PERCEPTUAL EVALUATION OF SPEECH INTELLIGIBILITY OF INDIVIDUALS WITH PARKINSON'S DISEASE FOLLOWING SPEECH RATE MODIFICATION THROUGH ALTERED AUDITORY FEEDBACK

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Abstract: Parkinson's disease (PD) is a neurodegenerative, progressive disease that presents with numerous symptoms, including motor and non-motor (Jankovic, 2008). There has been some research to document that people with PD present with a characteristic accelerating speech rate, commonly referred to as festinating speech (Duffy, 2013; Skodda, 2011; Skodda & Schlegel, 2008). A commonly recommended technique to treat speech rate deficits in individuals with PD is rate reduction (Hammen & Yorkston, 1996; Tjaden & Wilding, 2011). A majority of the studies have demonstrated beneficial effects of rate reduction (Hammen & Yorkston, 1996; Tjaden & Wilding, 2011). Various rate reduction strategies have been used in the past to modify the speech rate in individuals with PD (Blanchet & Snyder, 2010). The use of altered auditory feedback (AAF) has received considerable attention as a treatment technique to modify the rate of speech. The two common types of AAF include delayed auditory feedback (DAF) and frequency shifted feedback (FSF). While examining the acoustic bases of rate reduction is important, it has limited ecological validity. It is imperative to examine if the rate reduction as reflected by acoustic parameters translates to improved speech intelligibility to the outside world. This is possible only by perceptual evaluation of the individual's speech intelligibility by naïve listeners. The current study aims to evaluate the speech intelligibility in individuals with PD following rate modification using AAF. Five individuals with PD (clinical group) and five age-matched healthy controls (healthy group) aged 50 and above served as participants. Each participant was asked to read the grandfather passage, as well as give a monologue. They were first asked to complete these two tasks without the administration of AAF. Then, the participants were asked to do the same tasks again, but with the administration of AAF through a 150 millisecond delay and a pitch 1/20 octave higher. Thirty-two naïve listeners were recruited to listen to the speech samples of the participants and give each sample an intelligibility rating. It is anticipated that delivering AAF will increase intelligibility in individuals diagnosed with PD by slowing down their rate.

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CHAPTER I

INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative, progressive disease that presents with numerous symptoms, including motor and non-motor (Jankovic, 2008). Some of the primary motor symptoms include resting tremor, bradykinesia, instability of posture, and rigidity of movement. Secondary motor symptoms involve freezing, speech deficits, respiratory problems, dystonia, and dysphagia. Common non-motor symptoms include cognitive deficits, sleep conditions, and autonomic impairment (Jankovic, 2008). PD has an average onset of 60 years of age and its exact etiology is unknown. Research shows that it is most likely due to a spectrum of genetic and environmental factors, with each person falling in a different place on the spectrum. It is a highly individualized disease, with some people suspected to be affected by genetic components, and others suspected to be affected by environmental components ("Parkinson's Disease Causes," n.d.).

PD results from a lack of dopamine production in the basal ganglia. The basal ganglia is a structural site in the brain that processes signals from the cortex, allowing for adequate filtering of voluntary movements and in turn, their accurate execution. Five nuclei make up the basal ganglia: the caudate nucleus, putamen, globus pallidus, substantia nigra, and the subthalamic nucleus. When dopamine is no longer being produced, the circuitry of the basal ganglia is changed, resulting in hypo-activity. Efforts to correct the dopamine deficit in the brain include the prescription of the medication Levodopa (Blandini, Nappi, Tassorelli, & Martignoni, 2000). About 89% of people diagnosed with PD present with communication problems (Liotti et al., 2003). Parkinson's disease affects an individual's speech at many levels. It is common for people with PD to exhibit hypokinetic dysarthria (Ho, Iansek, Marigliani, Bradshaw, & Gates, 1998; Logemann, Fisher, Boshes, & Blonsky, 1978). Hypokinetic dysarthria is described to be a multimodal speech impairment (Skodda, 2011). The speech characteristics of hypokinetic dysarthria include hypophonia (decreased vocal loudness), monotonicity, breathiness/ hoarseness, imprecise articulation, and speaking rate problems (Duffy, 2013). Among the above-mentioned speech deficits, the effects of PD on phonatory and articulatory systems have been frequently and consistently reported among the past studies. Logeman et al. (1978) examined speech features of 200 patients with PD and found that about 90% of their patients presented with voice disorders characterized by hoarseness, roughness, tremulousness and breathiness (Logemann, Fisher, Boshes, & Blonsky, 1978). Zwirmer and Barnes (1992) reported that among the 31 patients with hypokinetic dysarthria they examined, about half of them presented with articulatory problems and about 20% demonstrated speech rate deficits. Similar to the findings of Logeman et al. (1978), Zwirmer and Barnes (1992) also reported that a majority of their patients presented with vocal deficits (Zwirner & Barnes, 1992). Ho, Iansek, Marigliani, Bradshaw, and Gates (1998) classified speech impairment in 200 patients with PD based on five levels of severity (no impairment, mild, moderate, severe, and profound) and reported the type of speech deficit associated with each level of severity. The results revealed that vocal deficits were noticed even during the milder stages of impairment. However, as the severity level progressed, articulation deficits were also as prominently perceived as the vocal deficits. As our knowledge regarding these deficits has been expanding, research related to treatment of phonatory and articulatory deficits in individuals with PD has also been burgeoning in the recent past (Fox, Ebersbach, Ramig, & Sapir, 2012; Ramig et al., 2001; Sapir et al., 2002).

