

2011

Using the ambulatory phonation monitor to measure the vocal parameters of older people with and without Parkinson's disease

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USING THE AMBULATORY PHONATION MONITOR TO MEASURE THE VOCAL
PARAMETERS OF OLDER PEOPLE WITH AND WITHOUT PARKINSON'S DISEASE

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Communication Sciences and Disorders

by
Danielle Marie Boudreaux
B.A., Louisiana State University, 2009
May 2011

ACKNOWLEDGMENTS

This project was by no means the result of one individual's efforts. Without those who are so close to me I would not have found the courage to forge on to the finish line. To Dr. Neila Donvoan, my thesis mentor, I am not sure how to express how much respect and gratitude I have for you. You have taught me so much and provided me with a sense of confidence in myself. To Dr. Hoffman and Dr. Kim, my thesis committee members, I would like to thank you for all of your help, insight, and encouragement that you provided throughout this time. To Meghan C. Savage, soon to be Dr. Savage, I don't think that I will ever be able to thank you enough for all of your help. I know how extremely busy you are, but you always found the time to help me with every problem, big or small, that I encountered. To my parents, grandparents, and family, thank you for always being there to support me through everything that I do. Without my family I would not be the person I am today, nor would I have been able to experience the things in life that I have. With love and support, they have instilled a sense of courage and confidence that has allowed me to accomplish so many things in my life. There are no words to express my appreciation and gratitude towards you all. To Gamee, Ganded, MawMaw, and Uncle Jr., thank you for willing to participate in all of the crazy projects I have asked you to. I never had to search far for support. To my COMD friends, our time has certainly been marked by monumental achievements, and I am sad to see our tome come to a close. To Meredith and Maisie, I know that you two are always one phone call away for anything I might need. Last but certainly not least by any means, to Kody and Moose, I am not sure how I would have made it through this process without you. The support, encouragement, and love you give is never ending. You have guided me to grow into a better person, and I thank you for everything you have done and for always standing by me no matter what. As sad as I am to see this chapter of my life come to a close, I am excited to see what the future holds.

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ABSTRACT

Our project was designed to determine if there was a difference in vocal parameters, including mean fundamental frequency, mean amplitude, and total phonation time, between individuals diagnosed with Parkinson's disease (PD) and age-and gender-matched individuals without a diagnosis of any neurologic or neurodegenerative diseases (NO PD) using the Ambulatory Phonation Monitor (APM: KayPENTAX, Lincoln Park, New Jersey). The APM was designed to gather objective data in a naturalistic environment by having participants wear the device over the course of three 8-hour days. The APM measured total phonation time, mean amplitude, and mean fundamental frequency throughout that time. The participants wore the APM on what they deemed "typical" days where similar routines were observed and "out of the ordinary" activities did not occur. Data collection was repeated three times to establish the reliability of the data collected. Descriptive statistics and two-way repeated measure ANOVA were computed using SPSS.

NO PD group exhibited significantly higher mean amplitudes in comparison to the PD group. The two groups did not differ in mean fundamental frequency or phonation time. When asked to estimate the amount of talking time, the PD group overestimated their talk time significantly more than the NO PD group. These data suggest that variability of vocal parameters exist among individuals diagnosed with PD and age matched individuals with no diagnosis of neurologic or neurodegenerative disease.

LITERATURE REVIEW

Parkinson's disease (PD) is a progressive, neurodegenerative disease that has many debilitating effects on an individual's life (NINDS, 2010; Spencer, Sanchez, McAllen, & Weir, 2010). Motor speech deficits are included among the documented effects of PD. Surprisingly, no one has attempted to use objective methods to study how these deficits may impact the individual's daily speaking habits. Until recently, researchers have not been able to gather objective data concerning vocal parameters beyond the clinical setting. However, technology has presented the opportunity to do so. By using the Ambulatory Phonation Monitor (APM) Model 3200 from KayPENTAX, data measuring vocal parameters across an extended period of time can be gathered. The APM was designed to inconspicuously and accurately capture a participant's daily speech habits and vocal characteristics over an eight hour time span. The current study was designed to determine if there were differences in vocal parameters including mean fundamental frequency, mean amplitude, and total phonation time using the APM, between individuals diagnosed with PD and age- and gender-matched individuals without a diagnosis of any neurologic or neurodegenerative diseases.

This review of the literature first provides the reader with foundational information about PD and its effect on motor speech components, followed by review of the APM research. Finally, a review of the literature focusing on the vocal parameters measured by the APM (mean fundamental frequency, mean amplitude, and phonation time) as characteristic of PD is provided.

Parkinson's Disease

Parkinson's disease is a progressive, neurodegenerative disease that affects the central nervous system (NINDS, 2010). Parkinson's targets the substantia nigra in the basal ganglia leading to a degeneration of dopaminergic neurons (Spencer et al., 2010). It is estimated that in

the United States more than 500,000 people suffer from this debilitating disease (NINDS, 2010). According to the National Institute of Neurological Disorders and Stroke (2010), the average age of onset for PD is sixty years old. About five to ten percent of those affected by the disease have been diagnosed with “early-onset” PD, which is diagnosed before the age of fifty (NINDS, 2010). Higher rates of the disease are found in males, as nearly fifty percent more men than women suffer from the disease (NINDS, 2010). Interestingly, the incidence of PD is higher in developed countries. This is possibly due to an increased exposure to toxins (NINDS, 2010).

Numerous debilitating symptoms accompany PD. The symptoms most encountered include tremor, rigidity, bradykinesia/akinesia, and postural abnormalities (Fernandez, Rodriguez, Skidmore, & Okun, 2007; Spencer et al., 2010; Watts & Koller, 2004). The predominant symptom of PD is muscular tremor. Another symptom of PD is rigidity, a stiff posture of the limbs and trunk (NINDS, 2010). Rigidity causes “jerky” movements, which are commonly exhibited by individuals diagnosed with PD (NINDS, 2010). Slowing initiation and executing movements is referred to as bradykinesia (Spencer et al., 2010). Akinesia, yet another neuromuscular symptom of PD, refers to the lack of the ability to initiate actions (Spencer et al., 2010). Finally, postural abnormalities or instability are characteristic of individuals with PD. This symptom is due to impaired balance, and is the cause of a stooped posture that is commonly adopted by individuals with PD (IwPD) (NINDS, 2010).

