudness variations when compared to control speakers.

PD Speech Self Perception

While a number of studies focusing on perception of listeners are reviewed above, studies focusing on self-perception of parkinsonian speech are less common. A study of self-perception of dysarthria in individuals with PD by Yorkston, Bombardier, and Hammen (1994) found that PD patients may not be completely aware of their deficits and difficulties arising from PD. In addition, a more thorough understanding of the weaknesses in self-perception is of clinical relevance for a number of reasons. Medical issues signaled by vocal changes may go unnoticed due to impaired self-perception. Also, impaired self-perception may affect self-referral for
speech and voice treatment. Identifying the specific ways in which self-perception is affected may help clinicians and caregivers increase understanding of the effects PD has on speech.

**Phonation**

Previous acoustic research suggests that individuals with PD exhibit decreased voice intensity compared to control speakers. Further, individuals with PD have been shown to have an impairment in volume self-perception (Fox & Ramig, 1997; Ho et al., 2000). In a study of 30 individuals with PD, Fox and Ramig (1997) performed a comparison of measured vocal sound pressure level (SPL) versus self-perception of loudness in individuals with PD. They found self-perception of impaired loudness to correlate with a reduced SPL in individuals with PD. This implied that self-perception was fairly accurate for speech volume self-perception. However, Fox and Ramig (1997) go on to state that when asked about their loudness, a common reply from some individuals with PD was that their loudness was “fine”. Taking into account general statements from the individuals with PD such as the one above, the ultimate results from the Fox and Ramig (1997) study are not definitive as to whether individuals with PD are impaired in volume self-perception.

Supporting a self-perception deficit in individuals with PD, a study by Ho et al. (2000) also showed that individuals with PD overestimated their own speech volume when subjected to a self-rating task. Ho et al. (2000) examined three groups of participants with PD (15 total), and three groups of control subjects without PD (15 total). Individuals both with and without PD were instructed to read a passage loudly, another group was instructed to read a passage quietly, and a third group was given no instruction, suggesting a normal speaking volume. All participants were asked to rate their speaking volume immediately after speaking, and after listening to a recording of the reading. Mean volume measurements indicated individuals with
PD consistently estimated their voices to be louder than did controls in both perceptual ratings. Overall, results from previous research appear to be mixed regarding volume self-perception accuracy in individuals with PD.

The study of self-perception of PD speech has centered primarily on perception of loudness. The main conclusions from these studies are that individuals with PD, when surveyed, often report their vocal intensity has decreased, with some reporting their loudness as fine. However, when these individuals are tested in an actual speaking task, it appears these individuals overestimate their own speech intensity production.

**Prosody**

Acoustic studies have found that prosodic aspects of speech production are impaired with PD; however, a lack of consistency is present for self-perception of these deficits. Self-perception of prosody in PD has not been effectively studied. The research that most closely approximates self-perception of prosody focuses on having individuals with PD perceive prosody in the speech produced by others. Studies have found prosody and lexical stress comprehension of others’ speech to be an area of difficulty for PD subjects (Blonder et al., 1989; Lloyd, 1999; Scott, Caird, & Williams, 1984). Based on this, one can make the prediction that individuals with PD may also be impaired in perceiving prosodic aspects of their own speech.

Additionally, Benke, Bosch, and Andree (1998) suggest that cognitively intact individuals with PD may not have any impairment in the perception of prosodic characteristics. However, they further suggest that perceptual deficits do exist in cognitively impaired individuals with PD (Benke et al., 1998). Breitenstein, Van Lancker, Daum, and Waters (2001) suggest a relationship between working memory dysfunctions and perception of emotional prosody in individuals with PD. This study also implied mental abilities have effects on prosodic
perception. Findings from these studies owe to the importance of cognitive state scores for individuals with PD when studying perception. Whereas other studies have considered the inability to produce normal prosody in PD as solely a motoric deficit independent from mental state (e.g., Ackermann & Ziegler, 1991; Hertrich & Ackermann, 1995), the above results suggest that self-perception deficits may also play a role in PD prosodic deficits. Nevertheless, existing research has focused primarily on the abilities of individuals with PD to perceive prosodic characteristics of other individuals, not self-perception of their own prosodic characteristics.

Research on self-perception of rate is limited. Graber et al., (2002) studied ten individuals with PD and ten controls. They played recorded samples of the German word “Boten” to all participants. The recorded samples had different durations between the /o/ and /t/, creating word-medial silence. Individuals with PD were less accurate at perceiving these durations than were controls. From the results of Graber et al. (2002), it is suggested PD disturbs an internal timing mechanism. The implication is that this could impair speech rate perception. Previous studies have indicated the slowing of an internal clock, controlled by dopamine (Graber et al., 2002; Lange et al., 1995; Pastor, Artieda, Jahanshahi, & Obeso, 1992). Pastor et al., (1992) showed that once an individual with PD received a dose of levodopa, their internal clock speed increased, suggesting their self-perception of speech rate would become more accurate. Goberman et al. (2005) suggested that the PD speaker may produce longer pauses, but due to the slowed internal clock, the speaker may perceive the pause as of a normal length. In addition to this previous work examining internal timing in individuals with PD, more research must be conducted to determine how these internal timing deficits may affect self-perception of rate and pausing.

In review, the existing research on self-perception of prosody in PD speech is limited primarily to studies of individuals with PD perceiving the prosodic characteristics of normal
speakers. Some of this research suggests individuals with PD are impaired at perceiving the prosody produced by others, including the articulation rate. However, other research has suggested individuals with PD are only impaired at such tasks when they present with cognitive impairment. See Table 1 for a summary of current research.

TABLE 1: Summary of acoustic features, including fundamental frequency (F₀), intensity, fundamental frequency standard deviation (F₀SD), and rate, in addition to listener perception and self-perception of PD speech compiled from current research.

<table>
<thead>
<tr>
<th>Acoustics</th>
<th>Listener Perception</th>
<th>Self Perception</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phonation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₀ ↑d (Goberman et al., 2002)</td>
<td>Pitch ↑d (Holmes et al., 2000)</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Pitch ↓d (Darley et al., 1969)</td>
<td></td>
</tr>
<tr>
<td>Intensity ↓d (Fox et al., 2002)</td>
<td>Loudness ↓d (Countryman &amp; Ramig, 1993)</td>
<td>Impaired (Fox &amp; Ramig, 1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accurate (Miller et al., 2006)</td>
</tr>
<tr>
<td><strong>Prosody</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₀ SD ↓d</td>
<td>Inflection ↓d (Pell et al., 2006)</td>
<td>?</td>
</tr>
<tr>
<td>Rate ↑d (Ackermann et al., 1997)</td>
<td>Rate ↑d (Bunton et al., 2007)</td>
<td>? – Probably impaired due to internal clock changes (Graber et al., 2002)</td>
</tr>
<tr>
<td>Rate ↓d (Ludlow et al., 1987)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No change (Metter &amp; Hanson, 1986)</td>
<td></td>
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</table>

Summary and Research Goals

Overall, speech production deficits have been extensively studied in individuals with PD, while listener-perception and self-perception have not been as comprehensively studied. Previous authors have stated that individuals with PD may underestimate deficits in their speech and voice relative to others’ perceptions; however this has not been comprehensively examined. Given the fact that perceptual deficits may cause some individuals with PD to fail to seek
services despite speech deficits, this study aims to examine self-perception relative to caregivers’ perception and acoustic features of speech. The specific goals of this study are as follows:

1. Describe self-perception of voice and speech of the individuals with PD, the perception of his/her primary caregiver, and acoustic measurements of that speech.