Review of Literature

Although our knowledge on the speech rate deficits in individuals with PD is still at its infancy, there has been some research to document that people with PD present with a characteristic accelerating speech rate during speech production commonly referred to as festinating speech (Duffy, 2013; Skodda, 2011; Skodda & Schlegel, 2008). A commonly recommended technique to treat speech rate deficits in individuals with PD is rate reduction (Hammen & Yorkston, 1996; Tjaden & Wilding, 2011). The main goal of rate reduction therapy is to slow the speaker's rate of speech so to provide the listener additional time to comprehend the degraded signal. Although there has been some inconsistency in the outcomes of rate reduction treatments in the past, a majority of the studies have demonstrated beneficial effects of rate reduction (Hammen & Yorkston, 1996; Tjaden & Wilding, 2011). Hammen and Yorkston (1996) examined speech and pause characteristics in six individuals with hypokinetic dysarthria secondary to PD and six healthy controls. The rate reduction was elicited using a computerized pacing software during a reading passage. The results revealed that the reduction in speech rate was reflected by increased articulation rate and pause time. However, this did not translate to improved speech intelligibility. Van Nuffelen, De Body, Vanderwegen, De Heyning, &Wuyts (2010) investigated the effects of a variety of rate control techniques on speech and pause characteristics of 27 individuals with dysarthria. The results revealed that the different rate control methods had varied effects on speech and pause characteristics. DAF affected mostly the articulation time, whereas techniques such as using a pacing board affected both articulation and pause time. Voluntary rate reduction failed to show a significant decrease in articulation or speaking rate.

Various rate reduction strategies have been used in the past to modify the speech rate in individuals with PD. Some of the rate reduction approaches that have been examined previously include the use of pacing boards, alphabet board supplementation, voluntary rate reduction, and altered auditory feedback (Blanchet & Snyder, 2010). The use of altered auditory feedback (AAF) has received considerable attention as a treatment technique to modify the rate of speech.

The effects of AAF on the reduction of speech rate and dysfluencies in people who stutter abounds in much of the literature (Borsel et al. 2003). Since this technique has been shown to slow speech rate, it is plausible to inquire about its relevance in treating people with PD. AAF requires the individual to use a device that alters the auditory feedback. The two common types of AAF include delayed auditory feedback (DAF) and frequency shifted feedback (FSF). In DAF, the individual receives auditory feedback that is delayed by a few milliseconds. In the case of FSF, the individual hears the auditory feedback in real time but with an altered frequency (Blanchet & Snyder, 2010; Lowit, Dobinson, Timmins, Howell, & Kröger, 2010). Some of the previous studies that have used AAF to modify speech rate in individuals with speech disorders are reviewed below.