Secondary neurological deficits that may accompany PD include dysarthria, dysphagia, cognitive decline, sensory processing deficits, psychiatric disturbance, and sleep disturbances (Spencer et al., 2010). The most common speech deficit observed in PD is hypokinetic dysarthria (Duffy, 2005; Spencer et al., 2010). Characteristics of hypokinetic dysarthria include a decreased volume, monopitch, monoloudness, prosodic insufficiency, imprecise consonants, inappropriate

silences, short rushes of speech, variable rate, and repeated phonemes (Duffy, 2005; Gamboa et al., 1997; Spencer et al., 2010).

Much of the research in the field of communication disorders and PD focuses on the reduced amplitude (perceptually called loudness) that interferes with successful communication (Canter, 1963; Duffy, 2005; Fox & Ramig, 1997; Ramig, Sapir, Fox, & Countryman, 2001; Scott & Caird, 1983; Stewart et al., 1995). Therefore therapies exist that focus on increasing vocal amplitude. Few studies have focused on examining fundamental frequency (perceptually called pitch) and total phonation time in relation to PD. Gamboa et al. (1997) noted higher mean fundamental frequencies in males diagnosed with PD when compared to a control group is comprised of 16 males and 12 women with a mean age of 67 years with a $SD=6.8$ years. Midi et al. (2008) found a higher fundamental frequency in individuals with PD compared to gender matched control individuals. This increase was attributed to the rigid state of the laryngeal muscles found in Parkinson's sufferers (Midi et al., 2008). No literature examining a correlation between a diagnosis of PD and phonation time was found.

Up to now vocal parameters (i.e. amplitude and fundamental frequency) have been measured in the laboratory. The results of these measures may have questionable ecological validity for predicting how an individual with PD will use his/her voice in everyday speaking situations. Objective measures that can be obtained in the client's natural environment are needed before we can assess the outcome of a treatment that aims to increase vocal loudness (i.e. amplitude). At the current time the only alternative available is the APM, which will be discussed next.

Ambulatory Phonation Monitor

When it comes to measuring vocal behaviors outside of the clinical setting, researchers often rely on subjective data supplied by the patient. However, these data rely on the client's ability to self-report and self-monitor, and may not be completely accurate (Hillman, Heaton, Masaki, Zeitels, & Cheyne, 2006). Out of necessity for a means to collect objective data the Ambulatory Phonation Monitor (APM) by KayPENTAX emerged. The APM was designed for mobility and functionality by 1) being small enough for a person to carry or wear all day, 2) being light weight, and 3) having an operational battery life for 10 or more hours (Ohlsson, Brink, and Lofqvist, 1989). The APM allows the clinician to collect objective vocal data in a person's natural environment (i.e. beyond the clinical setting). The APM uses a small accelerometer sensor placed above the sternal notch. It collects data by measuring skin vibrations (Popolo, Svec, & Titze, 2005). The sensor is connected to the processor by a thin wire.

There are many advantages of the accelerometer compared to a microphone. One main advantage of the accelerometer is that it virtually eliminates background noises compared to a microphone (Popolo et al., 2005). Background noise is reduced because the accelerometer collects data through vibrations rather than sound recordings. When background noises exceed 80 dB speech detection decreases (Airo, Olkinuora, & Sala, 2000). Hillman et al. (2006) suggested that the data gathered by the accelerometer "may represent a more robust approach for estimating phonation parameters in disordered voices" (page 800). With use of a contact microphone, the exact timing of voiced speech is impossible to determine (Airo et al., 2000). Another benefit of the APM is that ethical questions about privacy issues that result from using a microphone and recorder to collect vocal data are negated (Ryu, Komiyama, Kannae, & Watanabe, 1983) since the accelerometer utilizes vibrations from the skin without recording

actual words. One could hypothesize that if an individual is not concerned with “what is being recorded” that he might speak more freely. However that is an empirical question at this time.

Fundamental frequency estimations collected by the accelerometer are equivalent to those collected by a microphone (Hillman et al., 2006). However, several situations may lead to the collection of inaccurate data. The integrity of the bond between the client’s skin and the sensor itself should not be compromised. Data may become skewed or inaccurately measured if a gap forms between the two surfaces (Popolo et al., 2005). Another problem experienced while using an accelerometer is encountered when observing data collected on sound pressure levels (SPL). Svec et al. (2005) noted variability between the correlation of SPLs gathered by a microphone and the accelerometer estimated at ± 6 dB for males and ± 5 dB for females.

In addition to collecting objective data for voice amplitude and fundamental frequency in a naturalistic way, the APM is able to gather data continuously for up to approximately 10 hours if needed. In the study of individuals with communication disorders, the continuous data collection could be useful for identification of how behaviors change over the course of a day. This area is ripe for research since little is known about how much individuals of any age, with or without neurologic disease, talk over the course of a day. In sum, the APM does allow the clinician or researcher to gather objective data without subjective patient-reported input, and to protect the privacy of the individuals.

What follows is the state-of-the art information on known measures of the vocal parameters measured by the APM, amplitude and fundamental frequency. These will be used as comparisons for the results of this study. However, as stated above, the question about ecological validity has yet to be explored. Therefore we expect there may be differences in vocal parameter

measures when comparing normative data resulting from clinical collection to data collected in a naturalistic setting.

Fundamental Frequency

In healthy individuals, many vocal parameters change with age. One characteristic known to change is fundamental frequency. Fundamental frequency is the “lowest periodic component of vocal fold vibration” (Kent & Read, 2002). Research has shown that fundamental frequency increases with age in healthy males and decreases with age in healthy females (Decoster & Debruyne, 1997; Higgins & Saxman, 1991; Hollien & Shipp, 1972; Nishio & Niimi, 2008; Russell, Penny, & Pemberton, 1995). A change in fundamental frequency has also been reported associated with the progression of PD within an individual (Gamboa et al., 1997; Midi et al., 2008).

The significant increase in males has been observed to occur around the age of 70 (Hollien & Shipp, 1972; Nishio & Niimi, 2008). When Hollien and Shipp (1972) compared fundamental frequency changes in males between decades, no significant deviation was measured. However, when they compared results from the 20-29 age group to the 70-79 age group, a drastic increase in fundamental frequency was noted. This supported the results of previous studies (Decoster & Debruyne, 1997; Higgins & Saxman, 1991; Hollien & Shipp, 1972; Nishio & Niimi, 2008; Russell, Penny, & Pemberton, 1995). Some researchers attributed this raise in fundamental frequency to hormonal changes (Decoster & Debruyne, 1997; Hollien & Shipp, 1972). It is believed that a decrease in the amount of testosterone released in the male body around the age of 70 is responsible for the change in fundamental frequency. Alternatively, Kahane (1987) attributes the increase in fundamental frequency to age dependent vocal fold atrophy and stiffening of the vocal tissue.