2. Compare self-perception with caregiver-perception, and describe any relationships that may exist. It is predicted that individuals with PD will underestimate their deficits compared to their caregivers, based on limited work examining self-perception in individuals with PD.

3. Compare self-perceptions and caregiver-perceptions to trained listener perceptions, and describe any relationships that exist. It is predicted that the caregivers’ perceptions would be more closely aligned with trained listeners’ perceptions compared to individuals with PD.

4. Compare self-perception, caregiver-perception and trained listener perception with acoustic features of speech production, and describe any relationships or patterns that may exist. It is unknown how self-perception will relate to acoustic features, however limited evidence suggests that other listeners will be accurate with perceiving PD speech.
METHODS

Participants

Ten pairs of participants were recruited for this study, each pair consisting of an individual with PD, and his/her spouse. Nine participant pairs were males with PD (assigned to the role of speaker) and their female wives (assigned to the role of listener). One participant pair consisted of a female with PD (assigned to the role of speaker) and her male husband (assigned to the role of listener). Participants with PD ranged in age from 58 to 75 years old (Mean=65.8). The duration of disease since time of diagnosis ranged from 2 to 20 years (Mean=8.4). All pairs of participants lived with one another for a minimum of 24 years. All participants reported and exhibited (as judged by the researcher) hearing and vision abilities sufficient for the one-on-one testing situation. Four speakers reported receiving speech and language services at some point prior to the current study, and none of the caregivers received any speech or language services. Sex, duration of disease since diagnosis and history of speech-language services were not used as exclusionary criteria for this study due to the original research intent to examine “how” the individuals with PD and their caregivers perceive PD speech versus “why” they perceive PD speech.

To be included in the study, participants had to score above 123 (max raw score=144) on the Dementia Rating Scale-2 (DRS-2; Mattis, 2004), indicating no more than mild cognitive impairment per the test scoring guidelines. Cognitive level was controlled for based on findings by Breitenstein et al. (2001), indicating that cognitive dysfunctions may impair prosodic perception. Participants were recruited through the Northwest Ohio Annual Parkinson’s Symposium, previous speech studies and local support groups. See Table 2 for details on all participants.
TABLE 2: Description of participants with PD, including medical diagnosis, sex, age (individual with PD and caregiver), disease duration, Dementia Rating Scale-2 (DRS-2) score, and hypokinetic dysarthria rating.

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Diagnosis (Caregiver Diagnosis)</th>
<th>Sex (Caregiver Sex)</th>
<th>PD Age (Caregiver Age)</th>
<th>Disease Duration</th>
<th>DRS-2 Score</th>
<th>Hypokinetic Dysarthria Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>71 (67)</td>
<td>3</td>
<td>133</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>2</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>65 (64)</td>
<td>16</td>
<td>136</td>
<td>Moderate-Severe</td>
</tr>
<tr>
<td>3</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>60 (57)</td>
<td>8</td>
<td>137</td>
<td>Severe</td>
</tr>
<tr>
<td>4</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>58 (53)</td>
<td>7</td>
<td>141</td>
<td>Mild</td>
</tr>
<tr>
<td>5</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>71 (69)</td>
<td>7</td>
<td>136</td>
<td>Mild</td>
</tr>
<tr>
<td>6</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>59 (57)</td>
<td>2</td>
<td>143</td>
<td>Mild</td>
</tr>
<tr>
<td>7</td>
<td>PD + ? TBI (None)</td>
<td>Male (Female)</td>
<td>75 (75)</td>
<td>8</td>
<td>126</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>8</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>68 (66)</td>
<td>6</td>
<td>139</td>
<td>Mild</td>
</tr>
<tr>
<td>9</td>
<td>PD (None)</td>
<td>Female (Male)</td>
<td>66 (68)</td>
<td>5</td>
<td>142</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>10</td>
<td>PD (None)</td>
<td>Male (Female)</td>
<td>65 (61)</td>
<td>20</td>
<td>142</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Protocol

Initially, health questionnaires (specific to both speaker and listener) were completed (Appendix B, C), and the paragraph reading and recording followed. Speakers were asked to read the first paragraph of the Rainbow Passage (Fairbanks, 1960) out loud with a self-determined normal speaking voice. The speakers were told they could read it silently first, to make sure they were comfortable with the passage. The reading was recorded using a Shure microphone (Shure SM58) attached to a portable digital audio tape recorder (Sony PCM-M1). In addition to the reading, the speaker was asked to prolong the vowel /a/, perform diadochokinetic repetitions of /pa/, /ta/, /ka/, and /pataka/, and produce the vowels /i, u, a, æ/ each embedded in the phrase “say hVd again.” See appendix D for complete list of speaking tasks. After the reading and speaking tasks, separate listening forms (Appendix E) were then completed by both the speaker and the listener. The DRS-2 was administered last. In addition, the background noise level of the recording location was measured in dB-A using a BK Precision 732 sound level meter.
Background noise levels for all recordings were less than 38 dB-A (mean=34.1; Range=32.4 – 37.8).

**Perception tasks**

Immediately following the reading, both the speaker and listener were handed individual listening forms, and were instructed to complete these forms independently. A Visual Analog Scale (VAS) was selected as the instrument of perceptual measurement of speech and voice characteristics. The VAS consists of a continuous 100mm line upon which individuals may indicate their level of agreement between two characteristics, one at each end of the line (See Appendix E). A study by Grant, et al. (1999) compared the reproducibility and sensitivity to change of the VAS, the Borg scale, and the Likert scale in a study of respiratory and physical fatigue. Results indicated the continuous VAS scale was superior to the fixed-point Borg and Likert scales for both reproducibility and sensitivity to change. In the present study, the speaker and listener were both instructed to place an “x” on the 100 mm line when told to, one line at a time, corresponding to the representation of his/her own perception. Each perceptual rating was later measured and assigned a numerical value of 0-100, corresponding to its location on the line. The six speech characteristics examined included: pitch too low/too high, monotone/excessive pitch variations, talking too quiet/talking too loud, rate too slow/too fast, pauses too short-too few/too long-too many, not at all understandable/completely understandable. A seventh line asked “who talks more”, either the speaker or listener. Brief descriptions of the characteristics were given for pitch, monotone, excessive pitch variations, and rate (See Appendix E).