Researchers have delayed the auditory feedback in ranges from 25 milliseconds to 200 milliseconds and shifted the frequency of auditory feedback in ranges from -1/2 octave to +1/2 octave (Lowit et al., 2010; Natke, Grosser, & Kalveram, 2001). Borsel, Reunes, and Bergh (2003) supported the claim that DAF is a valid way to reduce dysfluency in individuals who stutter. In their study, speech was delayed by 93 milliseconds at pre-treatment, and participants got to determine the length of the delay at post-treatment. Results indicated that duration of exposure to DAF did not directly correlate with improved fluency. Kalinowski, Armson, Roland-Mieszowski, and Stuart (1993) studied the effects of AAF on dysfluencies in individuals who stutter, as well as its effects on speech rate. The researchers delayed the speech feedback by 50 milliseconds and by a shift in the frequency of speech feedback of one-half an octave higher. It was found that delaying the participant's speech by 50 milliseconds did not limit their speech rate. It was also found that specific altered auditory feedback was able to reduce stuttering in people at both normal and fast speech rates.

Webster, Hollins, Schumacher, and Lubker (1970) investigated the effects that DAF had on severe stutterers. The researchers recruited six participants. They were randomly assigned reading passages and were administered DAF at different time intervals to test for effectiveness in enhancing fluency. The time intervals utilized for DAF were .1, .2, .3, .4, and .5 seconds. The participants were required to read aloud for five minutes at each time delay. Results indicated dysfluency reductions were found during DAF at all time intervals. There was no significant effect found between the different time lengths.

Antipova, Purdy, Blakeley, and Williams (2008) assessed eight different combinations of DAF and FSF and their effects on the monologue speech of individuals who stutter. The results of this study indicated that AAF is an effective way to reduce the frequency of stuttering when involved in a monologue task. Not all of the AAF combinations reduced the frequency of stuttering with the same effectiveness, although all did reduce stuttering to some degree. Delaying participant's auditory feedback by 75 milliseconds with no frequency-shifted feedback was found to be the only experimental condition that produced a statistically significant reduction of stuttering. Wang, Metman, & Bernard (2008) investigated the effects of varying levels of AAF on the speech intelligibility of nine participants with idiopathic PD presenting with moderate-severe speech impairment (characterized by festinating speech, hesitations, etc.). Participants were administered AAF during monologue and reading tasks. Results showed that the participant's intelligibility of speech was improved for the monologue tasks, and not the reading task. However, the participant's speech rate was shown to slow down during the reading tasks versus the monologue task.

Lowit et al. (2010) evaluated whether the delayed feedback of 150 milliseconds, a ½ octave frequency shift upward, or a preferred AAF setting produced gains in speech rate and intelligibility in individuals with idiopathic PD. Results concluded that DAF and FSF produced slower speech rates. However, these slower rates did not always transform into an increase in speech intelligibility. Group statistics did not show significant improvements in speech intelligibility. Individual participant results varied considerably across speech rate and intelligibility with some improving, declining, and others remaining stable. Armson, Kalinowski, Foote, Witt, and Stuart (1997) evaluated the effects of a frequency-shifted feedback of -½ an octave on the stuttering of nine adults while reading to various audience sizes. The severity of the participants' stuttering ranged from mild to moderate-severe. There was a statistically significant reduction in stuttering when the individuals read aloud to audiences of two, four, and fifteen. Results of stuttering frequency when reading in front of various audience sizes were compared between frequency shifted auditory feedback and without feedback. The results of this study indicate that frequency shifted feedback can be a successful tool to reduce stuttering in adults.

Based on the above reviewed literature, three potential problems can be identified. First, while the impact of AAF on modifying speech rate has been well documented in individuals with stuttering, its application in modifying the speech rate in individuals with PD has not received considerable attention. Second, much of the literature has examined the acoustic basis of rate reduction in individuals with hypokinetic dysarthria. While examining the acoustic bases of rate reduction is important, it has limited ecological validity. It is imperative to examine if the rate reduction as reflected by acoustic parameters translates to improved speech intelligibility to the outside world. This is possible only by perceptual evaluation of the individual's speech intelligibility by naïve listeners. Third, the influence of the received stimulus (e.g. reading passage vs. monologue task) while delivering AAF to individuals with PD has not been systematically investigated in depth. Previous research has demonstrated that stimulus type can influence speech intelligibility outcomes. Sidtis, Cameron, and Sidtis (2012) found that stimulus task impacted the number of dysfluencies produced by a participant with Parkinsonian Syndrome. As previously mentioned, Wang, Metman, & Bernard (2008) found results suggesting that stimulus tasks of reading vs. monologue can influence outcomes of intelligibility and speech rate in participants with PD. Lowit et al. (2010) briefly mention the greater effectiveness of AAF when delivered during longer productions of speech versus short productions of speech. Stimulus tasks and their impact on treatment effectiveness are critical to understand in order to deliver the most successful forms of treatment to patients during the correct type of speech output. Therefore, the impact of stimulus on effectiveness of AAF treatment is an area that needs further investigation. Considering these three limitations in the literature, the current study aims to evaluate the speech intelligibility in individuals with PD following rate modification using AAF in comparison to age-matched healthy controls. Based on prior research, it is hypothesized that participants' speech intelligibility will improve following rate modification using AAF. It is also predicted that participants will perform better while reading a passage than when giving a monologue, due to the differences in cognitive load involved (Sidtis, Cameron, and Sidtis, 2012).