Most research has conclusively shown that the decrease in fundamental frequency in women is due to hormonal changes around menopause (Decoster & Debruyne, 1997; Higgins & Saxman, 1991; Russell et al., 1995). As stated by Nishio and Niimi (2008), a much greater change in fundamental frequency is seen in females than in males. However, some research does not support the hypothesis that fundamental frequency changes with ageing in either males or females. For example, Ramig and Ringel (1983) found that “no significant age-related differences were observed in mean fundamental frequency” (page 28) in a study comparing voice samples of 48 males group into three different age categories (25-35, 45-55, and 65-75).

A change in fundamental frequency has also been reported associated with the progression of PD within an individual (Gamboa et al., 1997; Midi et al., 2008). A study by Gamboa et al. (1997) showed that males with PD treated with dopaminergic drugs exhibited a higher fundamental frequency when compared to matched control subjects. In 2008, Midi et al. conducted a study that coincides with the findings from the previously mentioned study. In the study by Midi et al. (2008), individuals diagnosed with PD exhibited higher fundamental frequency than gender matched individuals from the control group. Midi et al. (2008) suspected that the elevated frequency average was contributed to rigidity of the laryngeal muscular structures. Rigidity of the laryngeal muscles may also attribute a breathy vocal quality to persons diagnosed with PD (Darley, Aronson, & Brown, 1969).

Amplitude

The motor speech disorder hypokinetic dysarthria is most commonly associated with PD (Duffy, 2005; Stewart et al., 1995). Hypokinetic dysarthria is characterized by a reduction in loudness or amplitude, a reduction in pitch inflection, a reduction in range of articulatory movements, short rushes of speech, and stuttering (Fox & Ramig, 1997; Ramig et al., 2001; Scott

& Caird, 1983; Stewart et al., 1995). Hypokinetic dysarthria is estimated to occur in 70-89% of individuals affected by PD (Darley et al., 1969; Duffy, 2005).

A reduction in vocal intensity, or amplitude, has frequently been reported as a major speech deficit associated with PD (Canter, 1963). In a study by Canter (1965) individuals with PD “showed a reduced ability to produce “loud” and “shouted” phonations.” Fox and Ramig (1997) perceived this inability to produce elevated phonations as a perceptual issue. The study by Fox and Ramig (1997) revealed on average, individuals with PD demonstrated a reduction of 2.0-4.0dB SPL across all speech tasks. This characteristic has been noted by family members and close friends of individuals afflicted by PD well before the disease has been diagnosed by a physician (Tetrud, 1991). Clinical observation suggests that individuals with PD may have impaired perception of vocal abilities. This may be related to impairment in a patient’s self-monitoring abilities during specific motor speech tasks (Solomon, Robin, Lorell, Rodnitzky, & Luschei, 1994). This perceptual difference was not attributed to any form of hearing loss (Solomon et al., 1994).

These findings regarding reduced vocal intensity in conjunction with PD have all been conducted in a clinical setting. As stated by Adams and Dykstra (2009), “Patients with PD may not use their habitual speech intensity levels in the unnatural context of the laboratory or speech clinic. Therefore, methods for obtaining acoustic measures of speech intensity outside of the clinical setting may need to be developed to establish valid estimates of hypophonia in PD” (p. 169).

Phonation Time

At one time, subjective reports from patients was all that researchers could rely upon when gathering data about an individual’s speaking habits beyond the clinical setting. Ohlsson et

al., (1989) found that individuals tend to overestimate the amount of talking they do in a given day. Little research exists that defines the average amount of speaking done by an individual during an entire day. This may be due to the extensive variability between individuals' personalities, vocations, and educational levels for example. Ryu et al. (1983) conducted a study that measured speaking time for 11 individuals including a bus driver, physician, pediatric nurse, and clerk. The average speaking time collected was 110 minutes a day (Ryu et al., 1983). Another study by Watanabe, Shin, Oda, Fukaura, and Komiyama in 1987 examined speaking time in relation to occupation. This study averaged speaking time of twenty control subjects consisting of: three doctors, five nurses, four company employees, four housewives, and four medical students (Watanabe et al., 1987). The mean speaking time across all occupations was 6 minutes and 25 seconds per hour \pm 1 minute and 36 seconds (Watanabe et al., 1987). The literature review did not reveal any studies focusing on the difference in average speaking times for individuals in relation to age or specific neurologic disorders. Our pilot data for two individuals with PD found an average phonation time of 11.25 minute over an average 8.25 hour time span.

Contemporary approaches, tools, and techniques have allowed for greater flexibility in gathering phonation data. The APM now allows researchers to study phonation patterns by collecting objective data in a natural setting without having to rely on subjective patient self-report. The capability to collect objective measures of vocal parameters in a person's everyday speaking environment might serve as a valuable pre- and post-treatment treatment outcome for individuals with PD and dysarthria who undergo therapy to increase vocal loudness. It certainly appears that it provides a more ecologically valid measure of vocal parameters than those typically gathered in the clinic. However, there are many unknowns, which led to this study's purpose.

Experimental Questions

This study will focus on determining whether a difference in vocal parameters, including mean fundamental frequency, mean amplitude, and total phonation time, exists between individuals diagnosed with PD and age-and gender-matched individuals without a diagnosis of any neurologic or neurodegenerative diseases. The experimental questions that this study aims to answer are:

1. Is there a comparable difference in mean fundamental frequency between the NO PD group and the PD group?

Based on a review of the literature, it is hypothesized that participants diagnosed with PD will have a higher mean fundamental frequency in comparison to individuals without PD.

2. Is there a comparable difference in mean amplitude between the NO PD group and the PD group?

A review of the literature supports the hypothesis that participants diagnosed with PD will have decreased mean amplitudes compared to healthy individuals.

3. Is there a comparable difference in total phonation time between the NO PD group and the PD group?

Anecdotal evidence supports the hypothesis that participants diagnosed with PD will have a reduced total phonation time in comparison to individuals without PD.

METHODS

This is a prospective, between-group study on the effect a diagnosis of PD has on phonation time, amplitude, and fundamental frequency in comparison to age- and gender-matched individuals using the APM to measure dependent variables. This study is defined as a Phase I study based on the five-phase model described by Robey (2004). “Phase I research is comprised of case studies, discovery-oriented single-subject studies, small group pre-post studies, and retrospective studies” (p. 404, Robey, 2004). Due to small sample size and frequent variance errors, Type I errors are allowed (Robey, 2004). This study proposal was approved by the Louisiana State University Institutional Review Board for the protection of human subjects prior to enrollment of subjects and data collection. Informed consent was collected from all participants.