**Trained Listeners**

In addition to self and caregiver perception ratings, graduate students specializing in speech-language pathology were recruited to provide perceptual ratings and to serve as trained
listeners. All 19 listeners completed a motor speech disorders class during the semester prior to this study. Trained listeners listened to the ten rainbow passage reading samples as well as three repetitions of readings embedded in a random order. Intra-judge reliability was calculated from the repetitions using Pearson Product Moment Correlation (PPMC) analysis, and only the 6 most reliable trained listeners were included in further analysis. For these 6 listeners, Pearson $r$ levels ranged from 0.916 to 0.963, with a mean $r$ value of 0.932. Reliability between listeners was also significant, as Pearson $r$ levels ranged from 0.834 to 0.956, with a mean $r$ value of 0.912. The means of the remaining 6 listeners’ ratings was utilized for statistical comparison to self and caregiver perceptions as well as to acoustic measurements. The inclusion of trained listener perceptions acted as a control for a more objective measurement to which self and caregiver (untrained listener) ratings were compared.

**Acoustic Analysis**

The Rainbow Passage recording was imported into a computer using the KAY CSL 4400 software / hardware package. All acoustic analysis was completed using the PRAAT software package (Boersma & Weenink, 2007). Acoustic measures are listed below.

The phonatory characteristics evaluated included mean fundamental frequency ($F_o$) and mean intensity. The mean $F_o$ was defined as the average fundamental frequency of the speaker’s voice during the recording with all non-speech sounds (e.g. breathing) removed. Mean intensity was defined as the average measurement in dB-A of the speaker’s voice during the passage reading. To calculate mean intensity, a calibration procedure was completed based on the input level of the DAT recorder for each recording.

The prosodic characteristics evaluated included $F_o$ standard deviation ($F_o$ SD), intensity SD, articulation rate, percent pause time and number of pauses. The $F_o$ SD was defined as the
calculated standard deviation of the F₀ values of the speaker during the reading. Intensity SD was
defined as the calculated standard deviation of dB-A values of the speaker’s voice during the
passage reading. Articulation time was defined as the time from the beginning to the end of the
paragraph after all silence and non-speech sounds (e.g., breathing) were been removed, and
articulation rate was defined as the number of syllables / articulation time. Percent pause time
was defined by the following formula [(total time of the passage – articulation time) / total
time] * 100. Finally, number of pauses was defined by counting the number of silences greater
than 0.05 seconds that were removed from the sample.

Statistics

After acoustic analysis and perceptual rating measurements were completed, those values
were statistically analyzed to answer the research questions. To examine perceptual differences
across the three listener types (self vs. caregiver vs. trained listener), multivariate analysis of
variance (MANOVA) testing was completed for all of the acoustic measures (F₀, F₀SD, intensity,
intensity SD, articulation rate, and percent pause time). A follow-up MANOVA was used to
examine differences between self and trained listener ratings. Pearson-Product Moment
Correlation (PPMC) analysis was used to examine relationships between perception and
acoustics, as well as relationships between the perceptions of different listener groups. Alpha
level for this study was 0.05, except where the Bonferonni adjustment was applied as appropriate
for post-hoc testing.

Reliability

After all recording and analysis was complete, reliability was examined using the PPMC
statistic. A total of 20% of the samples were reanalyzed (2 speakers) by the same researcher to
determine intra-judge reliability, and the same samples were analyzed by another researcher to
calculate inter-judge reliability. A significant correlation was found for both intra-judge reliability \( [r(12)=0.99, p<0.001] \) and inter-judge reliability \( [r(12)=1.00, p<0.001] \). Percent agreement was also high across all measures, with intra-judge agreement at 95.39% and inter-judge agreement at 96.47%.
RESULTS

Description of Perceptions and Acoustics

The first research question was interested in describing the self-perception of voice and speech of the individuals with PD, the perception of their primary caregivers, and acoustic measurements of that speech. Self, caregiver, and trained listener ratings were completed for pitch, pitch variation, intensity, rate, pausing, and understandability. On average, the highest self-rated feature of speech was understandability, at 62.33. Caregivers and trained listeners had similar ratings, with the highest rated speech characteristic also being understandability at 76.51 and 86.86 respectively (See Table 3).

On average, the lowest self-rated feature of speech was pitch variation at 30.86. The trained listeners agreed by rating pitch variation lowest as 43.20 (see Table 3). Caregivers found the lowest rated speech characteristic to be loudness, at 31.00, with pitch variation the second lowest with a rating of 36.8 (see Table 3). Although pitch variation was the lowest rating (on average) given by trained listeners, their rating (43.20) was relatively close to the “ideal” measurement of 50, while the self-ratings were much farther from this point.

Overall means indicate that trained listeners rated speakers with PD more favorably on four of six speech characteristics measured (loudness, pitch, pitch variation, and understandability) than did the caregivers or individuals with PD themselves. Comparing self-ratings, caregiver ratings, and trained listener ratings, the self-ratings were the lowest or most unfavorable ratings given for five of the six speech characteristics (all except loudness).

In addition to the speech and voice related ratings, one additional rating was completed by individuals with PD and their caregivers. These individuals were asked to indicate “who talks more” on a 100mm visual analog scale. The question referred to who talked more during typical
conversations between the individual completing the rating form versus his or her spouse. On average, both self and caregiver ratings tended to suggest caregivers hold the burden of the primary conversational partner. The individuals with PD rated the caregiver as talking more (57.33), and similarly, the caregivers also rated themselves as talking more (65.24). These results suggest that there is general agreement that individuals with PD speak less than their non-parkinsonian caregivers.
TABLE 3: Perceptual Speech Ratings Table. Ratings of pitch, pitch variation loudness, rate, pausing, and understandability were based on the reading passage.

<table>
<thead>
<tr>
<th></th>
<th>Mean Rating</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Pitch *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>37.94</td>
<td>14.09</td>
<td>16.34-51.84</td>
</tr>
<tr>
<td>Caregiver</td>
<td>38.18</td>
<td>17.84</td>
<td>4.83-69.95</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>47.54</td>
<td>6.24</td>
<td>41.31-60.95</td>
</tr>
<tr>
<td>**Pitch Variation *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>30.86</td>
<td>14.83</td>
<td>5.03-51.84</td>
</tr>
<tr>
<td>Caregiver</td>
<td>36.84</td>
<td>17.11</td>
<td>6.02-51.51</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>43.21</td>
<td>9.15</td>
<td>33.21-66.86</td>
</tr>
<tr>
<td>**Loudness *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>33.65</td>
<td>12.05</td>
<td>16.00-51.84</td>
</tr>
<tr>
<td>Caregiver</td>
<td>31.00</td>
<td>20.00</td>
<td>0.00-52.93</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>50.94</td>
<td>9.20</td>
<td>39.14-74.25</td>
</tr>
<tr>
<td>**Rate *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>45.20</td>
<td>17.69</td>
<td>16.00-79.37</td>
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<tr>
<td>Caregiver</td>
<td>45.59</td>
<td>13.90</td>
<td>23.04-68.49</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>59.02</td>
<td>14.15</td>
<td>41.79-76.46</td>
</tr>
<tr>
<td>**Pausing *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>38.93</td>
<td>14.75</td>
<td>14.94-62.45</td>
</tr>
<tr>
<td>Caregiver</td>
<td>50.26</td>
<td>14.64</td>
<td>22.78-67.76</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>47.26</td>
<td>14.68</td>
<td>17.98-72.75</td>
</tr>
<tr>
<td>**Understandability *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>62.33</td>
<td>29.48</td>
<td>8.00-86.72</td>
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<tr>
<td>Caregiver</td>
<td>76.51</td>
<td>22.54</td>
<td>37.85-100.00</td>
</tr>
<tr>
<td>Trained Listener</td>
<td>86.86</td>
<td>10.81</td>
<td>66.59-98.00</td>
</tr>
<tr>
<td>**During conversation, who talks more? *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>57.33</td>
<td>32.96</td>
<td>2.75-100.00</td>
</tr>
<tr>
<td>Caregiver</td>
<td>65.24</td>
<td>35.61</td>
<td>8.85-100.00</td>
</tr>
</tbody>
</table>