CHAPTER II

METHODS

Participants

Five individuals with PD (clinical group) and five age-matched healthy controls (healthy group) aged 50 and above served as participants. The participants were recruited through convenience sampling procedure from the community and local PD support groups in the state of Oklahoma. Clinical group participants who present with marked cognitive impairment or in the severe stages of PD were excluded from participation. Healthy group individuals with a history of cognitive, motor, and/or sensory impairments were also excluded from participation.

Table 1 Participant Demographic Data

Mean Characteristics	**Clinical Group (n=5)**	**Control Group (n=5)**
Age	68	66.2
Gender	2F/3M	2F/3M
Medication	3 Levadopa/Carvadopa 2 Pramipexole	N/A
Years since Dx	3.5	N/A
Motor UPDRS	29.6	N/A
Hoehn and Yahr	1.8	N/A
MoCA	26	27.2

Procedures

The entire experiment was conducted over one session. The beginning of each session involved collecting baseline measurements from the participants. The participants were administered Movement Disorders Society Sponsored Revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS), Montreal Cognitive Assessment (MoCA), and a hearing screening. Participants with a diagnosis of hearing loss were included in the study only when wearing hearing aids set to normal. In addition, a detailed history was collected from participants that included information regarding the onset of PD, medications, progression of disease, and treatment history. During the second half of the session the participants were required to read a passage and produce a monologue at their habitual speech rate. To elicit the monologue, the participants were asked standard questions that remained consistent throughout the study such as, "Where is your favorite place to go on vacation and why?". Following this, the participants were again involved in the reading and monologue tasks. The reading task involved the participants reading The Grandfather Passage. This time they were administered AAF, by delaying their speech feedback by 150 milliseconds and altering it by a fraction of an octave higher (in this case 1/20 of an octave) than normal frequency. Due to the previously mentioned research not discovering consistently significant results with higher octave shifts, a lower octave was chosen in conjunction with DAF for the present study. The participants were allowed to have a few trial speech productions to get used to AAF and ensure the feedback could be heard. The AAF was administered through an iOS App (http://artefactsoft.com/iphonedaf.htm) and high fidelity, over-the-ear headphones to manipulate the participants' speech rate. The participants' reading as well as monologue productions before and during the administration of AAF were recorded using a digital voice recorder kept the same distance away from each participant. Thus, there were four recordings obtained from each participant for a total of 40 recordings from the entire participant sample.

Data analysis

Thirty-two naïve listeners without prior exposure to Parkinsonian speech evaluated the speech intelligibility of clinical and healthy group participants before and during administration of AAF. The listeners were recruited from the student population at Oklahoma State University. The listeners were screened for hearing loss prior to their participation. They were instructed on how to rate the speech intelligibility using a seven-point intelligibility rating scale. The listening task was conducted in a spacious lab space that was free from visual and auditory distraction. The listeners were presented with 40 recorded speech samples in a random fashion through high-fidelity headphones. After presentation of each speech sample, the participants were given a maximum of one minute to rate the intelligibility of the speech sample. A mean rating for each of the four recorded samples from the thirty-two listeners were determined for the purpose of statistical analysis.

Statistical analysis

The data was analyzed using SPSS 23.0 for statistical analysis. The mean speech intelligibility ratings for each of the four speech samples were subjected to 2*2*2 mixed model analysis of variance (ANOVA). The data was analyzed as a function of participant groups, AAF, and speech sample. The between group factor was groups (clinical and healthy), whereas the within-group factors were feedback (during AFF and pre-AAF) phases, as well as the speech sample (dialogue and passage).