Subjects

10 community-dwelling individuals over the age of 65 years old were recruited to participate in this study. Two groups of 5 were created, a PD group (PD group) and a non-PD group (NO PD group). Participants for the PD group in this study were recruited from the Louisiana State University Speech, Language, and Hearing Clinic and the Baton Rouge PD Support Group. The individuals must have met the following inclusion criteria: 1) a diagnosis of PD (as diagnosed by a neurologist), 2) no history of or evidence of neurologic or neurodegenerative disease other than PD, 3) a Hoehn & Yahr Rating of PD (Hoehn & Yahr, 1967) between 1 and 3, 4) a Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) score >24, 5) an Apathy Scale (Starkstein et al., 1992) rating <14, 6.) a Geriatric Depression Scale (GDS) Short Form (Sheikh & Yesavage, 1986) score of <10, and 7) participants had adequate hearing as determined by patient report and conversational interaction.

Participants for the NO PD group were recruited from the Baton Rouge/New Orleans area. The healthy individuals must have met the following inclusion criteria: 1) no history or evidence of neurologic or neurodegenerative diseases, 2) a Mini Mental State Examination (Folstein et al., 1975) score >24, 3) an Apathy Scale (Starkstein et al., 1992) rating <14, 4) a Geriatric Depression Scale (GDS) Short Form (Sheikh & Yesavage, 1986) Score of <10, and 5) adequate hearing as determined by patient report and conversational interaction. Subjects were excluded from the current study based on the following criteria: (1) dementia, (2) apathy, or (3) depression.

Frequently, people with PD tend to exhibit symptoms of breathiness (Adams & Dykstra, 2009). A breathy vocal quality, which “correspond to presence of a glottal gap” (Kreiman & Gerratt, 2000), could affect data gathered by the APM. Kreiman, Gerratt, Precoda, and Berke (1992) have suggested that breathy voice quality can be assessed by comparing the amplitudes of the first harmonic amplitude (H1) and second harmonic (H2) of vowels. As stated by Hartl, Hans, Vaissiere, and Brasnu (2003), “An increase in H1-H2 has been correlated with breathy phonation in normal voices” (page 179). As part of the inclusion criteria, the participants were asked to read two sentences which were then assessed for breathiness using TF32.exe (Milenkovic, 2004). The H1-H2 of the same vowels were analyzed and compared to test whether the PD group exhibited more breathy qualities of the voice than the NO PD group. The PD group did not demonstrate greater ranges of H1-H2 values; therefore this group did not exhibit more breathy qualities in comparison to the NO PD group.

Design

The present prospective phase 1 study examined whether a difference existed in vocal parameters, including mean fundamental frequency, mean amplitude, and total phonation time,

between two groups, NO PD group and PD group, across an 8-hour day as measured by the APM. We hypothesized that there would be statistically significant differences in all three vocal parameters based on the literature. To test the hypotheses, we used a between-group two-way repeated-measures mixed design. Participants from the PD group and the NO PD group wore the APM for 8 hours on 3 separate days. The independent variables in this study were the inclusion criterion of each group: a diagnosis of PD or no diagnosis of neurologic disorders. The dependent variables included: mean amplitude, mean fundamental frequency, and total phonation time.

Procedures

Calibration was completed at the LSU Communication Outcomes Research Laboratory or in the participant's home. The procedures for operation of the APM-Model 3200 followed the manufactures (KayPENTAX) protocol. Prior to a full day's use, standardized preparation protocol was followed; 1) the APM was connected to a computer, 2) a patient file was created, 3) the sensor was placed on the patient, 4) the APM was calibrated according to manufacturer's instructions (APM: KayPENTAX, Lincoln Park, New Jersey).

In order to calibrate the APM to each participant's vocal parameters, the device was connected to a designated microphone, with a 15 cm distance guide from the mouth to ensure a consistent mouth-to-microphone distance. The investigator ensured accelerometer was properly affixed. The APM was connected to a computer, and the green light was on, indicating that the APM was powered (APM: KayPENTAX, Lincoln Park, New Jersey).

Once the APM was connected to the microphone, computer, and the batteries were in place, a patient file was created. When the APM program was opened the "Select activity" box appears. In this box the "Configure and acquire data on the APM" selection was made. The

“New Patient” button was selected to input patient information and the calibration phase begun. Once the patient information was entered, the accelerometer sensor was attached to the patient’s throat. The sensor was attached to the neck at midline in the hollow area above the sternal notch and below the larynx using the secure adhesive glue. Once a secure bond was ensured between the patient’s skin and the sensor, the patient fed the wire from the sensor down his/her shirt exiting at the waist. This end of the wire was plugged into the APM (APM: KayPENTAX, Lincoln Park, New Jersey).

The device was calibrated to each individual in order to obtain the most accurate vocal parameter measures. The patient was seated facing the microphone with the distance guide place in between the base of the nose and the top of the upper lip. The patient was directed to sustain a phonation beginning softly and increasing his volume to the loudest that he/she could produce during the calibration process. Once the instructions were clearly stated to the patient, the clinician selected “Calibrate,” and the patient produced the “/a/” phonation. As the phonation was being produced, the program displayed dots and a straight red line representing the calibration of the sound pressure levels measured by the microphone and the throat sensor (APM: KayPENTAX, Lincoln Park, New Jersey). Once the calibration was achieved, the clinician selected “Stop Calibration”.