* Note: Perceptual ranges: Pitch (0=pitch too low; 100=pitch too high), Pitch Variation (0=monotone; 100=excessive pitch variations), Loudness (0=talking too quiet; 100=talking too loud), Rate (0=rate too slow; 100=rate too fast), Pausing (0=pauses too short/too few; 100=pauses too long/too many), Understandability (0=not at all understandable; 100=completely understandable), During Conversation, Who Talks More (0=Individual with PD talks more; 100=Caregiver talks more)
TABLE 4: Mean, standard deviation (SD) and range for all acoustic measures, including Fundamental Frequency (F₀), F₀ SD, Intensity, Intensity SD, Articulation Rate, Percent Pause, and number of pauses.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₀ (Hz)</td>
<td>130.47</td>
<td>28.62</td>
<td>99.20-171.78</td>
</tr>
<tr>
<td>F₀ SD</td>
<td>22.22</td>
<td>6.77</td>
<td>14.45-31.07</td>
</tr>
<tr>
<td>Intensity (dB)</td>
<td>67.83</td>
<td>4.80</td>
<td>62.46-76.94</td>
</tr>
<tr>
<td>Intensity SD</td>
<td>7.15</td>
<td>1.00</td>
<td>6.25-9.53</td>
</tr>
<tr>
<td>Articulation Rate</td>
<td>4.88</td>
<td>0.60</td>
<td>4.07-6.13</td>
</tr>
<tr>
<td>Percent Pause</td>
<td>25.02</td>
<td>11.88</td>
<td>9.40-47.34</td>
</tr>
<tr>
<td>Number of Pauses</td>
<td>17.5</td>
<td>9.48</td>
<td>7.00-37.00</td>
</tr>
</tbody>
</table>

Self / Caregiver Perception vs. Trained Listener Perception

MANOVA testing was completed to examine perceptual differences across all three listener types (self vs. caregiver vs. trained listener). Across measures and all three listener groups, results revealed no significant multivariate effects of listener type [F(12,28)=1.82; p=0.09; η²=0.438]. However, given that the difference between the listener types may be expected to be different for different perceptual features of speech, univariate follow-up ANOVAs were completed.

Univariate ANOVA testing of listener type (self vs. listener vs. trained listener) for each perceptual measure revealed significant univariate effects for loudness [F(2,18)=6.03; p=0.010; η²=0.40], rate [F(2,18)=5.13; p=0.017; η²=0.36] and understandability [F(2,18)=4.66; p=0.023; η²=0.34]. There were no significant listener-type differences for pitch [F(2,18)=1.45; p=0.26; η²=0.14], pitch variation [F(2,18)=1.78; p=0.20; η²=0.17], or pausing [F(2,18)=1.83; p=0.19; η²=0.17].
Paired-groups $t$-tests were used for post-hoc testing of significant univariate effects (alpha adjusted to 0.025). Post-hoc testing for the significant loudness effect revealed a significant difference between self-ratings and trained listeners’ ratings [$t(10)=-4.13; p=0.003$], as self-ratings of loudness were significantly lower compared to trained listener ratings. Post-hoc testing of the significant univariate rate effect revealed a significant difference between self-ratings of speech rate and trained listeners’ ratings [$t(10)=-2.80; p=0.021$], and a significant difference between caregiver and trained listeners [$t(10)=-2.72; p=0.024$]. Self-ratings and caregiver ratings of speech rate were both significantly lower (rate slower) compared to trained listener ratings. Post-hoc testing of a significant univariate understandability effect revealed a significant difference between self-ratings and trained listeners’ ratings [$t(10)=-3.43; p=0.008$], where self ratings were significantly lower than trained listener ratings.

Self-Ratings vs. Caregiver Ratings

Multivariate ANOVA testing of the self-ratings vs. caregiver ratings revealed no significant differences across perceptual measures ($p>0.05$). When perceptual measures were examined individually using follow-up univariate analysis there were no significant differences for pitch [$F(1,9)=0.001; p=0.97; \eta^2=0.00$], pitch variation [$F(1,9)=1.06; p=0.33; \eta^2=0.11$], loudness [$F(1,9)=0.16; p=0.70; \eta^2=0.02$], rate [$F(1,9)=0.007; p=0.94; \eta^2=0.001$], or understandability [$F(1,9)=1.92; p=0.20; \eta^2=0.18$]. Perception of pausing was the only measure to approach statistical significance [$F(1,9)=4.64; p=0.06; \eta^2=0.33$]. Overall, there were no significant differences between self and caregiver ratings on any of the six speech characteristics rated.
Perceptual Ratings vs. Acoustics

Correlations were calculated to determine if any relationships existed between perceptual ratings (self, caregiver, and trained listener) and acoustic measures of the PD speakers’ speech. Results indicated there were positive and negative correlations between trained listener ratings and acoustics, and self ratings and acoustics. No correlations were found between caregivers’ ratings and acoustics.

For a number of measures, the trained listeners’ perceptions were more closely correlated with acoustic measurements compared to either the self-ratings or the caregiver-ratings. The following positive correlations were identified: A significant positive correlation was found between the trained listener pitch rating and mean $F_o$ \( [r(9) = 0.647, p=0.043] \), with no similar correlations with self or caregiver ratings. An increase in trained listener ratings of pitch was associated with increased $F_o$. A significant positive correlation was found between trained listener pause rating and percent pause \( [r(9) = 0.756; p=0.011] \), with no similar correlations with self or caregiver ratings. An increase in trained listener pause rating was associated with an increase in percent pause. Finally, a positive correlation was identified between trained listener perception of loudness and measured intensity \( [r(9) = 0.671; p=0.034] \), as trained listeners perceived increased loudness when measured intensity increased.