CHAPTER III

CONCLUSION

Results

The findings from the mixed-model ANOVA revealed that there was a significant main effect of the feedback, F (1, 318) = 20.92, $p < .05$. Overall, the participants had a better rating with AAF (M =1.72, SD =. 97) versus pre-AAF (M =1.90, SD = 1.09). Participants exhibited significantly better speech intelligibility when involved in reading passage (M =1.75, SD = .98) when compared to dialogue task (M =1.88, SD = 1.03), F (1, 318) = 14.69, $p < .05$. These main effects of sample and feedback were qualified by significant interactions of sample * feedback, F (1, 318) = 9.81, $p < .05$, sample * group, F (1, 318) = 8.19, $p < .05$ and group* feedback, F (1, 198) = 20.19, $p < .05$. Post hoc analysis was carried out for each of these interaction terms.

Multiple comparisons using Bonferoni correction revealed that overall when participants were involved in both the tasks their intelligibility was better during AAF than pre-AAF condition ($p < .05$). Participants had higher intelligibility scores for reading the passage (M = 1.70) than dialogue task (M = 1.74) during AAF. In pre-AAF condition also participants had better intelligibility for reading passage (M = 1.78) when compared to dialogue task (M = 2.02). The mean intelligibility ratings for the dialogue task are visually illustrated in Figure 1. The mean intelligibility ratings for the reading task are visually represented in Figure 2. Post hoc analysis of interactions revealed that the participants in both groups (clinical and healthy) performed better on reading passage when compared to dialogue task ($p < .05$).

Participants in the clinical group had better intelligibility scores for reading passage (M = 1.96) when compared to dialogue task (M = 2.20). Healthy participants also showed better intelligibility ratings for reading passage (M = 1.52) over dialogue task (M = 1.56). Further analysis of group* feedback revealed that participants in the clinical group performed better with AAF (M = 1.91) when compared to pre-AAF condition (M = 2.26) ($p < .05$). Healthy group participants did not show any difference in speech intelligibility with and pre-AAF conditions (M=1.54).

The mean speech intelligibility rating of participants across two groups; PD and control were significantly different from one another, F (1, 318) = 24.51, $p < .05$. The participants in the control group (M =1.55, SD =1.38) were rated higher on speech intelligibility when compared to those in the clinical group (M = 2.01, SD = 1.38).

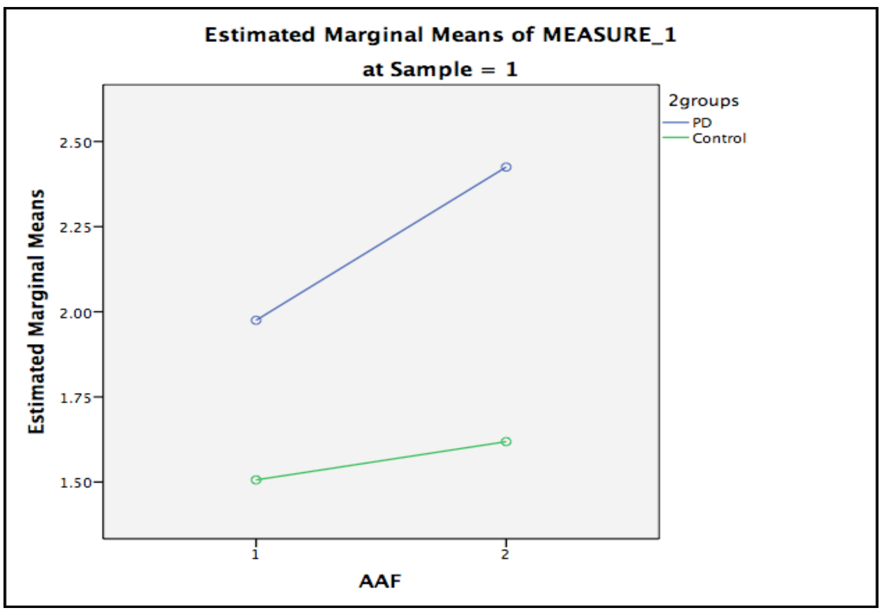

Figure 1. Mean speech intelligibility rating of both the groups during and pre-AAF for dialogue task