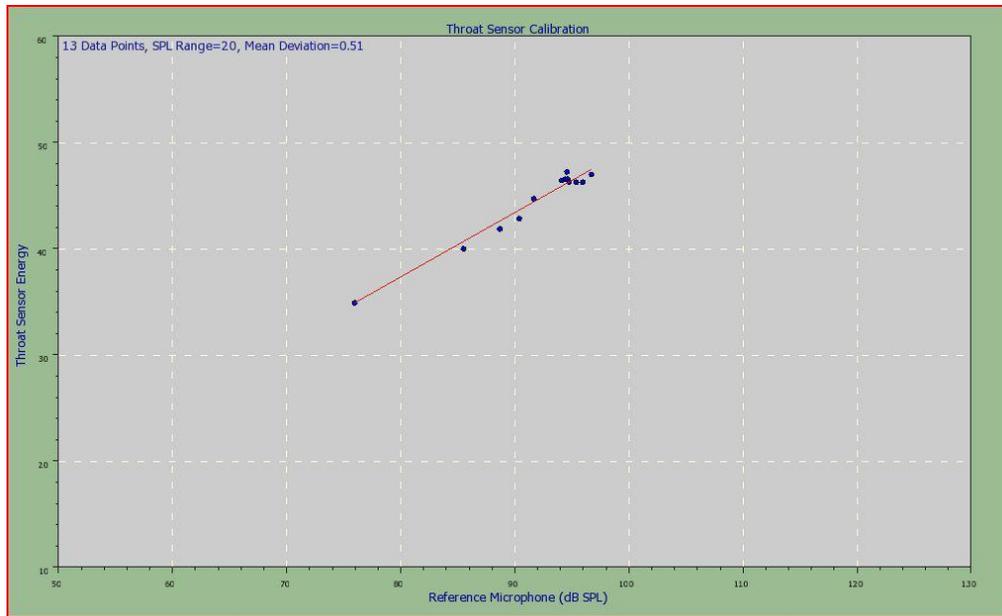


Figure 1. Example of dots and a straight red line representing the calibration of the sound pressure levels measured by the microphone and the throat sensor (APM: KayPENTAX, Lincoln Park, New Jersey).

The final step to complete the setup phase and to initiate the monitoring phase was disconnecting the device from the computer and microphone. The clinician selected “Start Monitoring” on the left-hand side of the screen, and a “Start Phonation Monitor” dialog box appeared. The clinician then selected “OK”, and the device light flickered green and red very quickly which indicated that it was in the monitoring setting. The device was then disconnected from the microphone and computer, and it was then placed in the waist pouch. The patient was given instructions to wear the device all day long, keep it safely away from water, and simply to disconnect the one wire running from the sensor to the APM before he/she prepared for bed. To remove the throat sensor, the patient was provided with an adhesive remover aid. He/she was instructed to lift one edge of the sensor and gently peel away from skin. He/she was also provided with an alcohol wipe to remove residual adhesive that may have been left on the skin. Finally, the patient placed the sensor in the pouch provided along with the Ambulatory

Phonation Monitor, which the clinician collected the following day. Once the clinician collected the pouch with the device, it was then plugged back into the computer used for calibration where the data collected was retrieved from the APM (APM: KayPENTAX, Lincoln Park, New Jersey).

This process was completed on three separate occasions for each of the ten subjects. The participants wore the APM on what was deemed “typical” days where similar routines were observed and “out of the ordinary” activities did not take place. Data collection was repeated three times to establish the reliability of the data collected. A short questionnaire was provided to participants in order to gather data regarding comfort and use of the device. Participants were also provided with a time journal to document their estimated amount of phonation time. Participants were asked to complete the time journal by estimating their amount of phonation time in minutes every two hours.

Data Analysis

The data were gathered for each person on the three separate occasions. The information gathered was compared between the two groups to find deviations and patterns of correlation. Measured variables included phonation time, mean fundamental frequency, and mean amplitude (SPL). Data was collected 20 times per second throughout the time the device was worn (APM: KayPENTAX, Lincoln Park, New Jersey). The information was collected over an 8 hour period of time. Phonation time was used in this study as an index of total speaking time.

Results for each measure were analyzed using two-way repeated measures ANOVA’s with diagnoses as between subject factors and phonation variables as repeated factors. Only effects of diagnosis were relevant to this investigation. T-tests were conducted to determine whether a difference between group estimation of phonation time verses actual phonation time were significant.

To check for accuracy of data entry, dual-entry method was used in recording data into the data base. A second graduate student in the LSU Department of Communication Sciences and Disorders entered all data points gathered by the APM (n=90) into a database. The total percentage of agreement was calculated by dividing the total number of agreements (n=87) by the total number of opportunities for agreement (n=90) and multiplying by 100.

RESULTS

Five participants with PD and five healthy age- and gender-matched participants were recruited for this study. Six males and four females participated in this study. All participants were Caucasian and ranged between the ages of 67 and 85. The length of diagnosis for the PD group ranged from 2.5 years to 8 years. MMSE (Folstein et al., 1975) scores ranged from 26 to 30 in NO PD participants and from 27 to 30 in PD participants. Among NO PD participants, Apathy Scale (Starkstein et al., 1992) rating ranged from 3-13, while PD participants' ratings ranged from 3 to 8. One PD patient scored 8 (10 indicates possible depression) on the Geriatric Depression Scale Rating (Sheikh & Yesavage, 1986), while ratings for all other participants ranged from 0 to 2. Table 1 shows the PD participants, along with age- and gender-matched NO PD individuals, as well as scores for screening for inclusion tests. The data for participant NO PD 03 was dropped from the analysis of mean amplitude, mean fundamental frequency, and phonation time due to insufficient data points.

Parkinson's Participants and Healthy Matched Individuals										
	PD 01	NO 01	PD 02	NO 02	PD 03	NO 03	PD 04	NO 04	PD 05	NO 05
Age	77	77	74	74	68	67	85	85	73	73
Gender	F	F	M	M	M	M	M	M	F	F
Years post-diagnosis	7	N/A	8	N/A	5	N/A	2.5	N/A	3	N/A
MMSE	29	30	28	26	27	30	30	30	30	30
H&Y Stage	2	N/A	2	N/A	2	N/A	1	N/A	1	N/A
Apathy Scale Rating	4	3	8	3	3	13	7	3	7	4
GDS	8	0	2	1	1	1	1	0	0	2

Table 1. Descriptive characteristics of participants

Note: MMSE = Mini Mental Status Exam (Folstein et al., 1975), H&Y = Hoehn & Yahr PD Stage (Hoehn & Yahr, 1967), GDS = Geriatric Depression Scale (Sheikh & Yesavage, 1986).

Reliability

Dual-entry method was used in recording data into the data base. A second graduate student entered all data points gathered by the APM (n=90) into a database. The total percentage of agreement was calculated by dividing the total number of agreements by the total number of opportunities for agreement and multiplying by 100. The two people had 97% agreement on data entry.

Experimental Questions

1. Is there a significant difference in mean fundamental frequency between the NO PD group and the PD group?

Two-way repeated measures ANOVA was used to test the hypothesis that there would be a significant difference between the NO PD group and the PD group on mean fundamental frequency across three trials. Levene's Test of Equality of Error Variances was conducted to test the null hypothesis that error variance of the dependent variable is equal across groups. The two groups have approximately equal variances during all three trials, time 1: $F(1,7) = .29, p = .60$, time 2: $F(1,7) = .46, p = .52$, time 3: $F(1,7) = .43, p = .53$. No difference was found between the two groups on mean fundamental frequency across time, $F(1,7) = .08, p = .78$.

To determine if there was a significant difference in mean fundamental frequency across time within both groups, we first examined the sphericity of the data using Mauchly's Test of Sphericity. This test was not significant, $W = .69, \chi^2(2) = 2.23, p = .33$, indicating that the data did not violate the assumption of equal variances and covariances. This test was significant, $W = .19, \chi^2(2) = 9.99, p = .01$, indicating that the data does not have equal variances and equal covariances. Therefore, a Greenhouse-Geisser corrected F-test was used. Mean fundamental frequency across the measured times was not significant, $F(1.11, 7.73) = 1.56, p = .25$. Mean

fundamental frequency across the measured times within the groups was not significant, $F(1.11, 7.73) = 2.87, p = .13$.

Table 2. Group means and standard deviations for measured variables

Dependent Variables	NO PD Group Means(SD)	PD Group Means(SD)
Mean Fundamental Frequency (Hz)	177.49 (41.49)	169.31 (39.47)
Mean Amplitude (dB)	81.15 (4.37)	71.24 (4.54)
Total Phonation Time (Minutes)	53.14 (35.17)	33.18 (15.24)

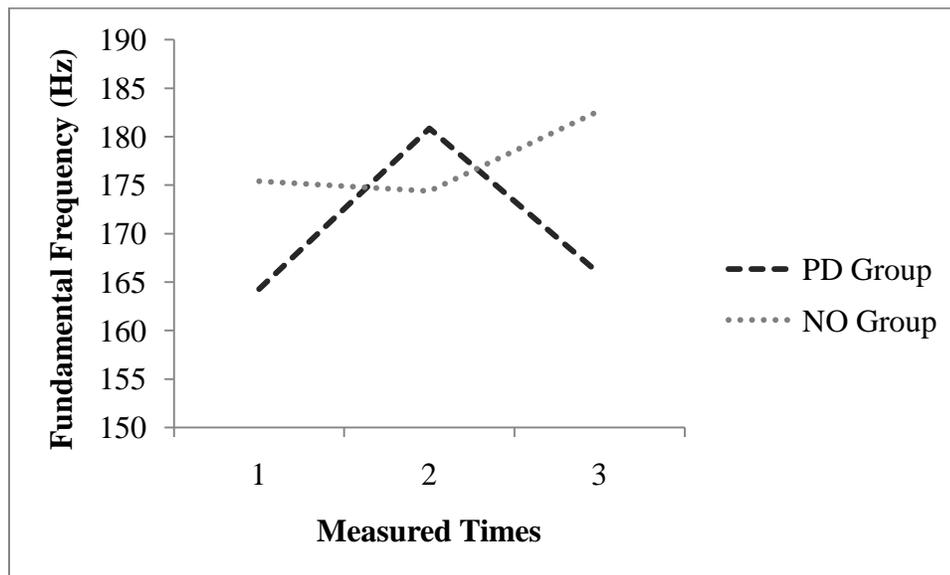


Figure 2: Mean fundamental frequencies across the three measured times comparing results between the NO PD group and the PD group.

2. Is there a significant difference in mean amplitude between the NO PD group and the PD group?

Two-way repeated measures ANOVA was conducted to determine whether a difference existed between the PD and NO PD groups comparing mean amplitude during three trials.

Levene's Test of Equality of Error Variances was conducted to test the null hypothesis that the

error variance of the dependent variable (mean amplitude) is equal across groups. The two groups have approximately equal variances during each trial, time 1: $F(1,7) = .17, p = .69$, time 2: $F(1,7) = .03, p = .87$, time 3: $F(1,7) = .00, p = .97$. Mean amplitude was statistically different among the PD group and NO PD group, $F(1,7) = 17.66, p < .001$. The strength of relationship between a diagnosis of PD and effect on mean amplitude, as assessed by η^2 , was strong, with a diagnosis of PD accounting for 72% of the variance of the dependent variable.

To determine if mean amplitude was significantly different across time within both groups, we first examined the sphericity of the data using Mauchly's Test of Sphericity. This test was significant, $W = .35, \chi^2(2) = 6.37, p = .04$, indicating that the data do not have equal variances and equal covariances. Therefore, a Greenhouse-Geisser corrected F-test was used. Mean amplitude across the measured times was not significant, $F(1.21, 8.46) = .75, p = .44$. Mean amplitude across the measured times within the groups was not significant, $F(1.21, 8.46) = 2.06, p = .19$. There was a significant difference between the two groups on mean amplitude with the NO PD group having a higher mean amplitude ($M = 81.16, SD = 4.37$) than the PD group ($M = 71.24, SD = 4.54$). Within each group, mean amplitude remained relatively stable. Refer above to Table 2 for group means and standard deviations.

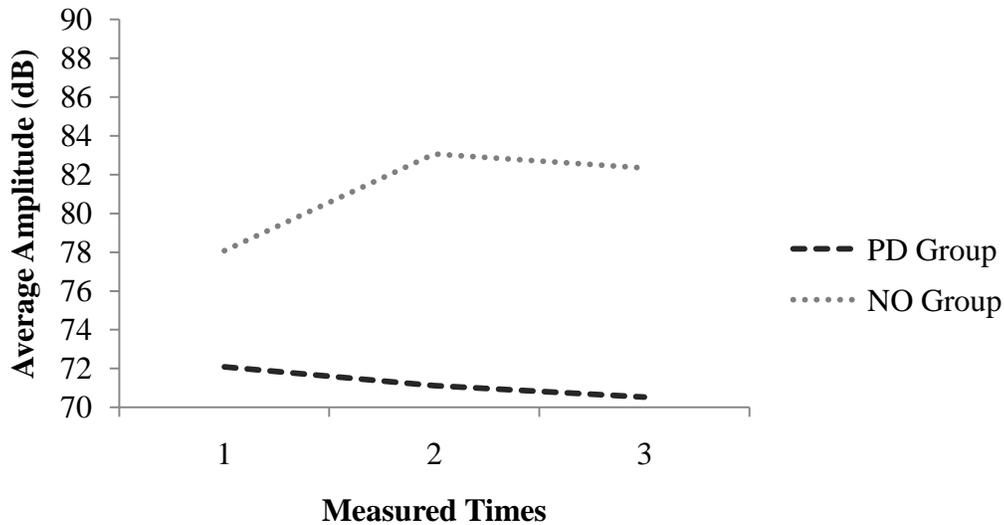


Figure 3. Mean amplitudes across the three measured times comparing results of the PD group and NO PD group.

3. Is there a significant difference in total phonation time between the NO PD group and the PD group?

Two-way repeated measures ANOVA was conducted to compare the difference between the two group's phonation times during three trials. The Levene's Test of Equality of Error Variances was conducted to test the null hypothesis that the error variance of the dependent variable is equal across groups. The two groups have approximately equal variances during each trial, time 1: $F(1,7) = .2.67, p = .15$, time 2: $F(1,7) = 1.97, p = .20$, time 3: $F(1,7) = 4.84, p = .06$. Neither a PD diagnosis nor a NO PD diagnosis have an effect on phonation time, $F(1,7) = 1.40, p = .28$.

To determine if there was a significant difference in fundamental frequency across time within both groups, we first examined the sphericity of the data using Mauchly's Test of Sphericity. This test was not significant, $W = .95, \chi^2(2) = .30, p = .86$, indicating that the data do not violate the assumption of equal variances and covariances. Therefore, the F-test did not need

to be corrected. Phonation time across the measured times was not significantly different, $F(2,14) = .75, p = .49$. Phonation time across the measured times within the groups was not significantly different, $F(2,14) = 3.50, p = .06$. Refer above to Table 2 for group means and standard deviations.

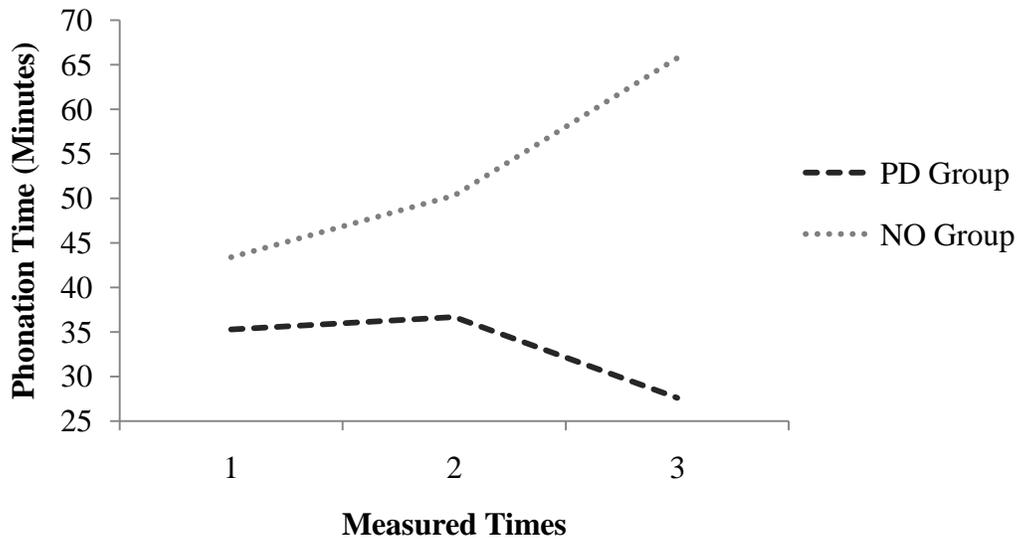


Figure 4. Phonation time across the three measured times comparing results of the PD group and NO PD group.

A paired-samples t test was conducted to determine if actual phonation time differed from self estimated phonation time among NO PD individuals. Results indicated that the mean for the actual phonation time ($M = 51.09, SD = 34.48$) was not significantly different than the mean for self-estimated phonation time ($M = 99.72, SD = 87.09$), $t(12) = -1.97, p = .07$.

Similarly, a paired-samples t test was conducted to determine if the PD group's actual phonation time differed from its self-estimated phonation time. Results indicated that the mean for self-estimated phonation time ($M = 86.86, SD = 31.74$) was significantly greater than the

mean for the actual phonation time ($M = 32.15$, $SD = 15.27$), $t(13) = -5.63$, $p = .00$. The PD group over-estimated their talk time. The implications of these results will be discussed next.

DISCUSSION

A number of studies have shown that PD may affect fundamental frequency (Gamboa et al., 1997; Midi et al., 2008) and amplitude (Fox & Ramig, 1997; Ramig et al., 2001; Scott & Caird, 1983; Stewart et al., 1995). However, no research has ever studied total phonation time of older adults with or without PD. This study attempted to determine if there was a difference in vocal parameters including mean fundamental frequency, mean amplitude, and total phonation time using the APM, between individuals diagnosed with PD and age- and gender-matched individuals without a neurologic or neurodegenerative disease. The ultimate goal of this project was to determine if it was feasible to use the APM to gather objective data on the vocal parameters of older participants with and without PD beyond the clinical setting, and to begin to collect normative data on talk time among older people.

Mean fundamental frequency refers to the average of the “lowest periodic component of vocal fold vibrations” (Kent and Reed, 2002). We used the APM to measure mean fundamental frequency and to determine whether a significant difference existed between the two groups. Results showed that mean fundamental frequencies of the NO PD and PD groups did not differ significantly. Although, the literature suggests that the progression of PD affects a patient’s fundamental frequency (Gamboa et al., 1997; Midi et al., 2008) this study failed to reject the null hypothesis that the PD group did not have a higher mean fundamental frequency compared to the NO PD group. One possible reason we found no difference in mean fundamental frequency could be attributed to the fact that all participants of the PD group had a Hoehn & Yahr PD Stage (Hoehn & Yahr, 1967) of 1-2. A higher mean fundamental frequency may be more pronounced as the severity of the disease progresses.

Reduced vocal intensity, or amplitude, has frequently been reported as a major speech deficit associated with PD (Canter, 1963; Duffy 2005; Fox & Ramig, 1997; Scott & Caird, 1983; Stewart et al., 1995; Ramig et al., 2001). Our results suggested that there was a significant difference between the mean amplitude of the two groups. The NO PD group exhibited significantly greater mean amplitudes than individuals in the PD group. This is consistent with the research published by Canter (1963 & 1965) and Fox and Ramig (1997). Interestingly, Fox and Ramig (1997) suggest that the inability to produce elevated phonations was due to perceptual deficits resulting from PD. Although a diagnosis of PD affected mean amplitude between groups, within both groups variation was similar. These patterns suggest that participants diagnosed with PD exhibited lower mean amplitudes outside of the clinical setting, although all had participated in speech therapy at some point since their diagnosis.

We recognize that a variation in amplitude may exist when measured by an accelerometer in comparison to a microphone (Svec et al., 2005). This may have had an effect when considering the average amplitude reduction associated with PD is only $\pm 2-4$ dB (Fox & Ramig, 1997). However, because we were not making comparisons between data collected by microphone and APM data, we do not feel the finding had an effect on our results.

Finally, we asked whether a significant difference in total phonation time between the NO PD group and the PD group existed. Our data showed that total phonation time was not significantly different between the two groups. Although, the mean length of 53.14 minutes for the NO PD group and 33.18 minutes for the PD group seemed short on first inspection. Results also showed that phonation time was similar within groups as well. The data collected in this study for the NO PD group were comparable to those found in a study by Wantanabe et al. (1987) who spoke an average of 6 minutes and 25 seconds per hour ± 1 minute and 36 seconds.

However both groups exhibited notably less phonation time compared to the participants of the study by Ryu et al. (1983) who spoke an average of 110 minutes a day.

To see how well participants were able to estimate their talking time while wearing the APM, each participant completed a “Time Journal” wherein they estimated how many minutes they spoke every two hours (APPENDIX A). No statistically significant results were found within the NO PD group. However, results for the PD group revealed that estimated talk time was statistically higher than APM-recorded total talk time. Thus the PD group thought they talked more than they did. This behavior seems to be consistent with the literature showing that people with PD overestimate their ability in self-report measures (Donovan, 2008). Moreover, this result might suggest that participants with PD may have impaired time management abilities, a frontal executive function. This would conform to the research findings that individuals with PD misjudge functional difficulties (Marsden, Parkes, & Quinn, 1981; Yorkston et al., 1994; Yorkston et al., 2004) because of executive function deficits (Ho et al., 2002). Dopaminergic cells depletion of the frontal cortex and mesocortical dopaminergic system deterioration is characteristic of PD, which is believed to influence executive function skills (Owen, 2004). People with PD have also overestimated loudness (Fox & Ramig, 1997), a perceptual skill. Therefore questions remain about whether this finding of overestimation in PD is related to decreased insight, or perceptual deficits.

Along with the “Time Journal,” the study’s participants were asked to complete a questionnaire regarding the comfort of wearing the APM (APPENDIX B). The questionnaire asked them to rate comfort wearing the device in general, wearing it in public, comfort while speaking with the device on, and other questions regarding whether or not they felt the device affected their speech output. When asked if the APM was a comfortable device to wear in

general on a scale of 1-5 (1 being very uncomfortable and 5 being very comfortable), the participants gave it an average rating of 3.82. The participants rated their comfort in public as 4.67 out of 5. When asked if the participants were comfortable speaking while wearing the APM, the participants gave it an average rating of 4.86. In an attempt to add a measure of validity to the study, Question 4 asked the participants if they felt that the APM measured a “normal” day of speech for them. 89% of participants felt that the APM measured a typical day of speech. 82% of the participants reported that they spoke the same amount as usual, 11% felt they spoke less than usual, and 7% felt they spoke more than usual. 93% of the participants reported that the APM did not affect his/her speech in anyway. Of interest, the 7% who reported that the APM affected their speech were in the PD group. These participants commented that the APM reminded them to use techniques learned in previous speech therapy sessions. In this study, the APM may have served as an external cue for the PD group to speak louder. If that is the case, we suggest that the difference in mean amplitudes between groups might have been even greater.

Limitations

There were a number of limiting factors encountered during the study. One limitation may have been the small sample size. The results indicated considerable variation on all vocal parameters both among and between participants, although they met the statistical assumptions needed to perform ANOVA. A larger sample size may have decreased the variability, and resulted in different findings. Another limitation may have had to do with the durability of the device. The APM was developed in a clinical setting and may not have been intended for the rigors of everyday wear and tear that it was given by the participants in this study. Although the PI applied the accelerometer each morning, individuals removed it at night. At one point late in the study, the wire leading to the accelerometer tore, rendering the device inoperable. We suspect

that although participants were trained in the careful detachment of the accelerometer at the end of the day, they may have pulled on the wire leads which resulted in tearing. We should note that the manufacturer was extremely helpful in replacing the damaged equipment so that the study did not have to be discontinued or suffer from a prolonged hiatus.

The most common complaint voiced by the participants of this study had to do with APM design. Participants suggested a smaller model or less bulky model would be better for portability and day-long wear. This might allow participants to be less aware of the device and possibly enter into more interactions. As mentioned above, the APM seemed to make some participants more aware of their speech throughout the day. Comments from 3 of the 5 PD group participants suggested that the APM served as an external cue, thus reminding them to use techniques they had learned in speech therapy to speak louder. Taking this into consideration, the finding of increased amplitude for PD participants is of interest because none of the participants of the NO PD group reported that the APM made them aware of their speaking patterns. Larger patterns of difference may have resulted between group had the APM not reminded the participants to speak louder.

Future Studies

While this study utilized a Phase I design, and a small sample size, we feel that these results justify further research on the viability of using the APM as a treatment outcome measure in participants' natural speaking environments. Future studies using larger sample size could establish normative phonation time for older adults with and without PD. A study could expand to capture middle age or young adults as well. This normative information could provide direction for treatment goals and daily planning. Along other lines, individuals with PD significantly overestimated their phonation time when the "Time Journal" was compared to

results of the APM. Given the literature that describes frontal executive function deficits in PD, further study about why this significant difference occurred could be useful.

SUMMARY

This is the first study of its kind to examine the difference in vocal parameters between individuals diagnosed with PD and age-and gender-matched individuals without a diagnosis of any neurologic or neurodegenerative diseases using an objective measure in a naturalistic setting. Although our findings are preliminary, they lead us to believe that the area is ripe for study and the results could benefit add to understanding more about the vocal behaviors of both healthy, elderly individuals and those with PD.

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APPENDIX A: TIME JOURNAL

Ambulatory Phonation Monitor

Please write down an estimation of how much you spoke in each two hour time slot.

Hours 1-2 (9:00-11:00)_____

Hours 3-4 (11:00-1:00)_____

Hours 5-6 (1:00-3:00)_____

Hours 7-8 (3:00-5:00)_____

VITA

Danielle Marie Boudreaux was born and raised in Monroe, Louisiana. Upon graduating Neville High School in 2005, she enrolled in Louisiana State University and Agricultural and Mechanical College of Baton Rouge in August 2005. In May 2009, Miss Boudreaux received a Bachelor of Arts in Communication Sciences and Disorders. In August following her graduation, she began her master's program in Communication Sciences and Disorders. Miss Boudreaux's interest in research grew when she began working in the Communication Outcomes Research Laboratory under the direction of Dr. Neila Donovan. She began working on a master's thesis under the direction of Dr. Donovan in partial fulfillment of the requirements for a Master of Arts degree, to be awarded in May of 2011. Upon graduation, Miss Boudreaux plans to reside in Monroe, Louisiana, where she will complete the necessary clinical fellowship requirements to become a licensed speech language pathologist.