A significant negative correlation was found between the trained listener understandability rating and percent pause \( [r(9) = -0.788; p=0.007] \), with no similar correlations with other listener types. This increase in trained listener understandability rating was associated with a decrease in percent pause. Another significant negative correlation was identified between trained listener perception of rate and the number of pauses \( [r(9) = -0.640; p=0.046] \). As the number of pauses increased the trained listener perception of rate decreased.
Along with the trained listener correlations, some significant correlations were found for the self-perception ratings vs. acoustics comparisons. A significant positive correlation was found between self-perception of speech rate and measured articulation rate \( r(9)=0.661; \ p=0.037 \), as an increase in self-rate rating was associated with an increase in measured articulation rate. No significant correlations were found between caregiver or trained listener ratings and articulation rate.

Other significant correlations occurred with self-ratings. Specifically, a significant negative correlation was found between self perception of rate and \( F_0 \) SD \( r(9) = -0.638, \ p=0.047 \), as a decrease of self-rate ratings was associated with an increase in \( F_0 \) SD. A significant negative correlation was found between self-perception of pitch and percent pause \( r(df) = -0.639; \ p=0.047 \), with no similar correlations found between caregiver and trained listeners. A decrease in self-rating of pitch was associated with an increase in percent pause.
DISCUSSION

The purposes of this study were to compare self-perception, caregiver perception, and trained listener perception of Parkinsonian speech, and to examine relationships that may exist between these perceptions and acoustic measurements of PD speech. This study sought to provide further insight into the relationship dynamic between individuals with PD and his/her caregiver regarding perception of speech deficits. The addition of trained listeners further allowed for descriptive analysis of accuracy of perceptions across listener groups. Below are descriptions of the correlations between perceptions and acoustics, the differences between self and caregiver ratings vs. trained listener ratings, as well as differences between self-ratings vs. trained listener ratings. In addition, qualitative descriptions of non-significant trends and implications for future research are presented.

Perceptual-Acoustic Correlations

When self, caregiver and trained listener perceptual ratings were correlated with acoustic measurements of PD speech, an interesting pattern emerged. Five correlations were found between trained listener perceptions and acoustics, and three correlations were found between self-perceptions and acoustics. However, no correlations were identified between caregiver perceptions and acoustic measurements. This finding is contrary to the original hypothesis that caregivers’ perceptions would be more closely related to acoustics than PD patients, who were suggested to be unaware of their speech deficits in a study by Yorkston et al. (1994).

Self-Perception Correlations

When self-perceptions were examined relative to acoustic measures, three correlations emerged. A positive correlation was identified between self-perception of speech rate and measured articulation rate. This relationship was not found with trained listener perception. As
measured articulation rate increased, self-perception of rate increased. This finding is clear in describing how individuals with PD are able to associate their own speaking rate with the actual measured articulation rate. This finding is made more important by the absence of any correlation between rate perception and articulation rate by either caregivers or trained listeners. Individuals with PD appear to be the best judges of their own speech rate.

Moreover, this finding does not completely agree with previous research. Specifically, Graber et al., (2002) found individuals with PD were not as accurate as non-impaired listeners at perceiving subtle timing differences, possibly resulting from a dopamine controlled internal clock disturbance. Pastor et al., (1992) noted administration of dopamine increased the accuracy of the internal clock for individuals with PD. During the current study, all participants were taking dopamine at the time of recording. It is possible that this factor increased accuracy of self-rate perception. However, a study by De Letter et al., (2007) found no significant changes in speech rate production during both on- and off-medication states. In addition, Goberman et al., (2005) also found no significant changes in speech rate production before and after administration of dopamine. Perhaps the administration of dopamine does not improve the prosodic production of PD speech, but does improve the perceptual abilities of individuals with PD. The current results may have therefore been different, had the participants been in an off-medication state.

Previous studies identified impaired prosodic production as a motoric deficit unrelated to mental functions (Ackermann & Ziegler, 1991; Hertrich & Ackermann, 1993). However, previous research did not comprehensively examine the role of self-perception when impaired prosody was produced, and focused mainly on individuals with PD perceiving the prosodic characteristics of other individuals’ speech. Considering these factors with the results of the
current study, it may be helpful for future research to examine prosodic production and self-
perception simultaneously during medication on- and off- states.

Two negative correlations were identified between self-perception and acoustic measures. One negative correlation was found between self-rate perception and F0 SD. A decrease in self-rate perception was associated with an increase in F0 SD. As there are more variations in pitch, speakers perceived a slower rate. It is difficult to say why this correlation exists, and it may not hold practical relevance because the two measures are so different. It is possible that when reading, individuals with PD attempted to use more pitch variation (even though they were instructed to use their regular speaking voice), and this in turn made them perceive they were speaking more slowly.

Another negative correlation identified was between self-pitch perception and percent pause. As measured percent pause decreased, self-perception of pitch increased. It is possible that speakers who perceive using a higher pitch use less pauses in their speech. There is not a clear explanation for this correlation, and as above, may not hold much practical significance. Both negative correlations may also exist due to a lack of understanding on the part of the PD speaker regarding what to listen for when perceiving pitch and rate. However, short descriptions of these terms were provided to participants prior to completing the rating form in an effort to minimize confusion effects. Further, it is also possible that individuals with PD were using a general severity score to make their perceptual ratings, and this resulted in the above two correlations.

Previous research was mixed regarding intensity self-perception in individuals with PD. However, a number of studies did support the finding that individuals with PD were inaccurate in their perceptions of their speaking volume (Ho et al., 2000, Miller et al., 2006). Results of the
current study are supported by these previous studies, as self-perceptual measurements of intensity did not correlate with acoustic measures, while trained listener perceptions did. Perhaps this also supports the theory by Ho et al., (2000) which stated that reductions on vocal intensity may be due to volume self-perception deficits in individuals with PD.

**Trained Listener Perception Correlations**

When the trained listener perceptions were examined relative to acoustic measures, a number of correlations were identified. One correlation identified was between trained listener pitch perception and measured F₀. As F₀ increased, trained listener perception of pitch increased. This finding supports the accuracy of trained listeners judgments of pitch, as neither self nor caregivers’ perceptions of pitch correlated with F₀. This finding supports previous work by Darley et al., (1969) and Pell (2006), which also found decreased F₀ of individuals with PD to be accurately perceived by listeners. Another correlation identified was between trained listener pause perception and measured percent pause. As percent pause measurements increased, trained listeners’ perceptions of pauses (too long/too many) increased. A study by Darley et al., (1969) also found similar results, as trained listeners noted inappropriate pauses to be a key perceptual feature of hypokinetic dysarthria. The use of pauses during speech was not correlated with either self or caregiver perceptions. Previous research has not comprehensively examined the perceptions of untrained listeners regarding pausing or F₀ in PD speech.

A third positive correlation identified was between trained listener perception of loudness and measured intensity. Trained listeners perceived increased loudness as measured intensity increased. Measured intensity was not correlated with any self or caregiver perceptions. This finding is supported by previous work by Countryman and Ramig (1993) and Holmes et al.,
(2000) which both identified decreased speaking intensity and listener perception of decreased speaking intensity as characteristic of individuals with PD.