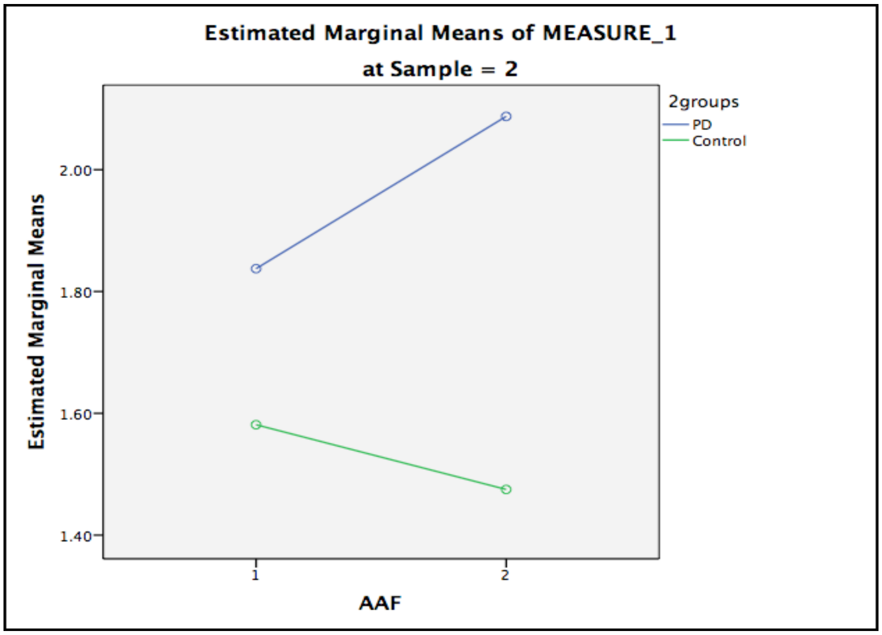

Figure 2. Mean speech intelligibility rating of both the groups during and pre-AAF for reading task

Discussion

The aim of the current study was to evaluate the speech intelligibility in individuals with PD following rate modification using AAF in comparison to age-matched healthy controls. The findings of this study revealed that altering speech feedback by 150 milliseconds and 1/20 an octave higher produced significantly greater speech intelligibility in people with Parkinson's disease when compared to healthy controls. The healthy participants did not produce significant effects on intelligibility when delivered the same feedback. It was anticipated that delivering delayed auditory feedback of 150 milliseconds and altering frequency by 1/20 an octave higher would increase intelligibility in individuals diagnosed with PD by slowing down their speaking rate. It was also anticipated that AAF would decrease speech intelligibility in healthy controls as perceived by listeners. Another prediction was that intelligibility would be greater for individuals with PD when reading a passage than when speaking a monologue, both without the inclusion of AAF and with the inclusion of AAF. This was hypothesized due to the differences in the cognitive load involved in reading a passage versus producing a monologue (Sidtis, Cameron, & Sidtis 2012). These findings are discussed below.

Interestingly, one of the current findings suggests that the stimulus task influences the speech intelligibility outcomes. The participants demonstrated better speech intelligibility while reading a passage in comparison to monologue. It was also accurately predicted that the clinical group would be more intelligible when reading a passage versus speaking a monologue. Sidtis, Cameron, and Sidtis (2012) investigated the amount of dysfluencies produced by a participant with Parkinsonian Syndrome during speech tasks such as conversation, reading, repetition, recited speech, and singing. The results showed that the highest amount of dysfluencies occurred during the conversational measure, versus the measures where external stimuli was provided such as reading. In a dialogue task, individuals are planning and monitoring their own speech, whereas during reading this cognitive load is lifted (Sidtis, Cameron, and Sidtis, 2012). This supports the results of the present study in that participants produced more intelligible speech when presented with external stimuli (reading the passage), therefore reducing higher cognitive demands while speaking.

Another finding in the current study was that AAF had a significant effect on enhancing speech intelligibility in individuals with PD when compared to healthy controls. Rousseau & Watts (2002) investigated the effects of a 50-millisecond delay and a 150 millisecond delay on the speech rate and intelligibility in individuals with PD when reading various sentences. Participants were divided into a low intelligible group with PD, highly intelligible group with PD, and a control group. Results of the study revealed that both DAF conditions produced slower rates of speech across all groups of participants. It was also found that the slower rates produced by the DAF led to increased intelligibility in the low intelligible group, decreased intelligibility in the highly intelligible group, and unchanged intelligibility in the control group. These findings suggest that different participants respond to DAF differently. This also points to the possibility that the clinical participants in the present study were of lower intelligibility levels prior to the introduction of AAF, and thus responded positively to the feedback.