One negative correlation was identified between the trained listener perception of rate and the number of measured pauses. As the number of measured pauses increased, the trained listener perception of rate decreased. No other correlations with the number of measured pauses were identified between self or caregiver perceptions. Pausing and perception of rate are related, as when the amount of pauses used during speech is increased the time to complete an utterance is also increased, resulting in a slower perceived rate. Previous work by Darley et al., (1969) did identify inappropriate pausing and rate disturbances in hypokinetic dysarthria. The current findings add evidence to a relationship between perceived rate and perceived pausing.

Another negative correlation was identified between trained listener perception of understandability and percent pause. Speakers with the higher measured percent pauses in their paragraph reading were rated as having the lower understandability ratings. To interpret this finding, it should be stated that there are at least two ways a speaker can increase their pauses in running speech. (1) A speaker can add pauses in semantically appropriate locations (ends of phrases or sentences), and this has been shown to increase intelligibility and clarity in previous studies (Goberman & Elmer, 2005). (2) A speaker can also add pauses in inappropriate locations (between or within words). This second type of pausing may be associated with impaired breath support (Solomon & Hixon, 1993), speech disfluencies, or akinesia (Goberman et al., 2005). In the current study, an increase of pausing in inappropriate locations may have happened, and this may have led to the perception of decreased understandability in these speakers. One note of caution should be applied to this interpretation of the relationship between pausing and understandability ratings. This interpretation should not be used to imply that the current
individuals with PD were abnormally high or low in their pause levels. In fact, their overall percent pause (25%) was higher than a previous similar-aged control group (19%; Goberman et al., 2005), and relatively similar to two previous studies of PD participants with values ranged from 16% (Goberman & Elmer, 2005) to 31% (Goberman et al., 2005).

In their 2005 study, Goberman and Elmer examined differences between “clear” and “conversational” PD speech. Results indicated that when individuals with PD were instructed to employ clear speech strategies they increased their percent pause times. However, it is unlikely that the current participants were utilizing a clear speech strategy, because their pausing was actually associated with a decrease in understandability. Further, since only 4 participants (40%) reported any formal speech therapy, it is unlikely that the group pausing levels were related to any previous formal therapy instructions. Further research must be conducted on this topic to determine if trained listeners perceive increased understandability with strategic pausing and decreased understandability with inappropriate pausing, as well as what types of pausing individuals with PD typically use.

Summary of Correlations

Correlations were examined between acoustic measurements and self-, caregiver, and trained listener perceptual ratings. No significant correlations were found between caregiver perceptions and acoustic measures. However, five correlations were found between trained listener perceptions and three correlations were found between self-perceptions and acoustics. If a correlation between perception and acoustics is indeed a sign of perceptual accuracy, then this finding suggests caregivers may be the group least able to make perceptual judgments of PD speech. This finding is contrary to the original hypothesis of this study which postulated that caregiver ratings would be more accurate than self-perception. Judging from the correlations
found, it appears the most accurate evaluation of PD speech incorporates both a trained listener rating to evaluate $F_o$, intensity, percent pause, and number of pauses, and a self-rating to evaluate articulation rate.

**Self and Caregiver Ratings vs. Trained Listeners**

Comparisons of perceptions across listener groups were completed. Trained listener ratings were included to put the self-ratings and caregiver ratings into perspective and identify potential differences between groups. Analysis revealed four significant differences. Speakers rated themselves significantly lower (more negatively) on loudness, rate, and understandability than did trained listeners, and caregivers rated the speakers lower (more negatively) on rate than did trained listeners. On all four significant differences, trained listener ratings were significantly higher, or rated more favorably than were the self or caregiver ratings. The implication is that both caregivers and speakers have a negatively skewed perception of the speaker’s deficits. One also may suggest that the trained listeners were underestimating the deficits in their perceptual ratings. It is possible that the rating differences may be a result of experience and context. The trained listeners have had more experience listening to individuals with different and possibly more severe speech deficits, and the speakers and caregivers may lack this context when completing their ratings.

Andresen, Vahle, and Lollar, (2001) conducted a study that examined comparisons of perceptions of quality of life of individuals with disabilities with the perceptions of family members, friends, and healthcare professionals. The correlation levels were highest between patients and family members, lower between patients and friends, and lowest between patients and healthcare professionals (i.e., trained listeners). The current study did find statistically significant differences between the trained listener ratings and both the self-ratings and caregiver
ratings, with a general trend of self-perceptions being the most negative, followed by more positive perceptions by caregivers, and the most positive perceptions by trained listeners. In both the study by Andresen et al., (2001) and the current study, healthcare professionals or trained listeners appear to be the groups in least agreement with individuals with the disability or disease.

**Self, Caregiver, and Trained Listener Perceptions**

Despite the above stated results, the comparison of self-ratings vs. caregiver ratings of PD speech yielded no statistically significant differences for perceptions of pitch, pitch variation, loudness, rate, pausing, or understandability. In other words, there were no statistical differences between self and caregiver ratings, but the above correlation analysis revealed some differences in the relationships between these ratings and trained listener ratings.

Given the prediction that individuals with PD would have impaired self-perception, the findings can be interpreted a number of ways. Specifically, the lack of significant differences between self and caregiver ratings could lead to a number of possible implications. (1) It is possible that neither individuals with PD nor their caregivers have any perceptual deficits. (2) Conversely, the individuals with PD and their caregivers may be equally impaired in perception of speech characteristics. (3) Finally, it is possible that subtle perceptual differences actually existed, but were not found to be significant because of the relatively small sample size of the current study. Based on the addition of trained listener perceptions to the current study, and the high level of correlation between trained listener perceptions and measured acoustics, the second scenario appears to be most likely, that individuals with PD and their caregivers are both equally impaired. It is possible that the third scenario is also true, with either self-perceptions or caregiver perceptions being more impaired than the other, but with the small sample size these
differences were not visible. Examining the perceptual abilities of caregivers and patients in other diseases may assist with interpretation of the findings of the current study.

Perception in Other Diseases

Research in related healthcare fields has examined the self vs. caregiver perception relationship. In a study by van der linden et al. (2006), 59 patients with Multiple Sclerosis (MS) and their partners were asked to rate the impact of the disease on the patient’s life. Agreement on the scale was good between patients and partners. Researchers did note that the level of agreement was lessened for psychological factors compared to physical factors. Another study by Sneeuw et al. (1999) found similar agreement between cancer patients’ self-perceptions of quality of life and their caregivers’ perceptions. Finally, a study by Zraick et al., (2007) found good agreement between patient and partner perception of a voice handicap. This finding does support the current study in that there were no statistical differences between self and caregiver ratings, despite the low level of correlation with acoustic measures. Essentially, in other diseases, caregiver and patient perceptions appear to be closely related. When the current study results are examined descriptively, trends do emerge which may add to the results of these previously mentioned studies. This is described further below.

Analysis of Descriptive (non-significant) Trends

When examined descriptively, non-statistically significant trends emerge between caregiver and self-perceptions, however these results must be interpreted with caution due to the lack of statistical significance. One pattern that emerged was that six of ten caregivers rated pausing more favorable or more normal (closer to the ideal rating of 50 on the VAS) than did the speakers themselves. For some of the other characteristics, the same types of patterns were visible. For pitch variation, eight of ten caregivers perceived a more normal (ideal/closer to
50mm) level of pitch variations than did speakers. For loudness, six of ten speakers rated loudness as more favorable or closer to the ideal 50mm than did caregivers. Finally, eight of ten caregivers rated understandability higher, or closer to the ideal 100mm (completely understandable) on the VAS than did speakers.

The initial hypothesis for this study was that caregivers would rate speech characteristics as less normal than speakers themselves (i.e., speakers may underestimate their own deficits). Based solely on statistical significance, there were no differences between self and caregiver perceptions; however, descriptive descriptions for pausing, pitch variations and understandability appear to suggest that self-ratings were less normal than caregiver ratings, contradicting the original hypothesis.

A recent study by Miller, Noble, Jones, Alcock, and Burn (2008) found results similar to the above trends when examining pairs of individuals with PD and their caregivers. When individuals with PD were asked to rate their voice across psychological characteristics regarding the impact of PD on communication, their self-ratings were lower/more negative than were the caregiver ratings. Miller et al., (2008) did not examine acoustic measurements of speech in their study, which does pose a limitation for comparison. The speech characteristics of the current study were acoustically measurable, while those characteristics used in the Miller et al., (2008) study were not all directly measurable (e.g., ratings of communicative impact of PD). However, it does appear that both the current study (regarding descriptive analysis of pausing, pitch variation and understandability) and the Miller at al. (2008) study found that self-ratings of PD speech were more negative than caregiver ratings of that same speech.

Overall, the interpretation of trends between self-ratings and caregiver ratings can be interpreted as showing that caregivers are underestimating the speech deficit of individuals with
PD on three of the perceptual speech characteristics measured. However, it may also be that individuals with PD are overestimating their deficits compared to caregivers and trained listeners. Future research must continue to examine the reasons for these discrepancies.

Role of Dementia in Perception

In the current study, participants were screened for dementia with the DRS-2. All PD participants in this study scored no worse than mild cognitive impairment. This was done due to evidence by Benke et al., (1998) which suggested cognitively impaired individuals with PD were inaccurate in perception of prosody. The study by Miller et al. (2008) also partially supported this decision, and may provide insight into the lack of statistically significant differences between self and caregiver perceptions in the current study. While not statistically significant, Miller et al., (2008) identified increased levels of difference between caregiver-individual with PD and dementia caregiver dyads when compared to caregiver-individual with PD only dyads. Additionally, in a study by Novella et al. (2001), reports of quality of life in patients with Alzheimer’s Disease and their spouses matched well, but the level of agreement did decrease with increased dementia. Interestingly, the spouses rated quality of life lower than did patients. Regardless, the study by Miller et al., (2008) also supported the current project when examining current results on a descriptive basis. Their results found individuals with PD perceived a greater communication handicap than did their caregivers.

Conversational Burden of Caregivers

One area where self and caregiver perceptions are in agreement is that of conversational burden. Both self and caregiver perceptions of “who talks more” were above 50 on the VAS, indicating both groups saw the caregiver as talking more than the individual with PD. The overall average self-perception of “who talks more” was 57.33 in favor of the caregiver and the
overall average caregiver-perception of “who talks more” was 65.24 also in favor of the
caregiver. In addition, results suggest caregivers appear to view themselves as holding more
conversational burden than individuals with PD view them as holding. A study by Miller et al.,
(2006) surveyed individuals with PD, and many noted difficulties with conversations as a result
of PD. This seems to suggest a reason for why caregivers end up doing more of the talking (or at
least feeling that they are doing more of the talking). In addition, the Miller et al., (2006) study
identified other factors individuals with PD noted as being troublesome when attempting to
speak, such as attention, word finding, and thought planning. These are all other possible areas of
deficits which may contribute to decreased conversational participation by individuals with PD.
Perhaps the reasons for the conversational burden shift to caregivers are not due solely to the
physical act of speech motor production, but are influenced by subtle decreased cognitive and
language abilities. Further, it is possible that female spouses routinely talk more than their males
husbands. In the current study only one pair of participants consisted of a female with PD and a
male spouse without. Perhaps if the majority of participants were females with PD and males
without, this conversational burden may shift. Further research in the cognitive and linguistic
abilities of individuals with PD may further illuminate the reasons for conversational burden
shift.

Limitations

While every attempt was made to create the optimal research design, there were
inevitable limitations to this study. A potential limitation is the use of graduate students as the
group of “trained” listeners. It is unknown whether the use of more experienced, licensed speech-
language pathologists as “trained” listeners would have different perceptions relative to acoustic
measures. In addition, only the six most reliable trained listeners were selected from the pool of
participants. Nevertheless, trained listener perceptions were correlated with acoustic measures on five speech characteristics, which provide clear results. Additionally, the effect of age on the agreement with acoustics was not examined in the current study. One study by Low and Gutman (2003) did note decreasing levels of agreement regarding quality of life for patients with chronic obstructive pulmonary disease and their non-impaired spouses as age increased. Given this previous result, and the fact that the age difference between the trained listeners and caregivers was approximately 40 years in the current study, age should be considered in future perceptual studies.

Finally, one may argue the six speech characteristics used for rating were unfamiliar to the speaker and caregiver, and that those individuals may have used an overall general speech severity perception to rate each of the six dimensions measured. In an attempt to counteract this possibility, specific definitions were given for each rating (See appendix E), and the ratings were completed one at a time only after the examiner read each rating dimension. This may actually not be a limitation if the participants rated specific speech characteristics using an “overall” severity score, as this is actually in part what the study was designed to assess. Speakers and caregivers are not specially trained in speech production or perception, and one of the study goals was to identify if these perceptions matched with acoustic measures.

Implications for Treatment

Many individuals with PD can and do benefit from treatment such as LSVT to improve phonation and prosody (Trail et al., 2005). Previous research suggested that individuals with PD may lack self-awareness of their speech deficits (Fox & Ramig, 1997), and that caregivers may bear the primary responsibility for providing access to treatment. These statements were made based on the assumption that caregivers would be unimpaired in their perception of PD speech,
however the current results call these assumptions into question. Specifically, the current findings indicate that individuals with PD may actually be slightly better at perceiving their own deficits than caregivers based on the correlation and descriptive trend analysis. This finding raises issues that must be studied further regarding what motivates individuals with PD to seek speech and language services. It is unknown whether the motivation to attend or be an active participant in therapy is internal, or from external sources such as caregivers. Even if the motivation is internal to the individual with PD, the willingness of the caregiver to provide access to speech and voice treatment must be examined. The role of caregiver education should also be examined, as their role of the caregiver in therapy is not completely understood.
CONCLUSIONS

To summarize, the results of this study assisted in answering the original research questions by describing the relationships between self-perception and caregiver perception, the relationships between self- and caregiver-perception compared to trained listener perceptions, and the relationships between all groups’ perceptions and acoustic measures. There were a number of significant findings presented that suggest strong relationships between different individuals’ abilities to perceive certain speech characteristics.

No significant differences were identified between comparisons of self and caregiver perceptions; however, significant differences were found between comparisons of self to trained listener and caregiver to trained listener perceptions. Speakers rated themselves significantly lower (more negatively) on loudness, rate, and understandability than did trained listeners, and caregivers rated the speakers lower (more negatively) on rate than did trained listeners. On all four significant differences, trained listener ratings were significantly higher, or rated more favorably than were the self or caregiver ratings. The next step was to identify correlations between perceptions from all three groups and acoustic measures.

Trained listeners’ perceptions were correlated with acoustics for most speech characteristics, self-perception was correlated with acoustic only for speaking rate, and caregivers’ perceptions did not correlate with acoustic measurements in any instance. In addition, many opportunities for future research were identified as well as implications for treatment, including increased caregiver education.
REFERENCES


Speech Production / Perception Study

INFORMED CONSENT

Introduction: You are being invited to participate in a study of speech production and perception. It is possible you are being contacted because of previous interest or participation in research. The results of this study will be used to learn more about the perception of features of different voices. This study will be conducted by Dr. Alexander Goberman with the Department of Communication Disorders at Bowling Green State University. You are ineligible to participate if you are under 18 years of age, or if you have any hearing disorders.

Procedures: Your participation will start with filling out a short questionnaire and possibly completing a test of thinking. The maximum time commitment for this session is 30 minutes.

- Speakers will then be asked to read a paragraph and some phrases, followed by answering some questions.
- Listeners will be asked to listen to the reading of the paragraph, followed by answering some questions.

Risks and Benefits: There are no known risks beyond those that you would normally encounter in your daily life. You may benefit by learning more about speech production and perceptions. The research community will benefit through increased understanding of factors affecting the perception of speech.

Payment / Costs: Participation in this study is voluntary. You will receive no payment for participation. Likewise, there will be no financial cost for participating.

Confidentiality: All records related to this research will be maintained in a locked laboratory and will be available only to those assisting with the project. The recordings will be maintained after the study is complete for future research / continuation of this study. You will be assigned a participant number and this will be used in place of your name. The investigators will not reveal any identities if they publish or present the results of this study.

Questions: If you have any more questions you can contact Alexander Goberman, Ph.D., at 419-372-2518 (goberma@bgsu.edu). If you have questions about the conduct of this study or your rights as a research participant, you may contact the Chair of Bowling Green State University's Human Subjects Review Board at (419) 372-7716 (hsrb@bgsu.edu).

Consent: I have been told what will be done in this study. I have also been told how it would be done, what I will have to do, and how long participation will likely take. I am aware that participation in this study is voluntary. I may quit and/or refuse participation at any time without repercussions. If I am a student, the decision to participate or not participate will have no impact on grades, class standing, or relationship to the institution in any way. If I am receiving speech-language-hearing services at BGSU, my decision to participate or not participate will have no effect on my relationship with the institution / clinic or the treatment I receive. If I want it, the investigators will give me a copy of this form to keep for my records.

__________________________________   ________________
Participant’s Name (print / type)    Date

__________________________________
Participant’s Signature
Speech Production / Perception Study
SPEAKER QUESTIONNAIRE

Have you completed the consent form? If not, please complete the consent form first.

Participant #: _____________      Sex: Male / Female
Date of Birth: ________________
Do you have any history of, or current:
  Speech deficits: Yes / No      Hearing deficits: Yes / No
  Language deficits: Yes / No    Visual deficits: Yes / No
Have you ever been enrolled in therapy with a Speech Pathologist?: Yes / No
Have you participated in speech, language, or hearing studies before: Yes / No
Is American English your first language: Yes / No
History of smoking: _____________      Education level: ____________________________

In the following questions, please circle n/a if the question does not pertain to you.

Medical Diagnoses: ______________________________________________________
Age at diagnosis of PD: n/a
Current Medications (related to PD, speech, language, or hearing): n/a
________________________________________________________________________
When did you take your last PD-related medication: n/a
Do you experience fluctuations before / after medication: Yes / No
What times of day are best / worst: _______________________________________
Date of last visit to neurologist: _________________________________________

Medication effectiveness:

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<td>Very effective</td>
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PD symptoms overall:

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<td>Severe symptoms</td>
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Speech Production / Perception Study

LISTENER QUESTIONNAIRE

Have you completed the consent form? If not, please complete the consent form first.

Participant #: _____________

Sex: Male  /  Female

Date of Birth: ________________

Do you have any history of, or current:

- Speech deficits: Yes / No
- Language deficits: Yes / No
- Hearing deficits: Yes / No
- Visual deficits: Yes / No

Have you ever been enrolled in therapy with a Speech Pathologist? : Yes / No

Have you participated in speech, language, or hearing studies before: Yes / No

Is American English your first language: Yes / No

History of smoking: _______________________________________________________

Education level: __________________________________________________________

The following questions refer to the speaker you will be listening to.

Relationship to speaker: ______________

How long have you been living with / caring for the speaker: _______________________

Typical amount of time spent per day directly in contact with the speaker:
____________________

Typical amount of time spent per day communicating with the speaker: ________________
The Rainbow Passage:

When sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch with its path high above, with its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Vowel Prolongation:

Say the vowel “aaaaaaaaaah” as long and as steady as you can.

HvD Task:

say “heed” again
say “who’d” again
say “hodd” again
say “had” again
Repeat

Diadochokinetic Task:

Say the following syllables as fast and steady as you can:

/papapapapapapapapapa/
/tatatatatatatatata/
/kakakakakakakakakaka/
/ptkptkptkptkptkptkptkptkptkptkptkptkptkptkptkptk/
Speech Production / Perception Study

LISTENING FORM

Date: ________________________   Participant number: ___________________

Place an X along each line to indicate your perception of the speech/voice used during the paragraph. Use the below definitions if needed.

Pitch too Low ____________________________  Pitch too High

Monotone ____________________________  Excessive Pitch Variations

Talking too Quiet ____________________________  Talking too Loud

Rate too Slow ____________________________  Rate too Fast

Pauses too short / too few ____________________________  Pauses too long / too many

Not at all understandable ____________________________  Completely understandable

During our conversations together, who talks more?

I talk more ____________________________  They talk more

DEFINITIONS:

Pitch = highness or lowness of the voice.
Monotone = no ups and downs in speech; no inflection.
Excessive pitch variation = too many ups and downs in speech; extreme alterations in inflection
Rate = speed of actual speaking