Blanchet & Hoffman (2014) investigated the effects of four different feedback conditions (0ms, 50ms, 100ms, and 150ms) in three males with PD. The authors discuss previous literature and how DAF typically slows down an individual's rate of speech by elongating vowels and steadying syllable lengths. DAF creates the perception that speech is farther behind than it really is, permitting the speaker to prolong speech sounds in an effort to allow the feedback to catch up with their real-time production of speech (Blanchet & Hoffman, 2014). This perception results in reduced speech rates and greater intelligibility of speech. The results of the study concluded that the delivery of DAF produced significantly slower speech rates in all three participants. The use of DAF also led to a statistically significant increase in intelligibility in the third speaker and a statistically significant increase in fluency in the first and second speakers. A delay of 150 milliseconds was found to be the most effective time delay for rate reduction in the three participants. The authors expected this result, as a 150-millisecond delay presents with the largest time gap between production and perception of the production, allowing for the greatest amount of prolonged syllables. Goldiamond, Atkinson, & Bilger (1962) looked at a delayed auditory stimulus and its effects in encouraging the speaker to extend vowel nuclei of words and therefore match their speech production with the auditory feedback stimulus. This allows the two stimuli to overlap for an instant and this elongation of vowels results in the reduction of speech rate. These findings suggest that the presentation of AAF in the present study assisted in slowing down the speech rates of the clinical participants, therefore allowing them to perceive their speech as behind, encouraging them to prolong sound productions. The productions of slower speech rates, as opposed to the festinating speech rates commonly found in individuals with PD, resulted in the perception of increased speech intelligibility in the clinical group. Due to the reduction of speech rate with AAF, the naïve listeners had more time to process the speech of the clinical group, in contrast to their typically festinating rate. This contributed to higher intelligibility ratings.

Yorkston, Strand, & Kennedy (1996) discuss different factors that lead to increased perception of speech comprehensibility and intelligibility in individuals with dysarthria. A figure in this paper demonstrates how quality of an acoustic signal directly effects how intelligible a person with dysarthria's speech is when processed by a listener. Shown in the figure are two areas that affect the quality of an acoustic signal, such as speech impairment and compensatory strategies. One of the compensatory strategies listed to enhance the acoustic signal produced by individuals with dysarthria is rate reduction. This leads to greater speech intelligibility as perceived by listener processing. This paper supports the findings of the present study that reduction in the rate of clinical participants through AAF led to increased intelligibly ratings as processed by listeners due to enhancement of the acoustic signal.

The results of the Lowit et al. (2010) study also suggest that individuals respond differently to different types of feedback, with some of their participants improving in intelligibility, some digressing, and some remaining the same. Lowit et al. (2010) also mentions that AAF has been found to be most affective when used with longer productions of speech versus shorter productions of speech (i.e. words or sentences). This may be a contributing factor to the present study's positive results with AAF, due to the fact that both stimulus tasks required speech productions that were longer in duration. Further outcomes of Lowit et al. (2010) evaluated the effects of various types of AAF on speech rate through the number of syllables per second. Results revealed that AAF induced significantly slower speech rates, with a DAF of 150 milliseconds producing the slowest speech rates in participants with PD. Another study by Hanson & Metter (1980) investigated DAF on a 59-year-old male with progressive supranuclear palsy, a degenerative disease with symptoms common of PD. This study investigated the participant's speech intelligibility before and during DAF of 100 milliseconds while reading the

Grandfather passage and while counting aloud. Results found that when judged by a 7-point scale similar to the scale of the present study, the participant's speech intelligibility was found to markedly increase while receiving DAF both when reading a passage and when counting. Van Nuffelen et. al. (2010) investigated various rate control methods on 27 participants with numerous kinds of dysarthria. Results of the study found that delayed feedback of 50 milliseconds and 100 milliseconds both significantly increased the speech intelligibility of four participants with dysarthria, and a delay of 150 milliseconds significantly increased the intelligibility of one participant with dysarthria. Overall their study found that rate reduction methods including DAF, could be beneficial for enhancing intelligibility in individuals with dysarthria.

It is also possible that a contributing reason that clinical participants in the present study yielded significant results in increase in intelligibility is their average score on the MoCA falling within normal range. Therefore, it is reasonable to believe that they had the cognitive abilities to undergo the altered feedback without negative effects. Furthermore, the present study looked at DAF of 150 milliseconds in conjunction with FSF of 1/20 an octave higher. Most of the previous studies have looked at octave increases of ½ an octave or 1 octave. Perhaps the smaller adjustment in frequency along with the DAF of 150 milliseconds contributed to the significant gains seen in the clinical population. The present study is not in contradiction with the literature, as many of the previous studies have found various methods of AAF to be beneficial for at least some of the participants. Further research is warranted to decipher what is the optimum delay for increasing speech intelligibility in people with PD.

However, the control group did not show a significant effect on intelligibility with AAF administration versus pre AAF administration, which contradicts what was predicted. This proposes the question of why their intelligibility of speech was not improved, as well as why their intelligibility of speech was not degenerated. This lack of improvement may be attributed to the fact that healthy adults without associated problems of sensory/motor processing will have the intact cognitive necessities for adequate speech intelligibility without the aid of external influences such as AAF. Since healthy individuals do not have a lack of dopamine in the basal ganglia network that contributes to the festinating speech of people with PD, their overall speech intelligibility will be greater due to the absence of these deficits (Blandini, Nappi, Tassorelli, & Martignoni, 2000). If these participants are already producing intelligible speech without the assistance of AAF, then it is reasonable to propose that they are speaking at a near maximum level of intelligibility. Any increase in intelligibility would therefore not be large enough to produce a significant result. The reason for the administration of AAF not having a significantly negative effect on the intelligibility of healthy controls could be attributed to their cognitive scores on the MoCA and its suggestion of the overall intact cognitive function of healthy individuals ("Parkinson's Disease Research," 2007). These factors suggest that the healthy controls had the cognitive capacities to undergo speaking with AAF and have no significant negative effects on their speech intelligibility.

A strength of this study is the use of a control group, allowing effects to be compared across a clinical population and a healthy population. A limitation of this study is the low sample size, causing results that are unable to be generalized to the rest of the population. Therefore, future studies should investigate the effects of AAF on the speech intelligibility of a greater number of people with PD when compared with healthy controls. It would be interesting as well, if future studies looked at people with a diagnosis of PD in the different stages of disease severity, and how they each respond to feedback such as AAF, DAF, or FSF.

Overall, this study supports the use of AAF to improve the speech intelligibility in individuals diagnosed with PD both while involved in a dialogue and reading task. This presenting evidence should encourage future studies to investigate these effects on larger populations.

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APPENDICES

Oklahoma State University Institutional Review Board

Date:	Tuesday, May 23, 2017
IRB Application No	AS1722
Proposal Title:	Investigating speech production and perception in individuals with and without Parkinson's disease
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved Protocol Expires: 5/22/2018

Principal Investigator(s):

Ramesh Kaipa 042 Murray Hall Stillwater, OK 74078	Chelsea McQuigg Stillwater, OK 74078	Natalie Miller Stillwater, OK 74078
Shea Walker Stillwater, OK 74078		

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

Oklahoma State University Institutional Review Board

Date:	Thursday, January 25, 2018	**Protocol Expires: 5/22/2018**
IRB Application No:	AS1722	
Proposal Title:	Investigating speech production and perception in individuals with and without Parkinson's disease	
Reviewed and Processed as:	Expedited **Modification**	

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

Ramesh Kaipa 042 Murray Hall Stillwater, OK 74078	Chelsea McQuigg Stillwater, OK 74078	Natalie Miller Stillwater, OK 74078
Shea Walker Stillwater, OK 74078		

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Mod to recruit 50 naïve listeners from the SONA system to rate the speech intelligibility of participants with PD from experiment 3 of the study.

Signature :

Hugh Crethar, Chair, Institutional Review Board

Thursday, January 25, 2018
Date

VITA

NATALIE LYN MCLAIN

Candidate for the Degree of

Master of Science

Thesis: PERCEPTUAL EVALUATION OF SPEECH INTELLIGIBILITY OF INDIVIDUALS WITH PARKINSON'S DISEASE FOLLOWING SPEECH RATE MODIFICATION THROUGH ALTERED AUDITORY FEEDBACK

Major Field: Communication Sciences and Disorders

Biographical:

Education:

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

Completed the requirements for the Bachelor of Science in Communication Sciences and Disorders at Oklahoma State University, Stillwater, Oklahoma in May, 2016.

Experience:

Professional Memberships: