A SPEECH ANALYSIS COMPARISON OF PEOPLE WITH PARKINSON'S DISEASE AND HEALTHY CONTROLS

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Abstract

This study explores the effects of Parkinson's Disease (PD) and a dance intervention on vocal features—specifically fundamental frequency standard deviation (F0SD) and intensity standard deviation (IntSD)—in individuals with PD and healthy controls over five years. The findings suggest that while both groups exhibited changes in these vocal features over time, the differences between the PD and control groups were moderate and likely masked by individual variability. F0SD, in particular, showed distinct patterns of change over time between the two groups, aligning with known voice impairments in PD. However, changes in IntSD appeared to be more influenced by the normal aging process rather than PD itself. Despite the lack of significant post-dance improvements, the study highlights the potential value of speech features as biomarkers for PD, emphasizing the need for larger, more intensive studies to fully understand the effects of interventions like dance on vocal performance in PD.

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Abbreviations	**Non-abbreviated format**
ANOVA	Analysis of Variance
BOLD	Blood Oxygenation Level Dependent
CPP	Cepstral Peak Prominence
DA	Dopamine
DBS	Deep Brain Stimulation
DDKR	DiaDochoKinetic Rate
DPI	Duration of Pause Intervals
F0	Fundamental Frequency
F0SD	Fundamental Frequency standard deviation
FCR	Formant Centralization Ratio
fMRI	functional Magnetic Resonance Imaging
GNE	Glottal to Noise Excitation ratio
HC	Healthy Controls
HNR	Harmonic to Noise Ratio
IntSD	Intensity standard deviation
LPC	Linear Predictive Coding
MDS-UPDRS	Movement Disorder Society's Unified Parkinson's Disease Rating Scale
MFCC	Mel Frequency Cepstral Coefficients
MPT	Maximum Phonation Time
NHR	Noise to Harmonic Ratio
NSR	Net Speech Rate
PD	Parkinson's Disease
PLP	Perceptual Linear Prediction
PPE	Pitch Period Entropy
PSI	Proportion of Subharmonic Interval

PwPD	People with Parkinson's Disease
QoL	Quality of Life
RAP	Relative Average Perturbation
RFA	Resonant Frequency Attenuation
RPDE	Recurrence Period Density Entropy
SMA	Supplementary Motor Area
SNpc	Substantia Nigra pars-compacta
SPI	Soft Phonation Index
VAI	Voxel Articulation Index
VOT	Voice Onset Time
VSA	Voxel Space Area

PART I

Preface

Over the last two years, while I was studying for my master's degree, the project that I wanted to work on changed a few times. Initially, my project had a broad focus on perception and the external world, specifically how the human brain defines and perceives the external world. However, some exemplified means were needed to reduce the measures and numbers to something that can be evaluated. While searching for objectified means and during my Advanced Topics in Theoretical Physics course, which Professor Joel Zylberberg taught, I got interested in comparing computers, especially deep learning methods, to the human brain. The course was about how to apply deep learning to science. My supervisor in the psychology department, Professor Joseph F.X. DeSouza, and his team were among the first scientists to demonstrate that dance improves motor symptoms and promotes brain plasticity using fMRI and EEG in individuals with Parkinson's disease, through a 7-year longitudinal study. At that time, a comparison between the human brain and a deep learning model could be an indicator of the logic that these two models (human brain and computers) were built on. One of them was built through the course of evolution and based on its rules and the other was based on mathematics, an invention of the human brain that was claimed by a group of scientists that is

perception-less. In the course of finding if it is rational to compare the rationality of human brains versus computers, I found my philosophy supervisor, Professor Brian Huss. When we started working on the subject, Professor Huss introduced defining the term “Rationality”. Although the subject was of interest, it was well pointed out by my committee that this project is broad and contains at least two sub-projects. Therefore, I chose to work on only one part of the project, the speech analysis of people with Parkinson’s Disease (PwPD), and compare that analysis with the control group. For the analysis, I used a machine learning model to extract the speech features. Although this project diverged from my initial Master’s degree proposal, it holds significant potential for advancing our understanding of perception and neuroplasticity. The journey that I went through during this two-year program has led me to more interesting subjects such as other logic for perception, or as we know evolution is based on survival of the fittest to the environment, so if the condition went other ways, would there be creatures with different means of perception on the Earth, and finally since there are a lot of aspects in any material, is there a universal perception that perceives the whole matter I would like to express my deepest gratitude to Professor Joel Zylberberg and Professor Joseph F.X. DeSouza, for their invaluable guidance and support throughout this journey. My sincere thanks to Professor Brian Huss for his insightful discussions on rationality and perception. Special thanks to my friends and all the members of the JoeLab for their unwavering support and patience during the completion of this thesis

Ashkan Karimi, York University, 2024

CHAPTER 1

INTRODUCTION: PARKINSON'S DISEASE

This study aims to describe the differences in voice parameters between individuals with Parkinson's Disease (PD) and healthy controls who participated in a community dance class over a period of five years.

Parkinson's Disease (PD) is the second most common neurodegenerative disease which affects 2-3 percent of people living over 65 years old (Poewe et al., 2017). It is a progressive bradykinetic disorder and can be characterized by the severe loss of substantia nigra pars-compacta (SNpc) cells (Lees et al., 2009). James Parkinson first described this disease in 1817, and it was more than a century after that the loss of SNpc neurons was associated with PD. Subsequently, the discovery of dopamine (DA) in the mammalian brain by Arvid Carlsson in 1958 accelerated the understanding of the disease's etiology. This was mainly because SNpc neuronal loss leads to striatal DA deficiency, which is responsible for PD's major symptoms. Additionally, administration of the DA precursor, levodopa, can alleviate most of the symptoms (Dauer & Przedborski, 2003).

Deep Brain Stimulation (DBS) is an alternative surgical method that shows promising results, not only in advanced stages of PD but also in patients with early motor complications (Malek, 2019).

There are four fundamental features of PD: **Resting Tremor, Rigidity, Akinesia (**or **Bradykinesia),** and **Postural Instability**.

Resting Tremor is the most common and easily recognizable sign in people with PD. The frequency of these tremors is usually between 4 and 6 Hz and is more prominent at the distal part of the extremities (i.e. hands and feet). This sign rarely involves the head and neck and disappears during action and sleep.

Rigidity. Increased muscular resistance, usually followed by the "cogwheel" phenomenon, which is more prominent when accompanied by underlying tremors. In mild cases, it may be misdiagnosed as arthritis, bursitis, or rotator cuff injuries.

Akinesia or Bradykinesia. Bradykinesia is the slowing of movements, usually a hallmark of diseases involving the basal ganglia. Manifestations associated with bradykinesia involve slow reaction time, slowness in daily activities, loss of spontaneous movements and gestures, and drooling.

Postural Instability. Axial rigidity may occur, resulting in a flexed neck and trunk posture, as well as elbow and knee flexion (Jankovic, 2008).

In addition to motor symptoms, there are non-motor signs and symptoms associated with PD (Müller et al., 2013). Some of these symptoms are mentioned in **Table 1**.

Table 1. Motor and Non-Motor Symptoms of Parkinson's Disease

Motor symptoms	Non-Motor symptoms
Communication	Sensory complaints
Personal needs	Autonomic dysfunction
Tremor	Cognitive impairment
Rigidity	Depression
Bradykinesia	Fatigue
Gait	Apathy
Axial symptoms	Sleep disturbances
Nocturnal motor symptoms	Daytime sleepiness
Dyskinesia and fluctuations	

According to Statistics Canada, in 2011/2012 an estimated 55,000 Canadians over the age of 18 have been diagnosed with PD (Wong et al., 2014). According to this report, the mean age of first symptoms was 64.4 years, where the diagnosis was made 1.9 years later at 66.3 years old.

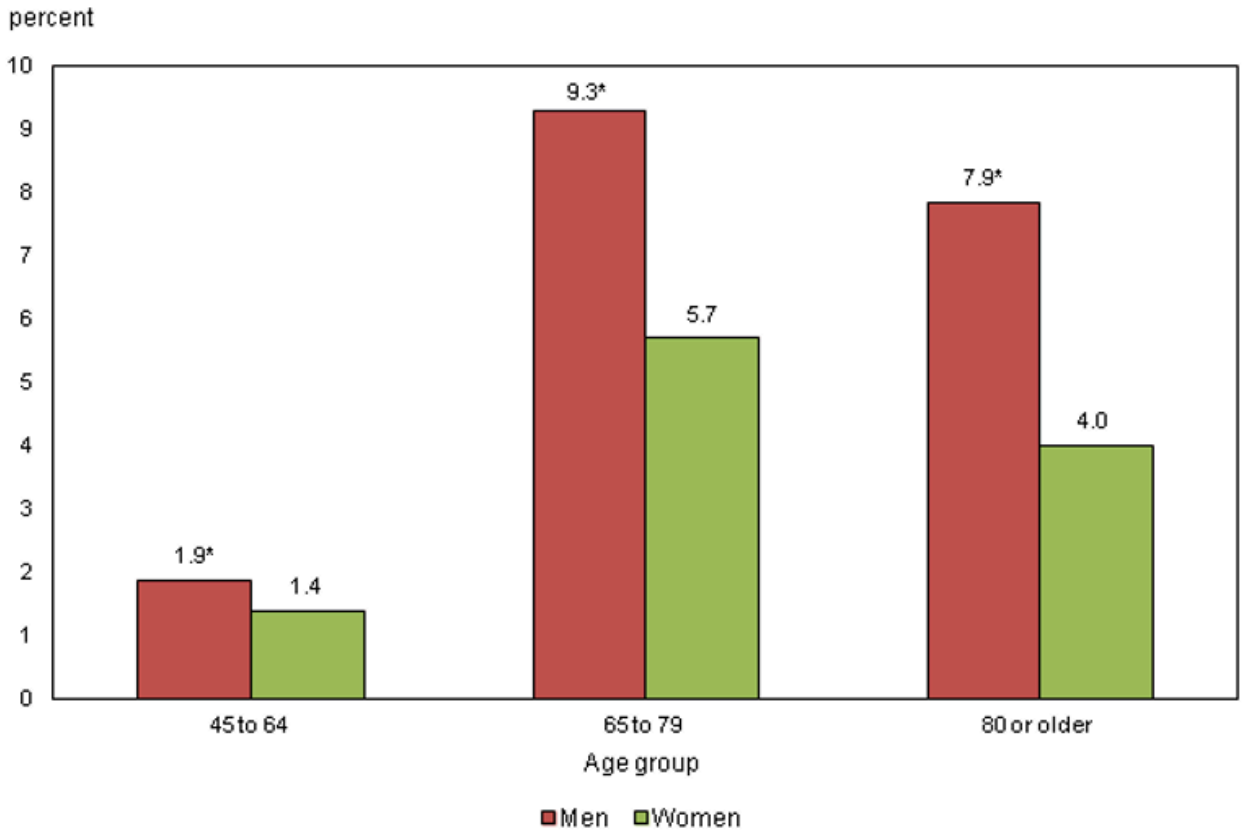


Figure 1. Prevalence of Parkinson's Disease in Institutional Population in Canada by Age Group and Sex [Source: (Wong et al., 2014)]

Figure 1 is based on research conducted in 2014 (Wong et al., 2014) and plots the prevalence of PD in 2011/2012. The prevalence of PD in the institutional population: 1.9% of men and 1.4% of women in the 45 to 64 age group, 9.3% of men and 5.7% of women in the 65 to 79 age group, and 7.9% of men and 4.0% of women in the 80 or older age group.

The proportion of people in Canada aged 65 years and older with PD increased from 15.6% (5,541,888 people) in 2011/2012 to 18.9% (7,568,308 people) in 2017 (Statistics Canada, 2017). The number of people with PD is increasing, therefore, greater recognition and improved diagnostic methods are necessary.

In 2008, the total cost of direct and indirect costs in Canada for neuropsychiatric conditions (including PD) was over $12.5 billion (Gaskin et al., 2017).

The burden of PD worldwide was reported to be over 9 million in 2020 (Pauwels & Boer, 2023). As there are currently no treatments that can stop or reverse the progression of PD (Yang et al., 2022), early diagnosis and intervention can help reduce the severity of PD progression, improve the quality of life, and lessen the socioeconomic burden.

Speech impairment is prevalent, affecting up to 90 percent of individuals with PD, both in the early and late stages (Smith & Caplan, 2018). Speech is one of the first functions in PD to be disrupted which makes it a promising indicator in PD diagnosis (Azadi et al., 2021). A case-control longitudinal study that investigated the fundamental frequency variability by Harel et al. showed that this measure started to deteriorate five years before the diagnosis of PD (Harel et al., 2004). This highlights the importance of speech analysis as an early detector of PD, which can be a cost-effective, targeted, and accessible method for screening PD (Azadi et al., 2021).

CHAPTER 2

LITERATURE REVIEW

The degree of communication impairment varies widely in individuals with PD and can result in inaudible voices, creating challenges in communication between people living with PD and their caregivers (Smith & Caplan, 2018). A cross-sectional survey in Sweden reported that 92.5 percent of respondents in the study had at least one symptom related to communication (Schalling et al., 2018).

Speech production results from the coordination of various motor activities, including respiration, phonation, articulation, and resonance. In people with PD, speech impairment arises from both motor and non-motor deficits (Dashtipour et al., 2018).

A review by Moro-Velazquez et al. (2021) on the phonatory aspects of speech. These features are outlined in **Table 2** (Moro-Velazquez et al., 2021).

Table 2. Phonatory Aspects Investigated in Parkinson's Disease

PHONATORY ASPECTS	
Jitter	RPDE[5]
Shimmer	Fundamental frequency
HNR[1]	MPT[6]
NHR[2]	D_2
GNE[3]	SPI[7]
Subglottal pressure	Tremor
PPE[4]	MFCC[8]

1. (Harmonic to Noise Ratio), 2. (Noise to Harmonics Ratio), 3. (Glottal to Noise Excitation ratio), 4. (Pitch Period Entropy), 5. (Recurrence Period Density Entropy), 6. (Maximum Phonation Time), 7. (Soft Phonation Index), 8. (Mel-Frequency Cepstral Coefficients)

PHONATORY ASPECT CHANGES IN PARKINSON'S DISEASE

Rusz et al. (2011) reviewed the phonation, articulation, and prosody in people with PD and healthy controls. Among phonation features, they found a significant difference between PD and healthy control groups in Jitter (local), Jitter (RAP), Jitter (PPQ5), Jitter (DDP), Shimmer (local), Shimmer (APQ3), Shimmer (APQ5), Shimmer (APQ11), Shimmer (DDA), NHR, and HNR (dB), but not the pitch variations (F0SD [Fundamental frequency standard deviation]) (Rusz et al., 2011).

Upadhya et al. (2017) investigated Jitter, Shimmer, and their variants in people with PD and healthy controls. Their findings showed higher metrics of central tendency for all parameters in Parkinson-affected individuals (Upadhya et al., 2017). Irregular vocal fold vibration, as a result of motor impairment in PD, causes random modulation of the sound signal's amplitude (shimmer) and its period (jitter) (Asgari & Shafran, 2010).

Vikas et al. (2014) explored the detection of PD through voice in the early stages. They have shown higher pitch in the PD group compared to healthy adults, along with more variations in Formants, higher values of Jitter and Shimmer, and an abnormal pattern in the glottal pulse (Vikas & Sharma, 2014).

Rahn et al. (2007) studied the correlation dimension (D_2) in parallel with Jitter and Shimmer. Their results showed increased D_2 in phonatory signals in the PD-affected group compared with control subjects. They also found that the PD group had significantly higher values for Jitter, but not for Shimmer values, compared with control subjects (Rahn et al., 2007).

Jimenez-Jimenez et al. (1997) also researched acoustic voice features in untreated people living with Parkinson's Disease. Their results showed higher F0 in PD females as compared to matched controls. Higher values for Jitter in PD males were reported (this was in the case that the female's values were nearly significant). The Shimmer values in this study were significantly higher in the PD-affected group. The HNR values were controversial. The value obtained from the laryngograph signals was significantly lower in the PD-affected group, whereas the results from the microphonic signal showed the value was lower only in the female subgroup (Jiménez-Jiménez et al., 1997).

GNE is a feature of voice that is useful in machine learning techniques for automatic detection and assessment of Parkinson's Disease (Galaz et al., 2018; Tsanas et al., 2013; Arora et al., 2018; Viswanathan et al., 2019).

Below is a brief definition of each voice feature that can be extracted from the voice signal:

1. **Jitter (absolute) and Jitter (relative),** refer to the cycle-to-cycle variation in the fundamental frequency. The Jitter (relative) is the average absolute difference between consecutive periods, divided by the average period (Vikas & Sharma, 2014).

$$Jitter\ (absolute) = \frac{1}{N-1}\sum_{i=1}^{N-1}|T_i - T_{i-1}|$$

Equation 1

$$Jitter\ (relative) = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}|T_i - T_{i-1}|}{\frac{1}{N}\sum_{i=1}^{N}T_i}$$

Equation 2

where $T_i s$ are the extracted pitch period length (fundamental frequency and pitch period length are reversely related by f = 1/T, the unit for the pitch period length is in seconds [s] and the fundamental frequency's unit is in Hertz [Hz]).

The threshold value to detect pathologies in adults is 83.2 µs for Jitter (absolute) and 0.0104 for Jitter (relative) (Teixeira et al., 2013).

Another variant of Jitter is relative average perturbation Jitter or Jitter (RAP):

$$Jitter\ (RAP) = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}|T_i - (\frac{1}{3}\sum_{j=i-1}^{i+1}T_j)|}{\frac{1}{N}\sum_{i=1}^{N}T_i}$$

Equation 3

The threshold value to detect pathologies is 0.68% for Jitter (RAP) (Teixeira et al., 2013).

The other variant is Jitter (PPQ5), which represents the amount of periodic disturbance within 5 periods. It can be calculated as follows (Upadhya et al., 2017):

$$Jitter\ (PPQ5) = \frac{\frac{1}{N-1}\sum_{i=2}^{N-2}|T_i - (\frac{1}{5}\sum_{j=i-2}^{i+2}T_j)|}{\frac{1}{N}\sum_{i=1}^{N}T_i}$$

Equation 4

2. **Shimmer (dB) and Shimmer (relative)** is the variability of the peak-to-peak amplitude in decibels, or in other words, the average absolute of 20 times the base-10 logarithm of the ratio between the amplitude of consecutive periods**.** The shimmer (relative) is the

average absolute difference between the amplitude of consecutive periods divided by the average amplitude (Vikas & Sharma, 2014).

$$Shimmer\ (dB) = \frac{1}{N-1}\sum_{i=1}^{N-1}\left|20log(\frac{A_{i+1}}{A_i})\right|$$

Equation 5

$$Shimmer\ (relative) = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}|A_i - A_{i+1}|}{\frac{1}{N}\sum_{i=1}^{N}A_i}$$

Equation 6

where A_is are the extracted peak-to-peak amplitude data, and N is the number of extracted pitch periods.

The limit to detect pathologies is 0.350 dB for Shimmer and 0.0381 for the Shimmer (relative) measure (Teixeira et al., 2013)

Other variants of Shimmer can be calculated as follows (Upadhya et al., 2017):

$$Shimmer\ (local\ absolute) = \frac{1}{N-1}\sum_{i=1}^{N-1}|A_i - A_{i+1}|$$

Equation 7

Shimmer (APQ3), shimmer (APQ5), and shimmer (APQ11) represent the amount of amplitude disturbance within three, five, and eleven periods respectively, and can be calculated as follows:

$$Shimmer\ (APQ3) = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}|A_i - (\frac{1}{3}\sum_{j=i-1}^{i+1}A_j|}{\frac{1}{N}\sum_{i=1}^{N}A_i}$$

Equation 8

$$Shimmer\ (APQ5) = \frac{\frac{1}{N-1}\sum_{i=2}^{N-2}|A_i - (\frac{1}{5}\sum_{j=i-2}^{i+2}A_j|}{\frac{1}{N}\sum_{i=1}^{N}A_i}$$

Equation 9

3. **HNR (Harmonic to Noise Ratio)** is an indicator of the overall periodicity of the voice signal, and this is articulated as the ratio between the periodic (harmonic part) and aperiodic (noise) components (Teixeira & Fernandes, 2014).

$$HNR\ (dB)\ =\ 10log_{10}\frac{AC_v(T)}{AC_v(0) - AC_v(T)}$$

Equation 10

where $AC_v(0)$ is the autocorrelation coefficient at the origin, consisting of all energy signals. The highest peak in the autocorrelation function beyond the zero-lag peak (at the origin) corresponds to the fundamental period ($AC_v(T)$).

4. **NHR (Noise to Harmonic Ratio)** is the average ratio of inharmonic (noise) to harmonic spectral energy (KILIÇ et al., 2011).

$$NHR\ (dB) = 10log_{10}(\frac{P_{noise}}{P_{harmonic}})$$

Equation 11

where P is the power of the component. In this context and how the HNR was calculated (in dB) the following relation is true between HNR and NHR:

$$\text{NHR (dB)} = -\text{HNR (dB)}$$

Equation 12

5. **GNE (Glottal to Noise Excitation ratio).** It was introduced in 1997 by Michaelis et al. and was to quantify the amount of voice excitation by vocal-fold oscillations against the excitation by turbulent noise (Michaelis et al., 1997).

   For calculating GNE, first a band-pass filter is applied to remove the irrelevant frequency components. Then the voice signals are segmented into overlapping frames, typically 20-40 milliseconds long, with a 50% overlap. At the next step the frequency range, which is usually between 0-4000 Hz, will be divided into three sub-bands. The energy for each of the three frequency sub-bands and the total energy will be calculated using the following formula:

$$E_{sub-band}(i) = \sum_{k \in sub-band} |X(k)|^2$$

Equation 13

$$E_{total} = \sum_{k=0}^{N-1} |X(k)|^2$$

Equation 14

where X(k) is the magnitude of the frequency component in the k bin. Finally, the GNE is calculated as follows:

$$GNE = \frac{E_{central\ sub-band}}{E_{total}}$$

Equation 15

6. **Subglottal pressure.** is a representative of the available energy for causing the vocal cord vibration. There are different means to measure this pressure:

   1) a direct measurement by tracheal puncture,

   2) direct measurement by placing a miniaturized pressure transducer under the glottis,

   3) an estimation based on esophageal pressure,

   4) body plethysmograph,

   5) an estimation of airway pressure during sudden interruption of vowel production, and

   6) an estimation based on the peak intraoral pressure during the production of the letter /p/ surrounded by vowels (Kitajima & Fujita, 1990).

7. **PPE (Pitch Period Entropy).** It quantifies the impaired control of fundamental frequency (F0) by using a logarithmic scale (Abdurrahman & Sintawati, 2020).

   To calculate the PPE measure, pitch periods must first be extracted from the voice data. A histogram is then computed to determine the frequency of each pitch period. The histogram should be normalized to obtain the probability distribution, p(i):

$$p(i) = \frac{number\ of\ occurance\ of\ pitch\ period\ i}{total\ number\ of\ pitch\ periods}$$

Equation 16

and finally, the PPE can be calculated using the following formula:

$$PPE = \quad -\sum_{i} p(i)(p(i))$$

Equation 17

8. **RPDE (Recurrence Period Density Entropy)** is a method for determining the periodicity or repetitiveness of a signal (A. Thomas & D. P. Gopinath, 2012):

$$RPDE = -\frac{\sum_{t=1}^{T_{max}} P(t) ln P(t)}{ln T_{max}}$$

Equation 18

where T_{max} is the largest recurrence value, and *P(t)* is the recurrence period density function.

9. **Fundamental frequency** is the physiological parameter of the frequency of vibration of the vocal cords measured in cycles per second or the equivalent acoustic parameter of fundamental frequency (f0), measured in hertz (Hz) (Knight & Setter, 2021).

   For determining the fundamental frequency in a speech signal, the highest peak in the autocorrelation function beyond the zero lag will be identified (refer to HNR calculation) The peak corresponds to the fundamental period (T0), and the inverse function of the fundamental period will give the fundamental frequency.

10. **SPI (Soft Phonation Index).** It is an evaluation of the weakness of the high-frequency harmonic components that can be an indicator of vocal cords being loosely adducted during phonation. Higher values are related to incomplete adduction of vocal cords (Mathew & Bhat, 2009).

11. **Tremor.** It happens when there is a rhythmical, involuntary fluctuation in the vocal tract and is referred to as pathologic voice tremor (related to neurological diseases). It causes fluctuations in fundamental frequency (F0) and amplitude of the voice (Gillivan-Murphy et al., 2019).

    To calculate the Tremor in the voice data, the fundamental frequency and amplitude contours will be extracted from the voice data. The rate of the rhythmic fluctuations in the fundamental frequency and amplitude, which is usually between 3-12 Hz corresponds to the **tremor rate**, and the extent of these fluctuations determines the **tremor magnitude**.

Table 3 summarizes the Phonatory aspect of voice that is influenced by PD and the studies that investigated their values in the People with Parkinson's Disease group and healthy controls, and their findings.

Higher values of Jitter and its variants, Shimmer and its variants, NHR, D2, PPE, RPDE, SPI, subglottal pressure, fundamental frequency, and voice tremor were reported in the PD group. MPT and HNR (which is the inverse of NHR), were reported to be lower in the PD group with respect to the healthy controls.

Table 3. Phonatory Aspect Changes in Parkinson's Disease

	Influence by Parkinson's Disease	Studies including the Feature Family
Jitter	Several studies have reported **higher** values in the PD group	(Jiménez-Jiménez et al., 1997), (Holmes et al., 2000), (Rahn et al., 2007), (Majdinasab et al., 2016), (Schoentgen et al., 2019), (Moro-Velázquez et al., 2019), (Ramig et al., 1988)
Shimmer	Several studies have reported **higher** values in the PD group compared to the controls	(Ramig et al., 1988), (Jiménez-Jiménez et al., 1997), (Holmes et al., 2000), (Rahn et al., 2007), (Rusz et al., 2011), (Midi et al., 2008), (Tanaka et al., 2011), (Sakar et al., 2013), (Skodda et al., 2013), (Rusz et al., 2013), (Bang et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012), (Bocklet et al., 2013), (Bayestehtashk et al., 2015), (Majdinasab et al., 2016), (Orozco-Arroyave et al., 2018), (Schoentgen et al., 2019), (Moro-Velázquez et al., 2019), (Ramig et al., 1988), (Jiménez-Jiménez et al., 1997), (Rusz et al., 2011), (Yücetürk et al., 2002), (Sakar et al., 2013), (Rusz et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012), (Majdinasab et al., 2016), (Khan et al., 2014)
NHR	Several studies have suggested **higher** values in PD group compared to the controls	(Holmes et al., 2000), (Rahn et al., 2007), (Tanaka et al., 2011), (Sakar et al., 2013), (Skodda et al., 2013), (Bang et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012)
D2	**Higher** values of this feature were reported in several studies for the PD group	(Rahn et al., 2007), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012)
PPE	The results of several studies suggested **higher** values in the PD group with respect to the controls	(Rusz et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012)
RPDE	Results of several studies suggested a **slightly higher** value for PD group with respect to controls	(Rusz et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012)
MPT	**Lower** values were reported in several studies	(Yücetürk et al., 2002), (Midi et al., 2008), (Rusz et al., 2013), (Little et al., 2008), (Tsanas et al., 2009), (Tsanas et al., 2012)
SPI	**Higher** values were reported in several studies	(Tanaka et al., 2011), (Mekyska et al., 2015), (Orozco-Arroyave et al., 2014), (Midi et al., 2008)
Subglottal pressure	People with PD had **higher** subglottal pressure with respect to controls when producing a sentence with the same Sound Pressure Level	(J. Jiang et al., 1999), (Hammer & Barlow, 2010)
Fundamental frequency	Some studies suggested **higher** values for the PD group with respect to controls	(Yücetürk et al., 2002), (Midi et al., 2008), (Tanaka et al., 2011), (Majdinasab et al., 2016), (Abur et al., 2018)
Vocal tremor	Tends to be **higher** in the PD group with respect to controls	(Logemann et al., 1978), (LO, 1994), (Perez et al., 1996), (Jiménez-Jiménez et al., 1997), (Little et al., 2008), (Tanaka et al., 2011), (Villa-Canas et al., 2015), (Brückl et al., 2018)

ARTICULATION AND PROSODY ASPECT CHANGES IN PARKINSON'S DISEASE

As the dataset in this study includes participants describing a drawing, phonatory voice features cannot be investigated. Only the F0SD and IntSD were investigated in people with PD and healthy controls (for more details about the reason for using these two features, refer to **Part II, Chapter 3, Section D**)

Articulatory aspect changes in PD involve hypokinetic articulation, i.e. imprecise consonants and vowels due to limitations in articulatory movements.

Dysprosody, characterized by reduced pitch inflections, monotone, rushed, dysfluent, hesitant, or stuttered-like speech, is also common in PD (Skodda, 2011).

- Articulatory decay (RFA [dB]), F0SD, and IntSD have been reported to differ significantly between healthy and PD groups (Rusz et al., 2022). A review article by Ma et al. (2020) revealed that prosody features are both decreased in people living with PD. VAI and F0SD showed significant differences between the PD and control groups both in males and females (Skodda et al., 2011). Kowalska-Taczanowska et al.(2020) showed a significant difference in F0 dev and reduced loudness between PD and the control group.
- J. Holmes et al. (2000) showed deterioration of breathiness, F0SD, and IntSD in the later stages of PD.

- Skodda et al. (2009) showed reduced F0 variation in male and female subjects with PD compared to the controls but the progression of prosodic impairment over time showed no correlation to the disease duration or UPDRS motor score.

Table 4 illustrates the articulatory aspects of voice that can be evaluated in individuals with PD.

Table 4. Articulatory Aspects Investigated in Parkinson's Disease

ARTICULATORY ASPECT	
FCR[1]	Duration of voiced segments
BBE[2]	Stop silence length
MFCC	VAI[5]
PLP[3]	VOT[6]
LPC[4]	VSA[7]-related

1. Formant Centralization Ratio, 2. Band Bark Energies, 3. Perceptual Linear Prediction, 4. Linear Predictive Coding, 5. Vowel Articulation Index, 6. Voice Onset Time, 7. Vowel Space Area

1. **Formant Centralization Ratio (FCR).** It was designed to maximize sensitivity to vowel centralization while minimizing sensitivity to inter-speaker variability. It is expressed as:

$$FCR = \frac{(F2u+F2a+F1i+F1u)}{(F2i+F1a)}$$

Equation 21

where F2u is the frequency of the second formant of the vowel /u/, F2a is the frequency of the second formant of the vowel /a/, F1i is the frequency of the first formant of vowel /i/, F1u is the frequency of the first formant of the vowel /u/, F2i is the frequency of the

second formant of the vowel /i/, and F1a is the frequency of the first formant of vowel /a/ (Sapir Shimon et al., 2010).

2. **Perceptual Linear Prediction (PLP)** is an approach that models a perceptually motivated auditory spectrum by a low-order all-pole function, using the autocorrelation of linear prediction and was introduced in 1985 (H. Hermansky et al., 1985).

   The low-order all-pole function in PLP refers to a mathematical model used to approximate the spectral envelope of the perceptual loudness spectrum. This model is characterized by having only poles (resonances) and no zeros in its transfer function, which makes it an all-pole model. In all-pole models, the denominator is a polynomial, but the numerator is a constant (and non-zero).

3. **Vowel Space Area (VSA)** refers to a two-dimensional area bounded by lines connecting the first and second formant frequency coordinates (F1/F2) of vowels (Sandoval et al., 2013).

   In the VSA measure, the area is defined as the polygon formed by plotting the first formant (F1) and second formant (F2) frequencies of specific vowels on a two-dimensional plane and connecting these points with straight lines.

The pathophysiological interpretation with respect to hypokinetic dysarthria is that in the IntSD, hypokinesia leads to decreased amplitude of respiratory and thyroarytenoid muscles (which is called Monoloudness). Also, in the F0SD, hypokinesia causes reduced amplitude of vocal cord movements, leading to glottal incompetence (which is called Monopitch) (Rusz et al., 2022).

Summary of Literature Review

The literature review provides an overview of the communication impairments in individuals with Parkinson's Disease (PD), noting the significant variability in speech and voice challenges faced by people living with PD. It highlights key studies that investigate the phonatory aspects of speech, such as jitter, shimmer, Harmonic to Noise Ratio (HNR), and subglottal pressure, all of which are found to differ between PD patients and healthy controls. For example, studies by Rusz et al. (2011) and Upadhya et al. (2017) found that phonation features such as jitter and shimmer are significantly higher in individuals with PD. The review also discusses articulation and prosody changes in PD, where features like F0 standard deviation (F0SD) and intensity standard deviation (IntSD) have shown significant differences between PD and control groups. Additionally, acoustic features such as correlation dimension (D2) and voice tremor are examined for their role in distinguishing PD from healthy individuals.

While previous studies have provided valuable insights into the voice and speech impairments in PD, they have largely been cross-sectional or focused on short periods. There is a notable gap in the literature regarding comprehensive longitudinal investigations that track changes in speech and voice characteristics over an extended period. This study helps fill that gap by examining voice features in participants over a 5-year period, with repeated measures taken before and after engaging in dance sessions. By investigating both short-term and long-term effects of the intervention, the study provides a more complete understanding of how voice features evolve in PD patients and how movement-based interventions like dance may influence these changes over time. This longitudinal approach offers a unique contribution to the existing body of research, addressing the limitations of previous cross-sectional studies.

PART II

CHAPTER 3

VOICE ANALYSIS OF PEOPLE WITH PARKINSON'S DISEASE AND CONTROLS

The study's investigation aims to analyze the speech features of people living with PD and compare these features to those of healthy controls. These features include the F0SD and IntSD, due to the limitations of the speech samples format.

A. INTRODUCTION

Identifying a correlation between two conditions—specifically, observing one condition with a ratio above a defined threshold while the other condition is consistently present—could potentially suggest a causal relationship between the primary cause and the observed condition. In the context of this study and the primary hypotheses, finding a correlation between the presence of PD and different voice feature values will add more to the strength of PD's influence on voice features. Also, comparing the voice feature values measured at different times in PwPD and controls who attended the dance classes, could potentially reveal the effect of dance on the voice features.

Finally, the results of this study and the other studies conducted on the same group can potentially propose the effect of dance on neuroplasticity in the brain.

As there has not been a definitive cure for PD, investigating multiple aspects of the disease can contribute to determining the etiology and mechanism of the disease, which is beneficial for gaining recognition of PD and finding a cure (Stoker & Barker, 2020).

In addition to the advantages of identifying the etiology and enabling early detection of the disease, exploring the effects of dance and demonstrating its potential to improve both motor and non-motor symptoms could provide therapeutic options that enhance Quality of Life (QoL) and alleviate depression and anxiety, which are commonly associated with Parkinson's disease in those already affected.

B. HYPOTHESES/ REASONS FOR MEASURES USED

The primary aim of this study is to identify and compare the voice parameters of individuals with Parkinson's Disease (PD) to those of healthy controls from a database collected around a dance for Parkinson's intervention where the experimenters videotaped the MDS-UPDRS over the years. The secondary aim is to determine which specific voice parameters are affected by the disease. The final aim is to explore the potential of speech analysis as an early detection tool for PD.

Speech impairments, which can occur in up to 90% of PD patients, may develop at any stage of the disease, whether early or late (Smith & Caplan, 2018). This suggests that if relevant speech features are systematically extracted and healthy reference ranges are established, these measures could be utilized as an effective early detection method for PD.

The literature review, as discussed in Part I, Chapter 2, highlights a range of voice features that could be investigated. The dataset for this study is derived from a longitudinal investigation by Bearss and DeSouza (2021), which examined the impact of regular weekly participation in dance with Parkinson's classes on the progression of Parkinson's Disease.

The primary hypotheses of this study are as follows:

1. **Fundamental Frequency Standard Deviation (F0SD) and Voice Intensity Standard Deviation (IntSD)**: These parameters will differ between individuals with Parkinson's Disease and healthy controls, as PD is known to affect voice features.
2. **Progression of PD**: It is expected that the progression of PD will lead to a deterioration in voice features over a five-year period, while the voice features of healthy controls will remain stable.

3. **Effect of Dance**: Dance, by promoting neuroplasticity in the brain, is hypothesized to mitigate the deterioration of voice features in individuals with PD.

The results of this study are anticipated to enhance our understanding of the effects of dance on voice features in both individuals with PD and healthy controls. We hypothesize that the neuroplastic changes induced by dance will manifest in improved speech measures.

Previous research by Bar and DeSouza (2016) on expert young dancers at the National Ballet of Canada has shown that dance promotes signal changes in the supplementary motor area (SMA) as dancers learn, practice, and perform novel ballets. These signal changes suggest that dance may help slow the progression of motor symptoms in individuals with PD by stimulating neuroplasticity in the SMA. The study observed that the rehearsal of complex ballet sequences initially led to increased activity within the SMA and auditory cortical regions up to the 7th week, followed by decreased activation between the 7th and 34th weeks.

Similarly, Simon et al. (2023 & 2024), using the same neuroimaging paradigm, reported modulation of BOLD (Blood Oxygenation Level Dependent) signals in the SMA in a single case study over eight months of dance classes. Notably, the subject in this study was one of the 29 individuals with PD followed in the current investigation.

C. METHODOLOGY

This study investigates voice features, specifically the standard deviation of fundamental frequency (F0SD) and intensity (IntSD), in individuals with Parkinson's Disease (PwPD) compared to healthy controls.

Ethical considerations

This study is a secondary analysis of previously collected data, conducted in adherence to the ethical standards of the Faculty of Graduate Studies at York University. The project received ethical approval (certificate number: 217-296), ensuring compliance with institutional guidelines and regulations.

The original data collection involved informed consent from all participants, who were fully briefed on the study's purpose, procedures, and their right to withdraw at any time without penalty. This consent included permission for future use of their data in subsequent research.

In conducting this secondary analysis, the following ethical considerations were addressed:

1. **Confidentiality and Anonymity**: All data was anonymized, with personal identifiers removed to protect participants' privacy. Data was securely stored and access was restricted to authorized personnel only.
2. **Data Integrity and Security**: Data integrity and security were prioritized. All data was stored in encrypted files and accessed through secure systems, in compliance with York University's data protection policies.

3. **Beneficence and Non-maleficence**: The analysis was conducted to maximize benefits while minimizing potential harm to participants. The results aim to contribute to scientific knowledge without causing harm or distress to the individuals whose data was analyzed.

4. **Transparency and Accountability**: The methods and procedures used in this analysis are transparently reported, ensuring that the study can be replicated and scrutinized, thus maintaining the integrity of the research process.

5. **Respect for Persons**: The rights and dignity of participants were respected throughout the research process, ensuring that their autonomy was honored.

6. **Ethical Approval**: The study adhered to the ethical guidelines provided by the Faculty of Graduate Studies at York University, with ethical approval obtained before the commencement of the analysis.

1. Speech Dataset

Voice features were collected from individuals who attended the dance classes for PD at Canada's National Ballet School and Trinity St. Paul's church in Toronto, Ontario from 2014 to 2019. The participants were part of a longitudinal study by Bearss & DeSouza (Bearss & DeSouza, 2021). In that study, people were filmed during the evaluation of the Movement Disorder Society's Unified Parkinson's Disease Rating Scale (MDS-UPDRS). They described a picture drawing for 30-60 seconds (**Figure 2**). The MDS-UPDRS evaluation was recorded twice for each participant before and after the dance session. In Part III (Item 3.1) of the scale, participants were examined for their speech. The UPDRS was originally developed in the 1980s and in 2001, a new version of it, termed the Movement Disorder Society (MDS) sponsored by UPDRS was created. This scale has four parts such as evaluating motor and non-motor subjectively and examining the person (Goetz et al., 2008).

(A sample part of the MDS-UPDRS questionnaire is provided in **Appendix C**).

Both PD patients and healthy controls participated in the weekly dance classes.

Participants were filmed for the MDS-UPDRS evaluation. In the video files, people are sitting on a chair 4-5 meters away from the camera and an examiner is performing the examination. Each video file was investigated during the parts where the person was describing the drawing. Those parts were trimmed using QuickTime Player version 10.5 and extracted to audio. The chosen section was the one that involved the participant's voice only. Files including background noise, a sudden loud noise, or music playing in the background were excluded.

A total of 281 audio files were created from the video files. 173 of these files were extracted from people with PD (nPD=173), and 108 were from healthy controls (nHC=108). These video

files were recorded from 2014 to 2019: n=34 (nHC=16; nPD=18) of these files were from 2014, n=49 (nHC=22; nPD=27) were from 2015, n=71 (nHC=20; nPD=51) were from 2016, n=44 (nHC=12; nPD=32) from 2017, n=39 (nHC=18; nPD=21) from 2018, and n=44 (nHC=20 HC; nPD=24) were from 2019.

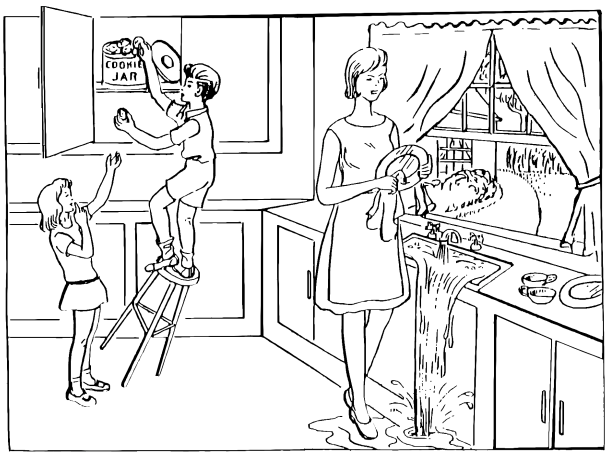


Figure 2. The Drawing Described in MDS-UPDRS Part III Examination

After excluding files with background noise (e.g., piano playing in the background) or files containing more than one person's voice, a total of 266 files remained. Of these, 135 files were extracted from data collected before the dance session, including 29 people with Parkinson's disease (PD) and 29 healthy controls (HC).

The after-dance session files included 131 recordings, consisting of 28 PD subjects (nPD=28; one subject's post-session file was excluded) and 29 healthy controls (nHC=29).

2. Extracting voice features

A Python machine learning pipeline was used to extract voice features from all 29 individuals with PD (PwPD) and 29 healthy controls (HC), resulting in a total of 266 voice file samples. This code has Praat scripts implemented in Parselmouth for Python (Feinberg, 2022). (The code for extracting the features can be found in the **Appendix B**).

The extraction of voice features was performed using a combination of machine learning-based frameworks integrated with Python libraries, including Praat, Parselmouth, and Librosa. The goal was to extract relevant acoustic features such as the standard deviation of fundamental frequency (F0SD) and intensity (IntSD) from recorded speech samples of PwPD and healthy controls.

1. ML Framework Overview:

The feature extraction pipeline was designed as an automated process using Python-based scripts that applied pre-trained models and algorithms embedded in Praat and Parselmouth libraries:

- Praat (Boersma, 2011): A speech analysis platform powered by a feedforward neural network-based learning algorithm. This algorithm performs supervised classification for extracting key acoustic features such as pitch, formant, and intensity patterns from voice files.

- Parselmouth (Jadoul et al., 2018): An open-source Python interface enabling integration with Praat's core functionalities, ensuring efficient batch processing of audio files.

- Librosa (McFee et al., 2015): A machine learning library widely used for audio signal processing, utilized for extracting the intensity standard deviation (IntSD).

2. Audio Processing Workflow:

- Audio Preprocessing: Audio files were initially stored in the .m4a format and converted to .wav for compatibility with Praat [using the Music application (version 1.4.2.83)].
- Automated Voice Analysis: The machine learning pipeline processed each audio file using PraatScripts hosted on GitHub, applying feature extraction models tuned to measure specific acoustic parameters.
- Output Generation: Extracted features were saved as .csv files, providing a structured format for statistical analysis and visualization.

3. Feature Extraction Details:

- Standard Deviation of Fundamental Frequency (F0SD):
    - Extracted using Praat's pitch-tracking algorithm.
    - F0SD reflects variability in pitch, which is often reduced in individuals with PD due to hypokinetic dysarthria.
- Standard Deviation of Intensity (IntSD):
    - Computed using Librosa's feature extraction functions.
    - IntSD measures amplitude variability, another critical marker in speech studies involving neurodegenerative disorders.

4. Statistical Analysis Integration:

The extracted features were analyzed using ANOVA models in R Studio (Version 2024.04.0+735) to evaluate the effect of time and group on F0SD and IntSD. This integration between the

ML-based feature extraction pipeline and statistical analysis framework enabled an end-to-end data processing pipeline, ensuring accuracy and reproducibility.

Given the study's observational and exploratory nature, the use of pre-existing ML models embedded in Praat and Parselmouth provided reliable and validated methods for feature extraction. These models are recognized for robust pitch and intensity analysis, making them ideal for research on voice features affected by PD. Additionally, the modular structure of the codebase allowed for customization and batch processing, ensuring scalability and reproducibility.

The Librosa library in JupyterLab (version 3.6.3) from ANACONDA Navigator (version 2.5.2) was used to compute the standard deviation of intensity (IntSD) from the processed voice files. (The code for extracting Intensity standard deviation can be found in the **Appendix B**).

The extracted audio files from healthy controls and people with PD were processed by the PraatScripts-Master before and after the dance sessions respectively.

Then, a .csv file of selected voice features: standard deviation of fundamental frequency, and standard deviation of intensity was created.

Additionally, a modified version of the 'Diagnosing Parkinson's Disease using Voice Sample Data Analysis' project by Maheshwor Tiwari (GitHub Repository) was used in the Google Colaboratory environment for further statistical analysis.

Voice features were measured across 11 time points from 2014 to 2019, as outlined in **Table 5**.

Table 5. Time Points of MDS-UPDRS Examinations

Time 1	2014
Time 2	2015
Time 3	2016 (Jan-Apr)
Time 4	2016 (May-Aug)
Time 5	2016 (Sep-Dec)
Time 6	2017 (Jan-Jun)
Time 7	2017 (Jul-Dec)
Time 8	2018 (Jan-Jun)
Time 9	2018 (Jul-Dec)
Time 10	2019 (Jan-Jun)
Time 11	2019 (Jul-Dec)

To enhance data visualization, the 11 time points were consolidated into four-time slots.

Time A (2014/2015): Time 1 and Time2

Time B (2016): Time 3, Time 4, and Time 5

Time C (2017): Time 6 and Time 7

Time D (2018/2019): Time 8, Time 9, Time 10, and Time 11

The decision to merge and average the 11-time points into 4 was based on both the proximity of certain data collections and the need to address variability in participant numbers. The first two time points, collected at the end of 2014 and the beginning of 2015, were merged due to their temporal closeness, allowing for a more accurate representation of that period. Similarly, the data from 2018 and 2019 were averaged together (time 4), as the number of voice samples in these later collections was significantly reduced due to lower participation rates. For the other two time points (2016 and 2017), an average was calculated to represent a measure for each year. By averaging these collections, the analysis could maintain statistical power while still capturing the longitudinal changes in voice features over the 5-year span of the study. This approach provided a balanced representation across the different stages of the intervention. Visualization and plotting of the voice feature's values across time were conducted using Python code (see **Appendix "F. Plotting Python code"** for the code that was used).

D. A NOTE ON SELECTED FEATURES

Various features can be extracted and analyzed based on the task performed by the subjects. Ruzs et al. 's (2022) study summarized the phonatory, articulatory, prosody, and speech timing acoustic features, and the tasks that the features can be extracted from. In phonation features, Harmonics-to-Noise Ratio (HNR), Cepstral Peak Prominence (CPP), and Proportion of Subharmonic Intervals (PSI) all can be extracted from sustained phonation tasks.

In a sustained vowel phonation task, the participants are asked to sustain the voicing of a vowel, usually /a/, at a comfortable pitch and loudness level for at least 5 seconds after a deep breath. The same process is typically repeated three times. The task can be extended to assess sustained phonation at different pitches and loudness. The articulatory acoustic features involve Voice Onset Time (VOT), which can be extracted from syllable repetition tasks, and Resonant Frequency Attenuation (RFA), which can be extracted from reading passage tasks.

Prosody acoustic features involve standard deviation of intensity (IntSD) and standard deviation of fundamental frequency (F0SD), which both can be extracted from reading passage tasks. Duration of Pause Intervals (DPI) and Net Speech Rate (NSR) can be extracted from reading passage tasks, while Diadochokinetic Rate (DDKR) extraction needs syllable repetition tasks (Rusz et al., 2022).

Studies investigating phonatory voice features affected by Parkinson’s Disease, such as jitter, shimmer, HNR, and NHR, typically employ sustained phonation of vowels (e.g., /a/, /u/, /e/, /i/). Most have found significant differences between PD and healthy groups, with higher jitter and shimmer and lower HNR in the PD group (Moro-Velazquez et al., 2021).

Figure 3 illustrates the process of extracting voice features and the number of files in each category.

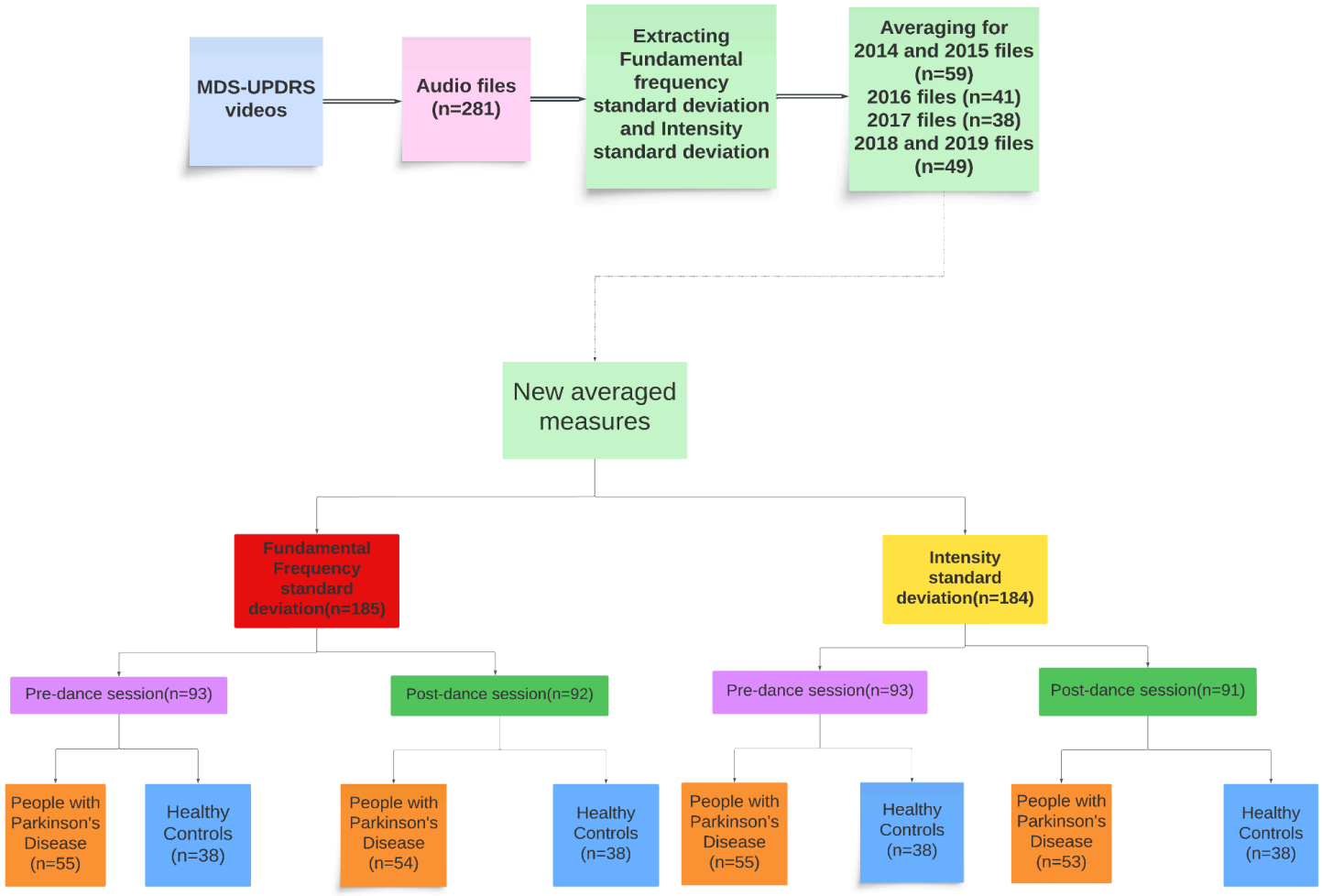


Figure 3. The Illustration of Extracting the Voice Files and Number of Files in Each Group

To visualize and compare the intensity contour between a subject with PD and a healthy control, a common sentence ("**water is overflowing**") from their descriptions was extracted, and the intensity contours were drawn using Praat software. **(Figure 4)**.

It is worth noting that this illustration was created using just one sentence for comparison purposes, whereas the entire description of the image was used for analyzing the voice features.

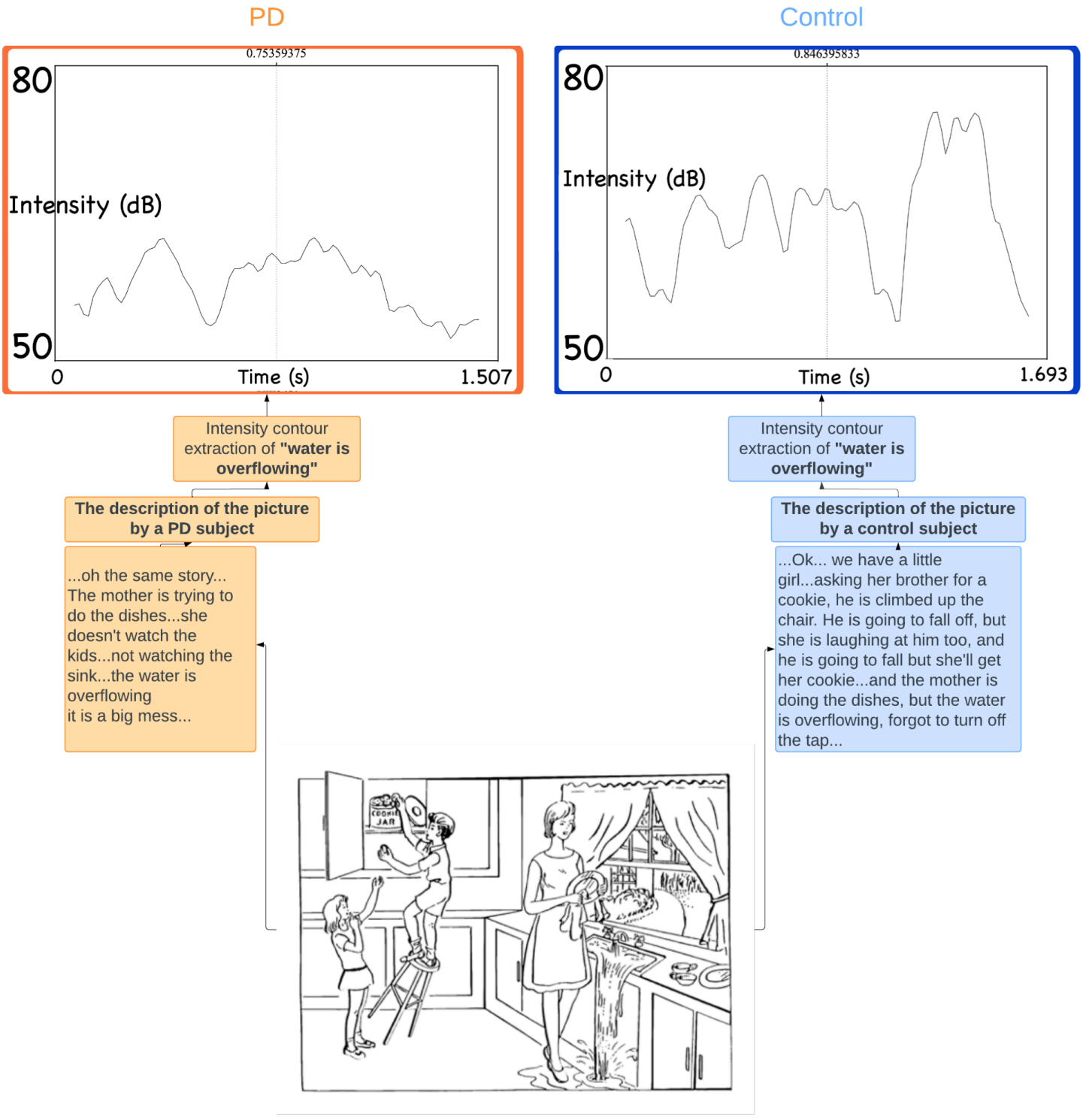


Figure 4. An Illustration of the Intensity Contour of a Common Sentence Between a Subject with PD and a Control Subject for Visualizing the Difference Between the Intensity of the Voice

E. RESULTS

The output tables from PraatScripts-Master are provided in the appendix. **Figure 5** illustrates the distribution of different voice features through histogram diagrams.

Histogram Comparison for Healthy controls and People with Parkinson

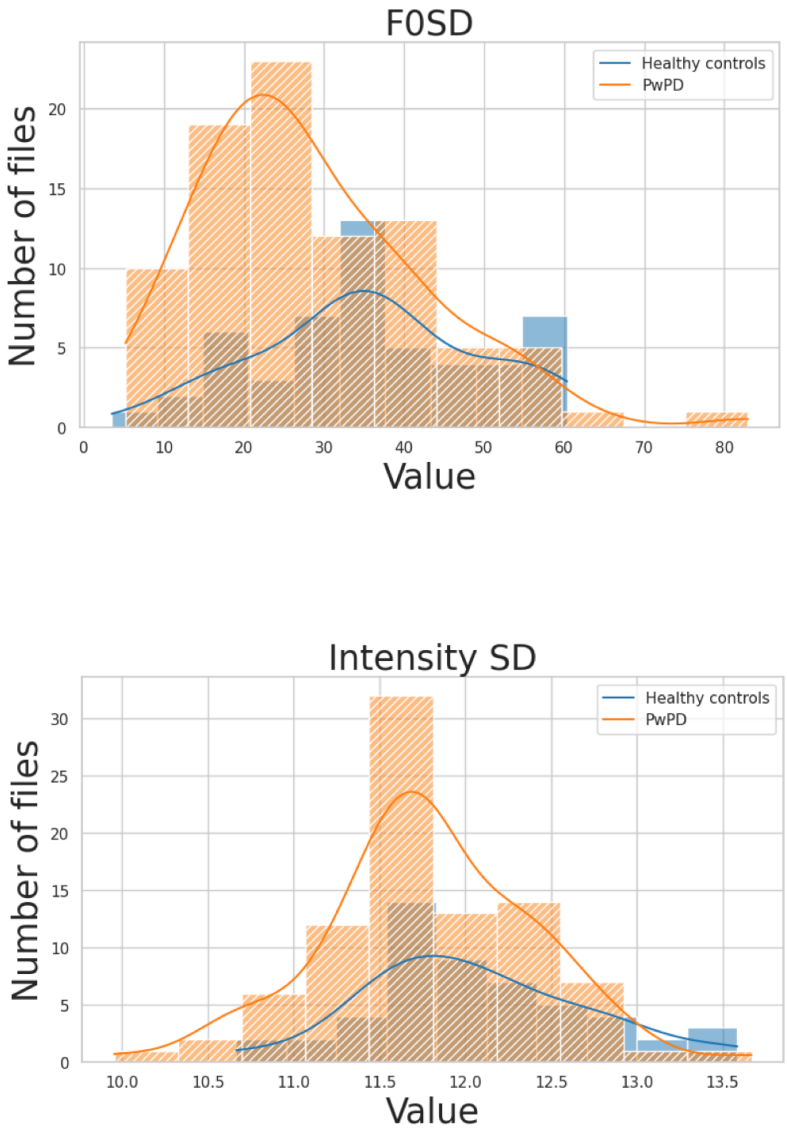


Figure 5. Histogram Diagrams of Voice Features

Box plots of different voice features are found in **Figure 6.**

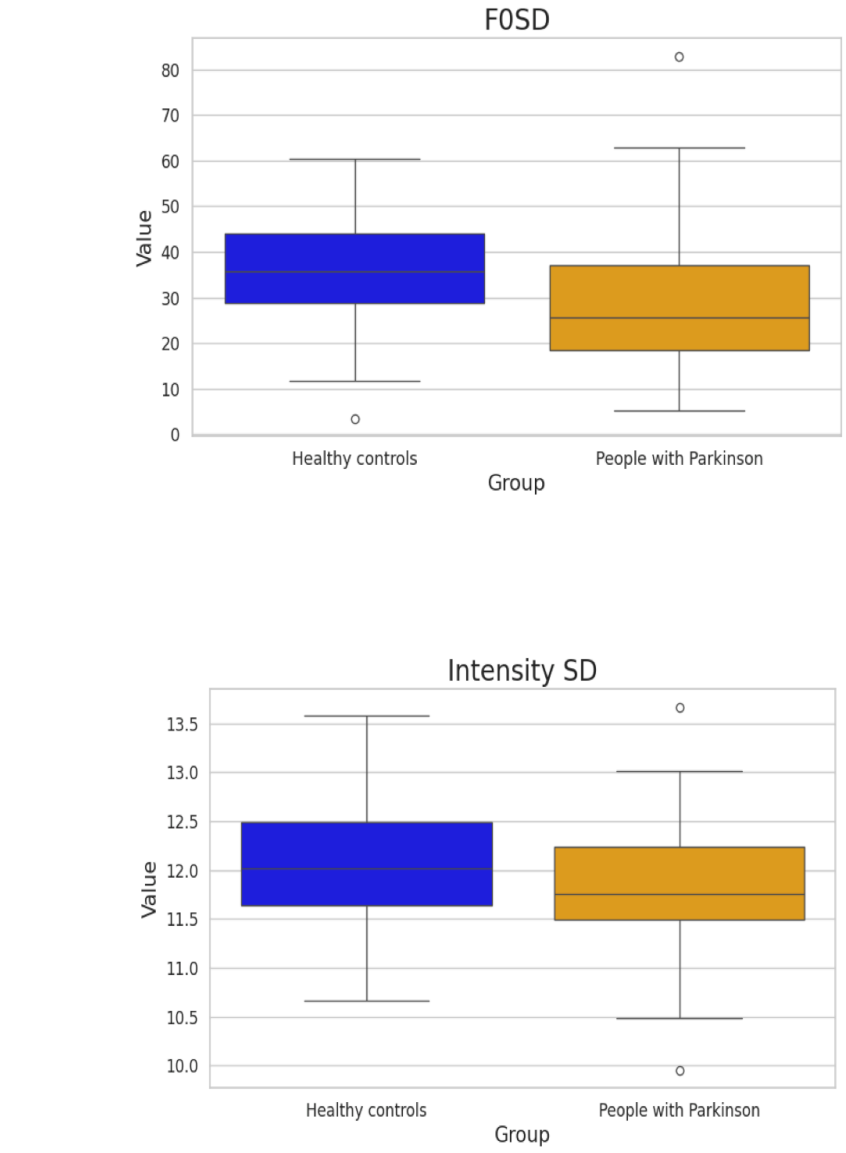


Figure 6. Box Plots of Voice Features

Figure 7 displays the mean differences between the two groups along with their confidence intervals.

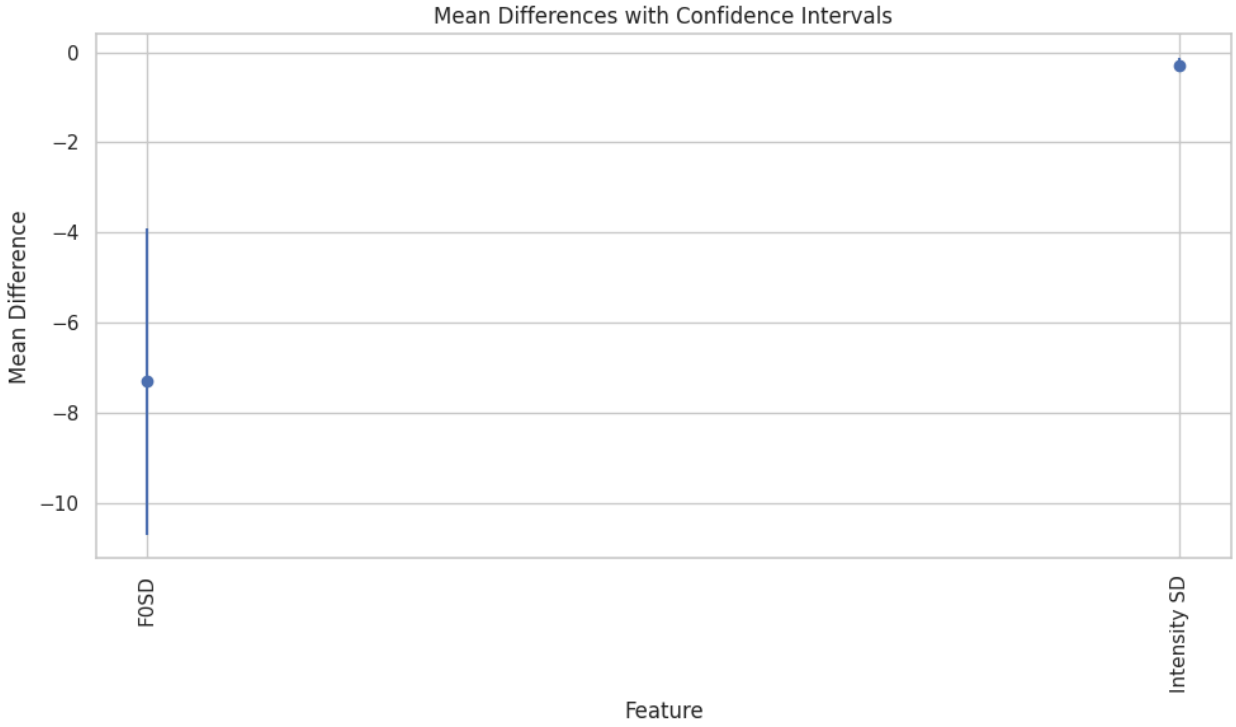


Figure 7. Mean difference and Confidence intervals

Table 6 summarizes the voice features that showed significant differences ($p < 0.05$) between PwPD and healthy controls.

Table 6. Voice features that Showing Significant Differences Between PD and Control Groups

Feature	Z-Score	Critical Z-Value	Result
Intensity standard deviation	-2.504312889788850	1.959963984540050	Reject H0
Fundamental frequency standard deviation	-2.9973199674744600	1.959963984540050	Reject H0

Table 7. Age and Sex Distribution of the PwPD and Healthy Controls Groups

	Age at 2014	Sex
PwPD (n=29)	68.2 (54-80)	Female:18 Male:11
Healthy Controls (n=29)	63.5 (50-75) *	Female:19 Male:10

* The age of 4 people was not available

Descriptive statistics of the voice features are presented in **Figures 8, 9, 10, and 11.**

Descriptive statistics for fundamental frequency standard deviation (F0SD)-PwPD

Group	count	mean	std	min	25%	50%	75%	max
	2014/2015							
PwPD-post	13	26.5390021	7.84034378	12.3207502	21.5096341	25.4335718	29.5627959	42.6200739
PwPD-pre	13	25.986851	12.9765431	9.15597417	17.5385211	22.7823244	31.8164081	55.0795046
	2016							
PwPD-post	14	27.4953197	11.2574281	11.5639506	19.3145526	24.3411463	32.2200486	46.4769009
PwPD-pre	15	24.7953814	9.84110696	10.7532737	19.5188762	22.3881456	29.7224937	46.7550156
	2017							
PwPD-post	14	26.0623771	10.6388365	13.7531536	17.5639129	25.3385544	32.1245208	49.846792
PwPD-pre	14	28.7494524	11.3615426	12.9352111	21.3169198	26.9123721	35.6145548	54.0921438
	2018/2019							
PwPD-post	13	34.9470419	19.9786556	12.547341	18.1625557	30.5609049	44.7362835	75.2458537
PwPD-pre	13	36.4314177	16.2772146	11.8834711	24.5284557	32.1899279	51.6146882	65.0856978

Figure 8

Descriptive statistics for fundamental frequency standard deviation (FOSD)-Healthy Controls

Group	count	mean	std	min	25%	50%	75%	max
	2014/2015							
Healthy controls-post	14	33.9179171	13.5353645	6.48490652	25.0178574	34.4460765	45.0014798	54.3435036
Healthy controls-pre	15	34.1042332	16.3771145	3.46880541	23.4132758	34.6642034	44.6802223	60.3555254
	2016							
Healthy controls-post	6	40.2664709	14.2663547	20.8138263	32.2841191	40.465993	46.3547857	61.9784686
Healthy controls-pre	6	35.4339572	16.2022103	13.9531469	24.243453	35.3768564	47.5386379	55.772
	2017							
Healthy controls-post	6	34.3940717	10.9144931	24.6389527	26.4716472	30.3387735	40.5233161	51.9471619
Healthy controls-pre	6	36.5725869	16.2039924	14.876908	27.6178924	33.5268342	50.2631198	56.0148184
	2018/2019							
Healthy controls-post	12	38.5638951	14.5144117	10.9020145	30.5805174	37.1482639	48.1204327	63.4874069
Healthy controls-pre	11	35.9200651	11.8632678	12.0789568	34.0645848	37.994231	42.0771613	52.4222289

Figure 9

Descriptive statistics for Intensity standard deviation (IntSD)-PwPD

Group	count	mean	std	min	25%	50%	75%	max
	2014/2015							
PwPD-post	13	11.8138287	0.41160897	11.1598339	11.6193686	11.8263097	12.0024691	12.4490786
PwPD-pre	16	11.938764	0.4145833	11.3258419	11.6485601	11.8749366	12.2300108	12.7721329
	2016							
PwPD-post	14	11.7292836	0.38558425	11.0240083	11.6078608	11.7273311	12.0012499	12.264029
PwPD-pre	13	11.6361002	0.47805516	10.7227192	11.4555292	11.7239873	11.9151416	12.387054
	2017							
PwPD-post	13	11.8887099	0.46419415	11.26227	11.582325	11.7987194	12.222414	12.9680595
PwPD-pre	13	11.7622516	0.59478251	10.7802525	11.3663797	11.6732845	12.1137676	12.8909101
	2018/2019							
PwPD-post	13	11.8041358	0.48981582	11.082325	11.5056324	11.8023951	12.0266609	12.708437
PwPD-pre	13	11.9483278	0.50859143	11.2661588	11.5574179	11.7990551	12.3272181	12.8751307

Figure 10

Descriptive statistics for Intensity standard deviation (IntSD)-Healthy Controls

Group	count	mean	std	min	25%	50%	75%	max
	2014/2015							
Healthy controls-post	15	11.96313	0.49076895	10.8729763	11.6919723	12.0390558	12.2918525	12.6506872
Healthy controls-pre	15	12.1117342	0.52404123	11.2358923	11.7802791	12.0187836	12.4495187	13.0171556
	2016							
Healthy controls-post	6	11.9903882	0.61565942	11.2469778	11.5139518	12.1299792	12.2252646	12.8697573
Healthy controls-pre	6	11.5241675	0.52343466	10.6658783	11.3021973	11.6235406	11.8204577	12.150866
	2017							
Healthy controls-post	6	12.3628756	0.30268637	12.0521097	12.1517832	12.2914567	12.5034876	12.8628407
Healthy controls-pre	6	12.5250638	0.6719002	11.6762791	12.1364028	12.482523	12.8148258	13.5624352
	2018/2019							
Healthy controls-post	11	12.3304036	0.69459792	11.3960943	11.844284	12.179677	12.6342135	13.8073997
Healthy controls-pre	11	12.1410076	0.82072152	10.6805058	11.7845268	11.9587657	12.3315373	13.585371

Figure 11

A. The Standard Deviation of Fundamental Frequency

The standard deviation of fundamental frequency values measured over time, from 2014 to 2019 is presented.

Figure 12 compares F0SD over four-time points for PwPD and healthy controls, both pre-dance and post-dance sessions.

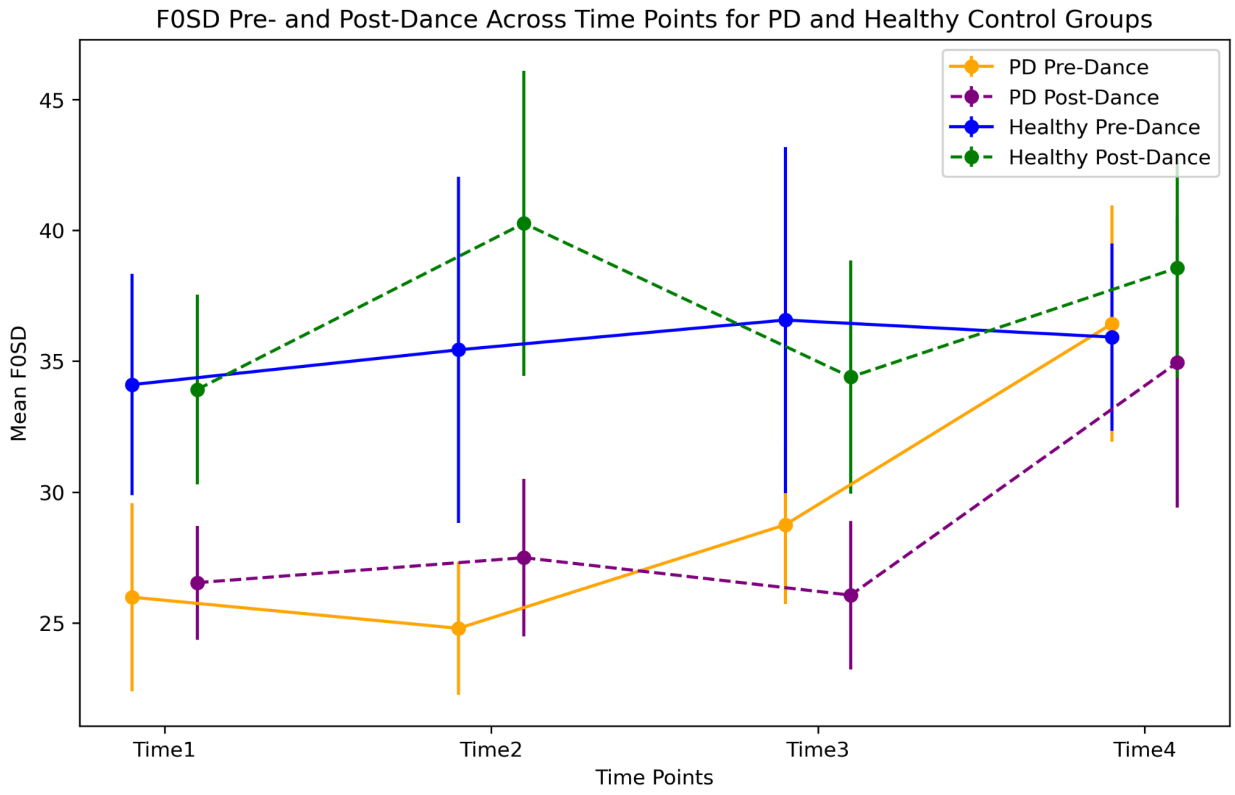


Figure 12

B. The Standard Deviation of Intensity

The standard deviation of intensity values measured over time, from 2014 to 2019 is presented.

Figure 13 compares IntSD over four-time points for PwPD and healthy controls, both pre-dance and post-dance sessions.

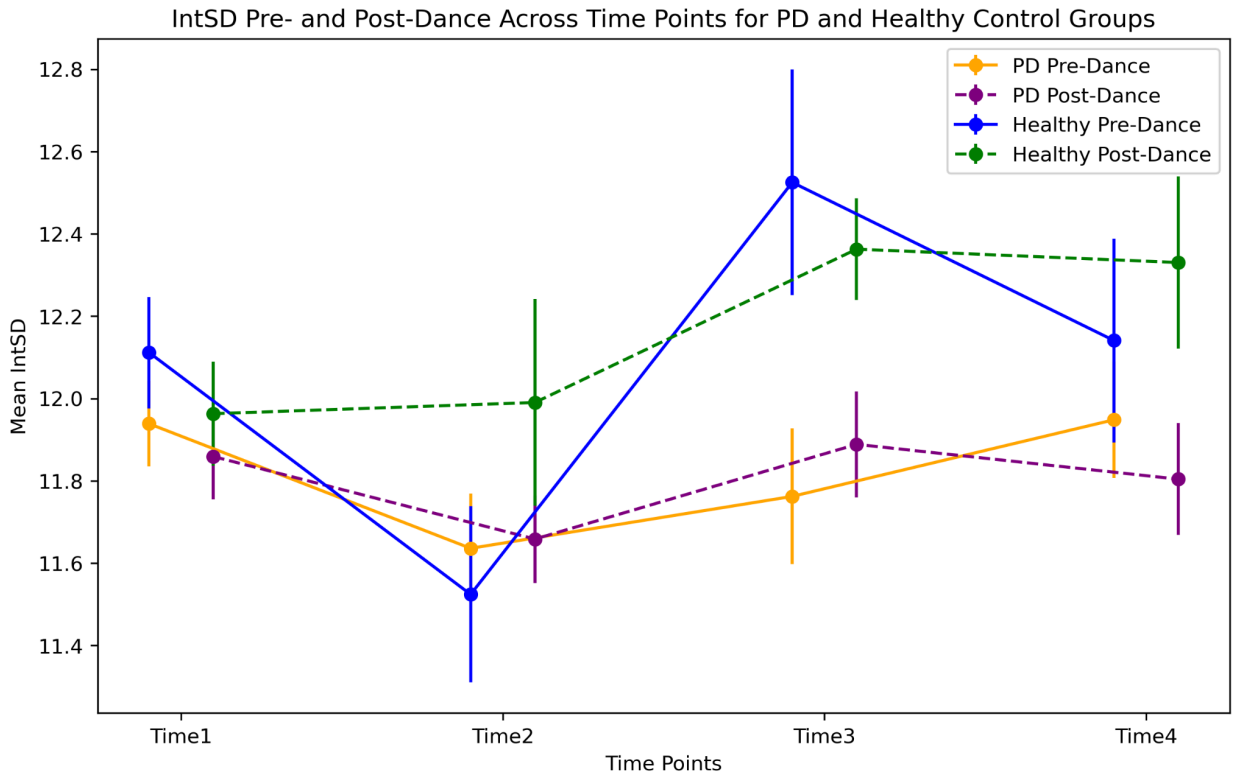
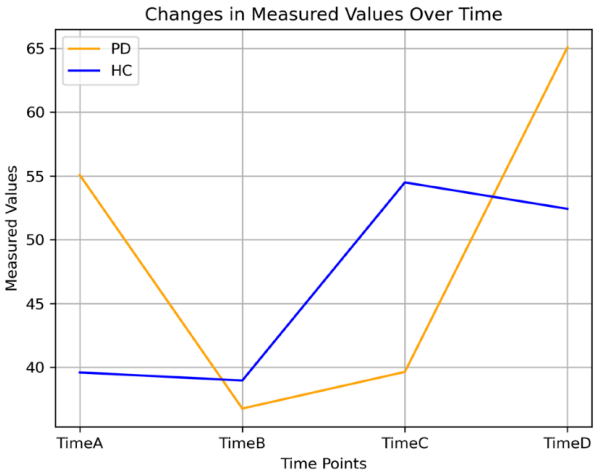


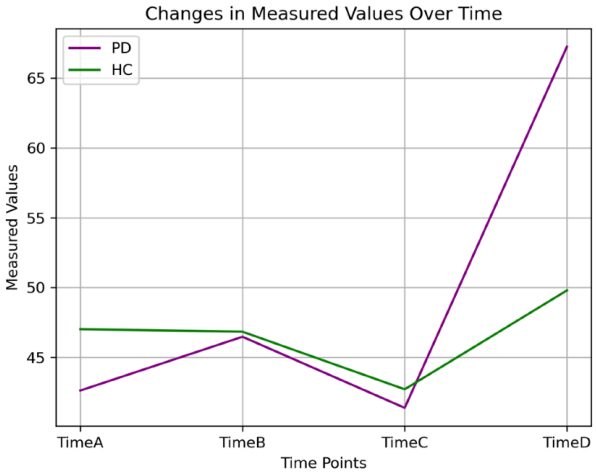
Figure 13

Changes in voice features over the four-time points for individual subjects, one with PD and one healthy control, are illustrated in **Figures 14** through **17**.

Fundamental frequency standard deviation comparison between one Subject with Parkinson and one Healthy control from before and after the dance session



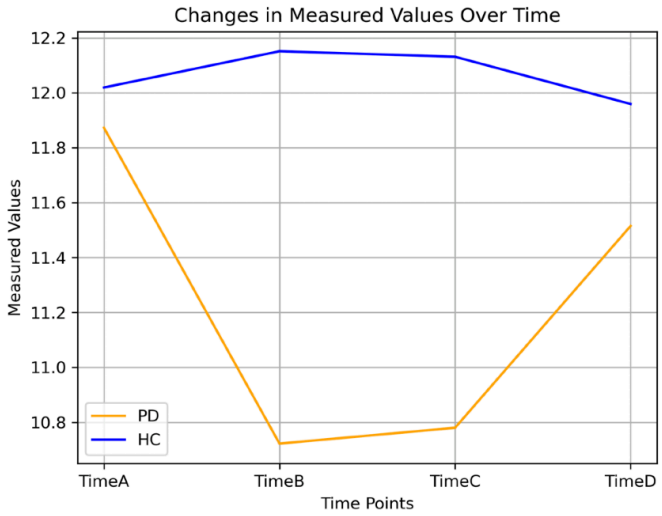
Before the dance session



After the dance session

Figure 14

Intensity standard deviation comparison between one Subject with Parkinson and one Healthy control from before and after the dance session

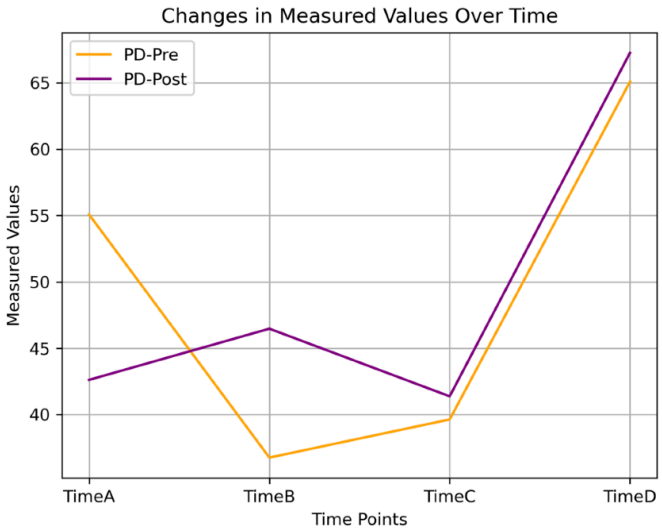


Before the dance session

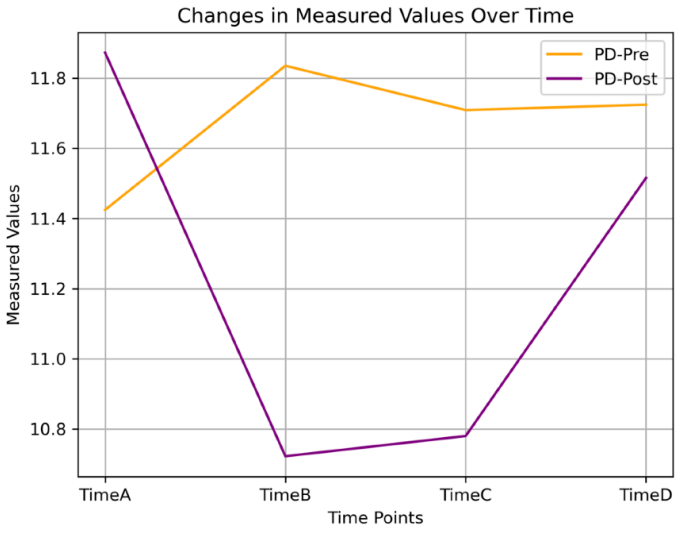
After the dance session

Figure 15

Fundamental frequency standard deviation and Intensity standard deviation for one subject with Parkinson from before and after the dance session



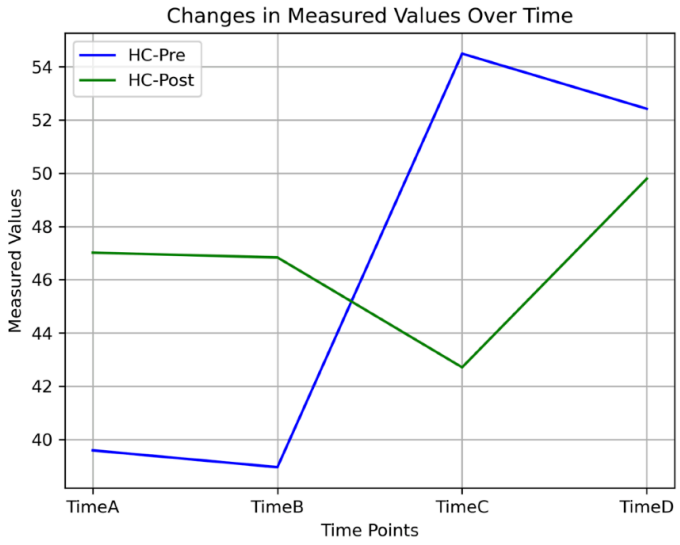
Fundamental frequency standard deviation



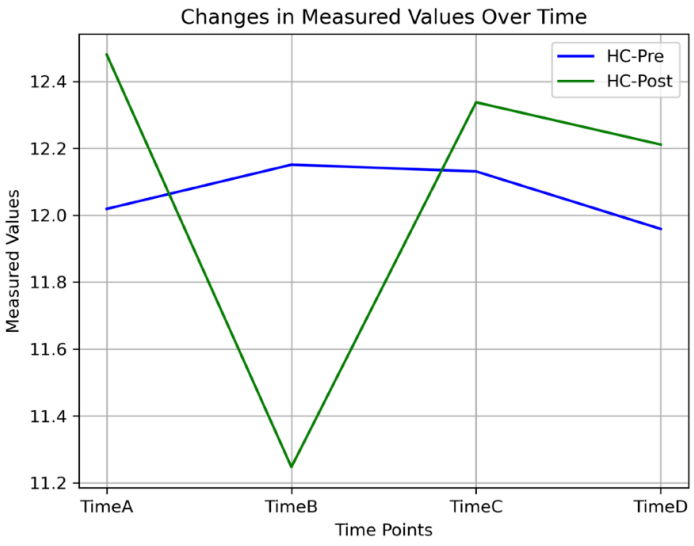
Intensity standard deviation

Figure 16

Fundamental frequency standard deviation and Intensity standard deviation for one Control subject from before and after the dance session



Fundamental frequency standard deviation



Intensity standard deviation

Figure 17

Table 8 presents the ANOVA results for comparing the standard deviation of fundamental frequency (F0SD) between 2014 (initial) and 2019 (final) in the two groups.

Table 8. ANOVA results for comparing 2014 and 2019 F0SD

ANOVA Table for Error: Subject					
Source	**Df**	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
GroupTime	1	323.0	322.9	1.18	0.289
Residuals	23	6294.0	273.7		
ANOVA Table for Error: Subject: GroupTime					
Source	**Df**	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
GroupTime	2	602.7	301.37	3.906	**0.0346***
Residuals	23	1774.4	77.15		

Table 9 demonstrates the Post hoc test (Bonferroni's correction) results of comparing the Fundamental frequency standard deviation between 2014 and 2019 files in the 2 groups.

Table 9. Post hoc (Bonferroni's correction) Results Table for F0SD

Contrast	Estimate	SE	df	t.ratio	p.value
HC_Post - HC_Pre	2.048	5.41	46	0.379	1.0000
HC_Post - PD_Post	1.398	5.30	46	0.264	1.0000
HC_Post - PD_Pre	10.824	5.30	46	2.042	0.2817
HC_Pre - PD_Post	-0.651	5.30	46	-0.123	1.0000
HC_Pre - PD_Pre	8.776	5.30	46	1.655	0.6281
PD_Post - PD_Pre	9.426	5.19	46	1.815	0.4566

Table 10 demonstrates the ANOVA results of comparing the Intensity standard deviation between the 2014 and 2019 files in the 2 groups.

Table 10. ANOVA results for comparing 2014 and 2019 IntSD

ANOVA Table for Error: Subject					
Source	**Df**	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
GroupTime	1	0.979	0.9791	5.904	**0.0242***
Residuals	21	3.483	0.1658		
ANOVA Table for Error: Subject:GroupTime					
Source	**Df**	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
GroupTime	2	0.155	0.07752	0.363	0.7
Residuals	21	4.487	0.21364		

Table 11 demonstrates the Post hoc test (Bonferroni's correction) results of comparing the Intensity standard deviation between the 2014 and 2019 files in the 2 groups.

Table 11. Post hoc (Bonferroni's correction) Results Table for IntSD

Contrast	Estimate	SE	df	t.ratio	p.value
HC_Post - HC_Pre	0.1592	0.186	42	0.857	1.0000
HC_Post - PD_Post	0.3460	0.182	42	1.903	0.3833
HC_Post - PD_Pre	0.3972	0.182	42	2.185	0.2073
HC_Pre - PD_Post	0.1869	0.182	42	1.028	1.0000
HC_Pre - PD_Pre	0.2381	0.182	42	1.309	1.0000
PD_Post - PD_Pre	0.0512	0.178	42	0.288	1.0000

The ANOVA results for F0SD (**Table 8**) showed:

- The subject-level analysis revealed no significant main effect of the group over time (F = 1.18, p = 0.289), suggesting that the overall change in F0SD between 2014 (initial) and 2019 (final) was not significantly different between the PD and healthy control groups.
- However, the interaction analysis indicated a significant effect (F = 3.906, p = 0.0346), showing that the two groups followed different patterns of change in F0SD between 2014 and 2019.

In the post hoc test (**Table 9**), although no statistically significant differences were found in the pairwise comparisons, these results suggest that both groups exhibited similar variability in fundamental frequency over time. For example, the difference between HC Final (2019) and PD Initial (2014) had an estimate of 10.824 but was not statistically significant (p = 0.2817). These results suggest that although the overall pattern of F0SD change over time differs between the two groups, no specific pairwise comparison reached statistical significance, likely due to high variability and the conservative nature of Bonferroni corrections. This high intra-group variability may have masked more subtle differences in vocal features between the PD and healthy control groups. Larger sample sizes in future studies could help to capture these distinctions more effectively.

The ANOVA results for IntSD (**Table 10**) indicated:

- In the **Subject-level analysis**, a significant effect of time was found (F = 5.904, p = 0.0242), showing that IntSD changed significantly between 2014 (initial) and 2019 (final).

This indicates that the overall intensity standard deviation either increased or decreased between these time points.

- However, the interaction analysis was not significant ($F = 0.363$, $p = 0.7$), suggesting that both the PD and healthy control groups experienced similar changes in IntSD over time.

The post hoc test results (**Table 11**) showed no significant differences between the groups or time points after the Bonferroni correction. For instance, the contrast between HC Final (2019) and PD Initial (2014) had an estimate of 0.3972 but was not statistically significant ($p = 0.2073$). Therefore, although there were significant overall changes in IntSD between 2014 and 2019, these changes were not significantly different between the two groups.

For analyzing the time and group effect on the two features (F0SD and IntSD), a mixed-effect ANOVA test was conducted. Given that different subjects had varying numbers of samples and some had missing data for either pre- or post-dance sessions, the mixed-effect ANOVA is best suited for investigating the impact of dance on voice features in the two groups. The results of the mixed-effect ANOVA for Fundamental Frequency Standard Deviation are summarized in **Tables 12 through 16.**

F0SD Mixed Effect ANOVA Table for Pre and Post-Dance Sessions for PwPD and Healthy Controls

Table 12. Scaled Residuals

Statistic	Value
Min	-3.2883
1Q	-0.5092
Median	-0.0631
3Q	0.4768
Max	3.2413

Table 13. Random Effects

Group	Name	Variance	Std. Dev.
Subject	(Intercept)	111.15	10.543
Residual		65.31	8.082

Table 14. Correlation of Fixed Effects

Factor	(Intercept)	Time	Measure pre	Group PwPD	Time: Measure pre	Time: Group PwPD	Measure pre: Group PwPD
Time	-0.799						
Measure pre	-0.513	0.495					
Group PwPD	-0.738	0.590	0.379				
Time: Measure pre	0.447	-0.550	-0.884	-0.330			
Time: Group PwPD	0.614	-0.768	-0.380	-0.786	0.423		
Measure pre: Group PwPD	0.369	-0.356	-0.719	-0.522	0.636	0.535	
Time: Measure pre: Group PwPD	-0.323	0.398	0.639	0.465	-0.723	-0.590	-0.899

Table 15. Type III Analysis of Variance Table

Factor	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Time	464.16	464.16	1	175.52	7.1065	**0.008397 ****
Measure	22.64	22.64	1	124.33	0.3466	0.557116
Group	207.32	207.32	1	128.09	3.1743	0.077177
Time: Measure	7.72	7.72	1	124.02	0.1182	0.731591
Time: Group	37.43	37.43	1	175.52	0.5730	0.450066
Measure: Group	13.51	13.51	1	124.33	0.2069	0.650033
Time:Measure: Group	46.66	46.66	1	124.02	0.7144	0.399601

Table 16. Pairwise contrast: Adjusted for Bonferroni Method

Contrast	Estimate	SE	df	t-ratio	p-value
Time2 post Healthy controls - Time2 pre Healthy controls	1.6247	1.87	123.5	0.870	1.0000
Time2 post Healthy controls - Time2 post PwPD	6.4828	3.34	71.3	1.941	0.3373
Time2 post Healthy controls - Time2 pre PwPD	6.4017	3.34	71.0	1.919	0.3537
Time2 pre Healthy controls - Time2 post PwPD	4.8581	3.33	71.2	1.457	0.8967
Time2 pre Healthy controls - Time2 pre PwPD	4.7770	3.33	70.8	1.435	0.9343
Time2 post PwPD - Time2 pre PwPD	-0.0811	1.55	122.7	-0.052	1.0000

The mixed effect ANOVA for fundamental frequency standard deviation (F0SD) revealed a significant effect of time ($F = 7.1065$, $p = 0.0084$), indicating that the F0SD varied significantly between pre- and post-dance sessions across all participants. These results suggest that the dance sessions had a measurable impact on the variability of fundamental frequency in the speech of both the PD and healthy control groups. However, the lack of a significant interaction between time and group ($p = 0.4501$) indicates that this effect of time was not significantly different between the two groups, implying that both the PD group and healthy controls exhibited similar changes in F0SD over time.

The analysis also showed a marginally significant **main effect of the group** ($F = 3.1743$, $p = 0.0772$), suggesting a trend toward differences in F0SD between the PD and healthy control groups. However, this result did not reach the traditional significance threshold ($p < 0.05$), and thus, no firm conclusions can be drawn about group differences. None of the interaction effects between measure, group, and time were significant, indicating no substantial combined effect of these variables on F0SD.

Pairwise comparisons further support these results, with no significant differences found between pre- and post-dance F0SD for either the healthy control or PD groups. As shown in **Figure 12**, the fundamental frequency variability appears to diverge at later time points, with the PD group showing a more pronounced increase compared to controls. Despite these visible trends, particularly an increase in F0SD for the PD group at Time 4, these changes were not statistically significant, likely due to high variability within the groups. Overall, while time had a significant effect on F0SD, the interaction between time and group did not reveal significant differences, and variability within the groups likely contributed to the non-significant findings for pairwise comparisons.

The results of the mixed-effect ANOVA for Intensity Standard Deviation are summarized in **Tables 17 through 21**.

IntSD Mixed Effect ANOVA Table for Pre and Post-Dance Sessions for PwPD and Healthy Controls

Table 17. Scaled Residuals

Statistic	Value
Min	-2.37964
1Q	-0.54084
Median	0.03201
3Q	0.50156
Max	2.69539

Table 18. Random Effects

Groups	Name	Variance	Std.Dev.
Subject	(Intercept)	0.1300	0.3606
Residual		0.1852	0.4303

Table 19. Correlation of Fixed Effects

Factor	(Intercept)	Time	Measure pre	Group PwPD	Time: Measure pre	Time: Group PwPD	Measure pre: Group PwPD
Time	-0.839						
Measure pre	-0.574	0.531					
GroupPwPD	-0.736	0.617	0.422				
Time: Measure pre	0.505	-0.603	-0.880	-0.372			
Time: Group PwPD	0.635	-0.757	-0.402	-0.834	0.456		
Measure pre: Group PwPD	0.418	-0.386	-0.727	-0.591	0.640	0.562	
Time: Measure pre: Group PwPD	-0.370	0.441	0.644	0.525	-0.732	-0.628	-0.892

Table 20. Type III Analysis of Variance Table

Source	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Time	0.41400	0.41400	1	172.21	2.2354	0.1367
Measure	0.05151	0.05151	1	114.85	0.2781	0.5989
Group	0.23231	0.23231	1	117.37	1.2544	0.2650
Time: Measure	0.08934	0.08934	1	114.43	0.4824	0.4888
Time: Group	0.03441	0.03441	1	172.21	0.1858	0.6670
Measure: Group	0.04175	0.04175	1	114.85	0.2254	0.6358
Time:Measure: Group	0.11964	0.11964	1	114.43	0.6460	0.4232

Table 21. Pairwise contrast: Adjusted for Bonferroni Method

Contrast	Estimate	SE	df	t-ratio	p-value
Time2 post Healthy controls - Time2 pre Healthy controls	0.0485	0.0988	122.8	0.491	1.0000
Time2 post Healthy controls - Time2 post PwPD	0.3266	0.1360	85.9	2.401	0.1109
Time2 post Healthy controls - Time2 pre PwPD	0.3051	0.1351	84.7	2.259	0.1588
Time2 pre Healthy controls - Time2 post PwPD	0.2780	0.1360	85.9	2.044	0.2638
Time2 pre Healthy controls - Time2 pre PwPD	0.2565	0.1351	84.7	1.899	0.3656
Time2 post PwPD - Time2 pre PwPD	-0.0215	0.0832	124.0	-0.259	1.0000

The mixed effect ANOVA for intensity standard deviation (IntSD) showed no significant main effects or interactions. Specifically, the effect of time ($F = 2.2354$, $p = 0.1367$) was not significant, indicating that the IntSD did not vary significantly between pre- and post-dance sessions across all participants. Similarly, the group effect ($F = 1.2544$, $p = 0.2650$) was not statistically significant, suggesting that there was no clear difference in IntSD between the Parkinson's Disease (PD) group and the healthy controls. Additionally, none of the interactions between time, measure, and group were significant, indicating that the combined effect of these variables on IntSD was minimal.

The pairwise comparisons adjusted for the Bonferroni correction further confirmed the lack of significant differences. No significant differences were found between pre- and post-dance IntSD for either the healthy control or PD groups. Although the plot indicated trends, such as a slight increase in IntSD for the healthy control group at later time points, these changes were not statistically significant, likely due to the large within-group variability, as reflected by the error bars.

Overall, the results suggest that the intensity standard deviation remained stable across pre- and post-dance sessions, with no substantial differences between the PD and healthy control groups. The lack of significant findings may be attributable to the high variability within each group, which could have masked smaller effects.

Summary

In summary, the ANOVA analysis comparing fundamental frequency standard deviation (F0SD) and intensity standard deviation (IntSD) between 2014 (initial) and 2019 (final) revealed distinct patterns for each measure. For F0SD, the interaction between group and time was significant ($F = 3.906$, $p = 0.0346$), indicating that changes in F0SD over time were influenced by group membership (PD vs. healthy controls). However, post hoc comparisons using Bonferroni's correction did not show statistically significant differences between specific time points or groups, likely due to variability within the groups. Additionally, a mixed effect ANOVA revealed a significant effect of time ($F = 7.1065$, $p = 0.0084$) for F0SD, suggesting that dance sessions influenced F0SD variability across all participants, although no significant interaction between time and group was found ($p = 0.4501$). Pairwise comparisons supported these findings, showing no significant differences in F0SD between pre- and post-dance sessions for either group.

For IntSD, the original analysis found a significant main effect of time ($F = 5.904$, $p = 0.0242$), indicating changes in IntSD between 2014 (initial) and 2019 (final), but no significant interaction effects between time and group. The mixed effect ANOVA further supported these findings, showing no significant main effects or interactions for IntSD ($F = 2.2354$, $p = 0.1367$), suggesting that IntSD remained stable across pre- and post-dance sessions for both groups. Pairwise comparisons, adjusted for Bonferroni correction, confirmed the lack of significant differences, with high within-group variability likely contributing to the non-significant results.

Overall, these findings suggest that F0SD is more sensitive to changes over time, particularly in PD patients, while IntSD appears less affected by both time and group factors. Future studies should investigate whether targeted interventions, such as speech therapy or dance programs, could more effectively address these changes in vocal features.

CHAPTER 4

DISCUSSION AND CONCLUSION

Discussion

The analysis of speech features, specifically the fundamental frequency standard deviation (F0SD) and intensity standard deviation (IntSD), reveals significant insights into how Parkinson's disease (PD) affects vocal patterns over time, as well as the potential therapeutic effects of dance on these features.

The results for F0SD showed that while there was no significant difference between the PD and healthy groups at the subject level, the interaction of group and time was significant. This suggests that the pattern of change in F0SD over the five years differed between the PD and healthy control groups. These findings align with existing literature, which suggests that voice features, particularly related to pitch and frequency, are often impacted in PD, with decreased pitch variability being a hallmark symptom of hypokinetic dysarthria (Skodda, 2011). However, the post hoc pairwise comparisons did not reveal significant differences between any specific time points. This could be attributed to the high variability within each group, potentially masking smaller, more nuanced changes.

To further quantify the differences between the groups, Cohen's d was calculated to assess the effect size for F0SD. The overall Cohen's d for F0SD between the PD and healthy control groups was 0.54, suggesting a moderate effect size. This indicates that while there is a noticeable difference in F0SD between the two groups, the effect is moderate, and individual variability within the groups could have masked more significant effects. A moderate effect size suggests that PD does have a measurable impact on pitch variability, even if it was not large enough to reach statistical significance in this sample size. While the moderate effect size is a positive finding, the high variability and relatively small sample size likely limited the study's power to detect significant pairwise differences. Clinically, moderate effect sizes can be important in tracking disease progression or evaluating therapeutic interventions, even in the absence of statistical significance. These findings may still hold relevance for treatment decisions, where moderate changes in vocal features could indicate early intervention points.

For the IntSD, the results were more straightforward. The ANOVA indicated a significant effect of time but no significant interaction between time and group. This indicates that both PD and healthy participants experienced changes in vocal intensity over the study period, with no significant differences between the groups. This could be explained by the normal aging process, which is associated with decreased vocal intensity and other voice changes in healthy individuals. As individuals age, changes in respiratory and laryngeal function can contribute to reduced vocal intensity, making it difficult to distinguish these changes from those caused by PD. Similar to the F0SD results, post hoc analyses did not show any significant pairwise differences between the time points, reinforcing the idea that individual variability was likely a contributing factor.

The effect size for IntSD was also calculated using Cohen's d. The overall Cohen's d for IntSD between the PD and healthy control groups was 0.57, also suggesting a moderate effect size. This implies that there is a moderate difference in vocal intensity variability between the PD and control groups. However, similar to the F0SD results, the moderate effect size indicates that while the groups differ, the variability within each group may have reduced the ability to detect statistically significant differences. The effect of aging on vocal intensity likely contributed to the lack of significant group differences, as both PD and control subjects experienced similar reductions in intensity over time. While the moderate effect sizes are a promising indication of the impact of PD on these vocal features, future studies with larger sample sizes or more intensive interventions may be needed to detect more pronounced effects.

Given that this study was observational and exploratory in nature, serving as a pilot investigation into the effects of dance on vocal features in PwPD, selecting appropriate statistical models was crucial. This study employed ANOVA and mixed-effect ANOVA models to explore changes in F0SD and IntSD over time, and more advanced models, such as Linear Mixed-Effects Models (LMMs) and LISREL, were not implemented due to specific methodological considerations.

LMMs are particularly well-suited for analyzing longitudinal data with repeated measures, especially when there is substantial missing data, which was a notable limitation in this study. Despite this, ANOVA models were selected because of their simplicity and interpretability, aligning with the exploratory nature of the research. Implementing LMMs would have increased the complexity of the analysis, requiring more advanced statistical assumptions and a larger sample size, which was not feasible for this pilot study.

LISREL, a structural equation modeling tool, could have been used if the study aimed to model latent constructs related to voice performance. However, this was not applicable, as the focus was on directly measured acoustic features without an underlying theoretical framework involving latent variables. Given the limited existing research on the impact of dance on vocal features in PD, ANOVA and mixed-effect ANOVA were deemed appropriate for this preliminary investigation. Future studies may benefit from more complex statistical models as the field evolves.

When considering the potential effects of dance on these voice features, the lack of significant post-dance improvements in either F0SD or IntSD for the PD group contrasts with previous studies suggesting that dance can promote neuroplasticity and improve motor symptoms (Bearss & DeSouza, 2021). While the dance intervention may have provided some benefits, these effects may have been too subtle to detect with the speech parameters measured or the duration of the intervention. Furthermore, the variability within the PD group and the observational nature of the study may have limited the ability to detect more subtle improvements in vocal features. Future studies with longer intervention periods and additional speech parameters are needed to fully understand the impact of dance on speech in PD. Alternatively, the effects of dance on speech may require a longer duration or more intensive interventions to become apparent. Given the significant role that speech impairment plays in the quality of life for individuals with PD, these findings highlight the need for further research into non-pharmacological interventions that could help preserve or improve communication abilities in this population.

Conclusion

This study aimed to investigate the effects of Parkinson's disease and a dance intervention on two critical voice features: F0SD and IntSD. The results indicate that PD influences these features, as evidenced by the significant interaction between group and time for F0SD. Additionally, the calculation of Cohen's d revealed moderate effect sizes for both F0SD (0.54) and IntSD (0.57), suggesting that while there are noticeable differences between the PD and healthy control groups, the individual variability within each group likely limited the ability to detect statistically significant differences. These moderate effect sizes are clinically meaningful, indicating that even moderate changes in speech features could be important for tracking PD progression or developing interventions.

The changes observed did not differ significantly between the PD and healthy control groups in terms of intensity standard deviation, indicating that voice intensity may be similarly affected by aging in both groups. However, the moderate effect size for IntSD suggests that vocal intensity may still be impacted by PD. The absence of significant post-dance improvements could also suggest that the dance intervention was either not long enough or not specifically targeted to address speech-related symptoms. Extending the duration of interventions or incorporating additional therapeutic approaches may yield more observable changes in vocal intensity.

Although no significant post-dance improvements were observed in either group, this study contributes to the growing body of literature on the use of speech features as biomarkers for PD and how interventions like dance may influence these features over time. Future research should focus on larger sample sizes, longer intervention periods, and the inclusion of additional speech parameters such as articulation rate, speech rhythm, and voice tremor to capture a

more comprehensive picture of voice changes in individuals with PD. Incorporating neuroimaging techniques alongside speech analysis may also help uncover the neural mechanisms underlying these changes.

These findings underscore the critical need for early detection and intervention for voice impairments in PD. Given that speech features like F0SD and IntSD are often affected early in the disease, they represent valuable biomarkers for both diagnosis and tracking therapeutic outcomes. Early interventions, particularly non-pharmacological ones like dance or speech therapy, may help mitigate the progression of speech impairments and improve the quality of life for individuals with PD. The **m**oderate effect sizes observed in this study provide a foundation for future research aimed at refining and expanding the use of voice features in clinical practice, particularly for early diagnosis and intervention in PD. Future studies should consider pairing dance interventions with targeted speech therapy or vocal exercises to determine if combined therapeutic approaches can better address the speech impairments observed in PD.

LIMITATIONS AND FUTURE WORK

Limitations

While this study provides valuable insights into the effects of Parkinson's disease (PD) and dance on vocal features, several limitations must be acknowledged.

First, the study is exploratory in nature and observational, conducted in a community dance class. It was not a randomized controlled trial, and as such, corrections for multiple comparisons were not applied. The lack of randomization may introduce confounding variables and limit the generalizability of the findings. Factors such as disease progression, changes in medication, and variability in individual responses may have influenced the outcomes independently of the intervention. Future studies should consider applying multiple comparison corrections where appropriate to reduce the risk of Type I errors, especially in observational studies where variability is high. Additionally, factors like medication changes or cognitive declines over time may have introduced variability, limiting the ability to isolate the effects of the intervention on speech.

Second, the sample size may have limited the statistical power of the analyses. With 29 participants in each group, the study may not have had sufficient power to detect smaller but

meaningful differences between the PD and healthy control groups or subtle effects of the dance intervention on speech features.

Increasing the amount of data in future studies could significantly enhance the reliability and generalizability of findings on the effects of dance on vocal features in individuals with Parkinson's Disease (PD). In this study, a total of 266 audio files from 29 individuals with PD and 29 healthy controls were analyzed, with recordings spanning five years. Despite the longitudinal nature of the dataset, several factors limited its overall size, including participant drop-out, missing data due to technical issues, and incomplete post-dance recordings.

A. Enhancing Statistical Power:

A larger dataset would increase statistical power, allowing for the detection of smaller, more subtle effects that may have been masked due to high within-group variability observed in measures like F0SD and IntSD. Given the moderate effect sizes (Cohen's d: 0.54 for F0SD, 0.57 for IntSD), a larger sample would increase confidence in detecting meaningful changes with greater precision.

B. Reducing Bias from Missing Data:

The inclusion of more data could mitigate the impact of missing data points caused by participant drop-out or incomplete post-dance sessions. Advanced statistical models, such as Linear Mixed-Effects Models (LMMs) or Generalized Estimating Equations (GEEs), could be more effectively applied if a larger dataset were available, allowing for better handling of missing records while preserving the integrity of longitudinal analyses.

C. Capturing Disease Progression:

A more extensive dataset would enable better tracking of **disease progression** by capturing more frequent speech assessments over time. This could provide insights into whether speech features like F0SD and IntSD change gradually or exhibit sudden shifts in response to the progression of PD or the intensity of dance interventions.

D. Improving Generalizability:

Including data from a more diverse participant pool with different PD severity levels, ages, and genders would improve the external validity and generalizability of the findings. This would allow future research to explore how factors such as disease stage or baseline vocal characteristics affect treatment outcomes.

E. Exploring Additional Speech Features:

With a larger dataset, future analyses could expand beyond F0SD and IntSD to include other critical speech features such as articulation rate, phonation time, speech rhythm, and voice tremor. This would provide a more comprehensive understanding of how PD affects speech production and how interventions like dance may mitigate these effects.

F. Incorporating Advanced Analyses:

A more extensive dataset would support applying machine learning algorithms for automated classification tasks, enabling prediction models for disease severity or progression. Additionally, incorporating neuroimaging data alongside

speech features could reveal how dance-induced neural changes influence vocal outcomes in PD.

Third, the variability within groups was substantial, particularly in both the fundamental frequency and intensity standard deviations. This intra-group variability likely reduced the ability to detect significant effects in the post hoc analyses, as the wide range of speech characteristics in both the PD and healthy control groups may have masked more subtle group differences. The moderate effect sizes suggest that while there is a measurable impact of PD on speech features, this variability limited the study's ability to detect stronger statistical differences.

Fourth, the duration and intensity of the dance intervention may not have been sufficient to elicit detectable improvements in speech features. While dance has been shown to have therapeutic benefits for motor symptoms in PD, the effects on speech may require a longer or more intensive intervention to become evident. Additionally, the lack of significant post-dance improvements could indicate that the dance sessions used in this study were not optimized to target speech-related symptoms.

Fifth, A key limitation of this study is the lack of matching participants based on age, sex, or disease severity levels within the Parkinson's Disease (PD) group. Although efforts were made to include similar numbers of male and female participants, the groups were not fully matched for demographic variables such as age or disease progression. This could have introduced confounding variables that influenced the results.

Additionally, the analysis did not account for the stages of Parkinson's Disease, which likely varied among participants due to the community-based nature of the study. The lack of clinical

staging data, such as the Hoehn and Yahr scale or Unified Parkinson's Disease Rating Scale (UPDRS) scores, limited the ability to assess whether differences in speech features were related to disease severity or progression. Including this information could have strengthened the analysis by enabling subgroup comparisons based on disease stage or severity, offering more precise insights into how speech features evolve in PD.

Sixth, speech data collection and measures were limited to specific parameters (F0SD and IntSD). While these features are known to be affected in PD, they may not fully capture the complexity of speech impairments in the disease. Other features, such as articulation rate, speech rhythm, or voice tremor, could provide a more comprehensive picture of how PD affects communication. Additionally, the study relied on pre- and post-dance measurements, which may not fully capture the day-to-day variability in speech production for PD patients.

Finally, the longitudinal nature of the study presents challenges, as some participants may have experienced disease progression or changes in medication that could have influenced their speech patterns independently of the dance intervention. Without accounting for changes in disease severity or treatment over time, it is difficult to isolate the specific effects of the intervention on speech.

Future Directions

Future research on vocal changes in PwPD could benefit from the application of more complex statistical and machine learning models, incorporating non-linear effects and additional covariates. While this study used linear ANOVA models to evaluate the effects of dance intervention on F0SD and IntSD, several promising directions could further enhance understanding of vocal changes over time.

1. Modeling Non-linear Effects:

Given that disease progression in PD often follows a non-linear trajectory, future studies could explore statistical models that capture these complex dynamics. Generalized Additive Models (GAMs) or non-linear mixed-effects models (NLMMs) could account for potential non-linear changes in vocal features due to disease progression, dance intervention intensity, or participant-specific factors. These models could also detect threshold effects where improvements in vocal features occur only after reaching a specific intervention intensity or time point.

2. Incorporating Additional Covariates:

Future models could include relevant covariates such as:

A. Demographic Variables: Age, gender, and years since PD diagnosis.

B. Clinical Data: Hoehn and Yahr stages, medication regimens, or UPDRS scores.

C. Intervention-Related Data: Frequency and intensity of dance participation, session attendance, and engagement level.

Including these covariates in models such as Hierarchical Bayesian Models or Multivariate, Mixed-Effects Models could help identify individual-level responses and refine predictive models for vocal feature changes.

3. Machine Learning and Deep Learning Models:

The development of machine learning models, including Random Forests, Support Vector Machines (SVMs), or Recurrent Neural Networks (RNNs), could allow for more precise prediction of disease progression from longitudinal speech data. Long Short-Term Memory (LSTM) networks could model time-dependent changes by leveraging sequential audio features.

4. Multimodal Integration:

Combining speech features with neuroimaging data (e.g., fMRI, EEG) could enable a deeper understanding of the relationship between brain activity and vocal function. Advanced models could integrate data from multiple sources through multimodal deep learning frameworks, offering a holistic view of the effects of PD on speech production.

5. Time-Series and Survival Analysis:

Given the longitudinal structure of the dataset, time-series models like autoregressive integrated moving averages (ARIMA) or survival models could predict the likelihood of significant vocal changes over time or identify the critical points when such changes become statistically detectable.

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Yang, Y., Yuan, Y., Zhang, G., Wang, H., Chen, Y.-C., Liu, Y., Tarolli, C. G., Crepeau, D., Bukartyk, J., Junna, M. R., Videnovic, A., Ellis, T. D., Lipford, M. C., Dorsey, R., & Katabi, D. (2022). Artificial intelligence-enabled detection and assessment of Parkinson's disease using nocturnal breathing signals. *Nature Medicine*, *28*(10), 2207–2215. https://doi.org/10.1038/s41591-022-01932-x

APPENDIX-

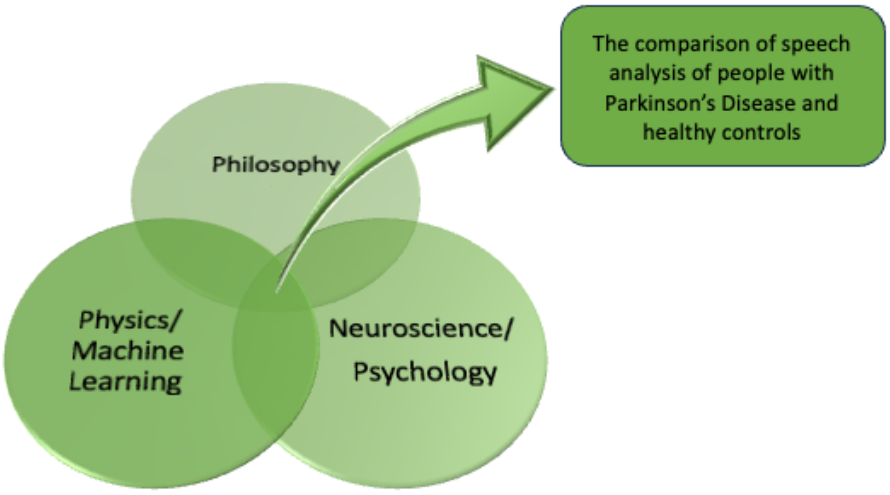
NOTES, CODES AND FORMS

A. Notes

1. A NOTE ON INTERDISCIPLINARITY

The term “discipline” in “interdisciplinary” refers to a branch of knowledge, teaching, education, or learning. Interdisciplinarity occurs when two or more disciplines converge to address a specific problem (Alvargonzález, 2011). In reality, most problems benefit from an interdisciplinary approach, as nature itself operates as an interconnected system. The categorization of science into different disciplines was created to provide clarity in the study of nature, even though nature itself is not divided in such a way. Utilizing knowledge from various disciplines to investigate a problem is highly advantageous.

In this study, the primary disciplines involved include neuroscience/psychology, physics, machine learning, and philosophy. The investigation of speech analysis in people living with Parkinson’s Disease (PD) draws on these disciplines to generate and analyze meaningful data.



Venn diagram of the project's disciplines

B. PYTHON CODES FOR EXTRACTING VOICE FEATURES

1. Measuring Pitch and HNR

In [ ]:
```
pip install praat-parselmouth
```

In [ ]:
```
#Measure pitch of all wav files in directory
import glob
import numpy as np
import pandas as pd
import parselmouth
from parselmouth.praat import call
```

In [ ]:
```
# This is the function to measure voice pitch
def measurePitch(voiceID, f0min, f0max, unit):
    sound = parselmouth.Sound(voiceID) # read the sound
    pitch = call(sound, "To Pitch", 0.0, f0min, f0max) #create a praat pitch object
    meanF0 = call(pitch, "Get mean", 0, 0, unit) # get mean pitch
    stdevF0 = call(pitch, "Get standard deviation", 0 ,0, unit) # get standard deviation
    harmonicity = call(sound, "To Harmonicity (cc)", 0.01, 75, 0.1, 1.0)
    hnr = call(harmonicity, "Get mean", 0, 0)
    return meanF0, stdevF0, hnr
```

In [ ]:

```
# create lists to put the results
file_list = []
mean_F0_list = []
sd_F0_list = []
hnr_list = []

# Go through all the wave files in the folder and measure pitch
for wave_file in glob.glob("/Users/ashkan/Downloads/updrsa/*.wav"):
    sound = parselmouth.Sound(wave_file)
    (meanF0, stdevF0, hnr) = measurePitch(sound, 75, 500, "Hertz")
    file_list.append(wave_file) # make an ID list
    mean_F0_list.append(meanF0) # make a mean F0 list
    sd_F0_list.append(stdevF0) # make a sd F0 list
    hnr_list.append(hnr)

df = pd.DataFrame(np.column_stack([file_list, mean_F0_list, sd_F0_list, hnr_list]),
                                  columns=['voiceID', 'meanF0Hz', 'stdevF0Hz', 'HNR'])  #add these lists to



# Write out the updated dataframe
df.to_csv("processed_results_pitch_HNR.csv", index=False)
```

2. Measuring Jitter and Shimmer and their variants

In [ ]:
```
#Measure pitch of all wav files in directory
import glob
import numpy as np
import pandas as pd
import parselmouth

from parselmouth.praat import call
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
```

In [ ]:
```
# This is the function to measure voice pitch
def measurePitch(voiceID, f0min, f0max, unit):
    sound = parselmouth.Sound(voiceID) # read the sound
    pitch = call(sound, "To Pitch", 0.0, f0min, f0max) #create a praat pitch object
    meanF0 = call(pitch, "Get mean", 0, 0, unit) # get mean pitch
    stdevF0 = call(pitch, "Get standard deviation", 0 ,0, unit) # get standard deviation
    harmonicity = call(sound, "To Harmonicity (cc)", 0.01, 75, 0.1, 1.0)
    hnr = call(harmonicity, "Get mean", 0, 0)
    pointProcess = call(sound, "To PointProcess (periodic, cc)", f0min, f0max)
    localJitter = call(pointProcess, "Get jitter (local)", 0, 0, 0.0001, 0.02, 1.3)
    localabsoluteJitter = call(pointProcess, "Get jitter (local, absolute)", 0, 0, 0.0001, 0.02, 1.3)
    rapJitter = call(pointProcess, "Get jitter (rap)", 0, 0, 0.0001, 0.02, 1.3)
    ppq5Jitter = call(pointProcess, "Get jitter (ppq5)", 0, 0, 0.0001, 0.02, 1.3)
    ddpJitter = call(pointProcess, "Get jitter (ddp)", 0, 0, 0.0001, 0.02, 1.3)
    localShimmer =  call([sound, pointProcess], "Get shimmer (local)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    localdbShimmer = call([sound, pointProcess], "Get shimmer (local_dB)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    apq3Shimmer = call([sound, pointProcess], "Get shimmer (apq3)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    aqpq5Shimmer = call([sound, pointProcess], "Get shimmer (apq5)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    apq11Shimmer =  call([sound, pointProcess], "Get shimmer (apq11)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    ddaShimmer = call([sound, pointProcess], "Get shimmer (dda)", 0, 0, 0.0001, 0.02, 1.3, 1.6)


    return meanF0, stdevF0, hnr, localJitter, localabsoluteJitter, rapJitter, ppq5Jitter, ddpJitter, loca
```

In [ ]:
```
def runPCA(df):
    #Z-score the Jitter and Shimmer measurements
    features = ['localJitter', 'localabsoluteJitter', 'rapJitter', 'ppq5Jitter', 'ddpJitter',
                'localShimmer', 'localdbShimmer', 'apq3Shimmer', 'apq5Shimmer', 'apq11Shimmer', 'ddaShimm
    # Separating out the features
    x = df.loc[:, features].values
    # Separating out the target
    #y = df.loc[:,['target']].values
    # Standardizing the features
    x = StandardScaler().fit_transform(x)
    #PCA
    pca = PCA(n_components=2)
    principalComponents = pca.fit_transform(x)
    principalDf = pd.DataFrame(data = principalComponents, columns = ['JitterPCA', 'ShimmerPCA'])
    principalDf
    return principalDf
```

In [ ]:
```
# create lists to put the results
file_list = []
mean_F0_list = []
sd_F0_list = []
hnr_list = []
localJitter_list = []
localabsoluteJitter_list = []
rapJitter_list = []
ppq5Jitter_list = []
ddpJitter_list = []
localShimmer_list = []
localdbShimmer_list = []
apq3Shimmer_list = []
aqpq5Shimmer_list = []
apq11Shimmer_list = []
ddaShimmer_list = []

# Go through all the wave files in the folder and measure pitch
for wave_file in glob.glob("audio/*.wav"):
    sound = parselmouth.Sound(wave_file)
    (meanF0, stdevF0, hnr, localJitter, localabsoluteJitter, rapJitter, ppq5Jitter, ddpJitter, localShimm
    file_list.append(wave_file) # make an ID list
    mean_F0_list.append(meanF0) # make a mean F0 list
    sd_F0_list.append(stdevF0) # make a sd F0 list
    hnr_list.append(hnr)
```

```
    localJitter_list.append(localJitter)
    localabsoluteJitter_list.append(localabsoluteJitter)
    rapJitter_list.append(rapJitter)
    ppq5Jitter_list.append(ppq5Jitter)
    ddpJitter_list.append(ddpJitter)
    localShimmer_list.append(localShimmer)
    localdbShimmer_list.append(localdbShimmer)
    apq3Shimmer_list.append(apq3Shimmer)
    aqpq5Shimmer_list.append(aqpq5Shimmer)
    apq11Shimmer_list.append(apq11Shimmer)
    ddaShimmer_list.append(ddaShimmer)
df = pd.DataFrame(np.column_stack([file_list, mean_F0_list, sd_F0_list, hnr_list, localJitter_list, local
                                  columns=['voiceID', 'meanF0Hz', 'stdevF0Hz', 'HNR', 'localJitter', 'locala
                                           'ppq5Jitter', 'ddpJitter', 'localShimmer', 'localdbShimmer', 'apq
                                           'apq11Shimmer', 'ddaShimmer'])  #add these lists to pandas in the
pcaData = runPCA(df)

df = pd.concat([df, pcaData], axis=1)

# Write out the updated dataframe
df.to_csv("processed_results.csv", index=False)
```

3. Measure Pitch, HNR, Jitter, Shimmer, Formants and estimate VTL

Measure Pitch, HNR, Jitter, Shimmer, Formants, and Estimate VTL

Import the external modules

In [ ]:
```
pip install praat-parselmouth
```

In [ ]:
```
#!/usr/bin/env python3
import glob
import numpy as np
import pandas as pd
import parselmouth
import statistics


from parselmouth.praat import call
from scipy.stats.mstats import zscore
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
```

This function measures duration, pitch, HNR, jitter, and shimmer

In [ ]:
```
# This is the function to measure source acoustics using default male parameters.

def measurePitch(voiceID, f0min, f0max, unit):
    sound = parselmouth.Sound(voiceID) # read the sound
    duration = call(sound, "Get total duration") # duration
    pitch = call(sound, "To Pitch", 0.0, f0min, f0max) #create a praat pitch object
    meanF0 = call(pitch, "Get mean", 0, 0, unit) # get mean pitch
    stdevF0 = call(pitch, "Get standard deviation", 0 ,0, unit) # get standard deviation
    harmonicity = call(sound, "To Harmonicity (cc)", 0.01, f0min, 0.1, 1.0)
    hnr = call(harmonicity, "Get mean", 0, 0)
    pointProcess = call(sound, "To PointProcess (periodic, cc)", f0min, f0max)
    localJitter = call(pointProcess, "Get jitter (local)", 0, 0, 0.0001, 0.02, 1.3)
    localabsoluteJitter = call(pointProcess, "Get jitter (local, absolute)", 0, 0, 0.0001, 0.02, 1.3)
    rapJitter = call(pointProcess, "Get jitter (rap)", 0, 0, 0.0001, 0.02, 1.3)
    ppq5Jitter = call(pointProcess, "Get jitter (ppq5)", 0, 0, 0.0001, 0.02, 1.3)
    ddpJitter = call(pointProcess, "Get jitter (ddp)", 0, 0, 0.0001, 0.02, 1.3)
    localShimmer =  call([sound, pointProcess], "Get shimmer (local)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    localdbShimmer = call([sound, pointProcess], "Get shimmer (local_dB)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    apq3Shimmer = call([sound, pointProcess], "Get shimmer (apq3)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    aqpq5Shimmer = call([sound, pointProcess], "Get shimmer (apq5)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    apq11Shimmer =  call([sound, pointProcess], "Get shimmer (apq11)", 0, 0, 0.0001, 0.02, 1.3, 1.6)
    ddaShimmer = call([sound, pointProcess], "Get shimmer (dda)", 0, 0, 0.0001, 0.02, 1.3, 1.6)

    return duration, meanF0, stdevF0, hnr, localJitter, localabsoluteJitter, rapJitter, ppq5Jitter, ddpJi
```

This function measures formants at each glottal pulse

Puts, D. A., Apicella, C. L., & Cárdenas, R. A. (2012). Masculine voices signal men's threat potential in forager and industrial societies. Proceedings of the Royal Society of London B: Biological Sciences, 279(1728), 601-609.

Adapted from: DOI 10.17605/OSF.IO/K2BHS

In [ ]:
```
# This function measures formants using Formant Position formula
def measureFormants(sound, wave_file, f0min,f0max):
    sound = parselmouth.Sound(sound) # read the sound
    pitch = call(sound, "To Pitch (cc)", 0, f0min, 15, 'no', 0.03, 0.45, 0.01, 0.35, 0.14, f0max)
    pointProcess = call(sound, "To PointProcess (periodic, cc)", f0min, f0max)

    formants = call(sound, "To Formant (burg)", 0.0025, 5, 5000, 0.025, 50)
```

```
    numPoints = call(pointProcess, "Get number of points")

    f1_list = []
    f2_list = []
    f3_list = []
    f4_list = []

    # Measure formants only at glottal pulses
    for point in range(0, numPoints):
        point += 1
        t = call(pointProcess, "Get time from index", point)
        f1 = call(formants, "Get value at time", 1, t, 'Hertz', 'Linear')
        f2 = call(formants, "Get value at time", 2, t, 'Hertz', 'Linear')
        f3 = call(formants, "Get value at time", 3, t, 'Hertz', 'Linear')
        f4 = call(formants, "Get value at time", 4, t, 'Hertz', 'Linear')
        f1_list.append(f1)
        f2_list.append(f2)
        f3_list.append(f3)
        f4_list.append(f4)

    f1_list = [f1 for f1 in f1_list if str(f1) != 'nan']
    f2_list = [f2 for f2 in f2_list if str(f2) != 'nan']
    f3_list = [f3 for f3 in f3_list if str(f3) != 'nan']
    f4_list = [f4 for f4 in f4_list if str(f4) != 'nan']

    # calculate mean formants across pulses
    f1_mean = statistics.mean(f1_list)
    f2_mean = statistics.mean(f2_list)
    f3_mean = statistics.mean(f3_list)
    f4_mean = statistics.mean(f4_list)

    # calculate median formants across pulses, this is what is used in all subsequent calcualtions
    # you can use mean if you want, just edit the code in the boxes below to replace median with mean
    f1_median = statistics.median(f1_list)
    f2_median = statistics.median(f2_list)
    f3_median = statistics.median(f3_list)
    f4_median = statistics.median(f4_list)

    return f1_mean, f2_mean, f3_mean, f4_mean, f1_median, f2_median, f3_median, f4_median
```

This function runs a 2-factor Principle Components Analysis (PCA) on Jitter and Shimmer

In [ ]:
```
def runPCA(df):
    # z-score the Jitter and Shimmer measurements
    measures = ['localJitter', 'localabsoluteJitter', 'rapJitter', 'ppq5Jitter', 'ddpJitter',
                'localShimmer', 'localdbShimmer', 'apq3Shimmer', 'apq5Shimmer', 'apq11Shimmer', 'ddaShimm
    x = df.loc[:, measures].values
    x = StandardScaler().fit_transform(x)
    # PCA
    pca = PCA(n_components=2)
    principalComponents = pca.fit_transform(x)
    principalDf = pd.DataFrame(data = principalComponents, columns = ['JitterPCA', 'ShimmerPCA'])
    principalDf
    return principalDf
```

This block of code runs the above functions on all of the '.wav' files in the /audio folder

In [ ]:
```
# create lists to put the results
file_list = []
duration_list = []
mean_F0_list = []
sd_F0_list = []
hnr_list = []
localJitter_list = []
localabsoluteJitter_list = []
rapJitter_list = []
ppq5Jitter_list = []
ddpJitter_list = []
localShimmer_list = []
localdbShimmer_list = []
apq3Shimmer_list = []
aqpq5Shimmer_list = []
apq11Shimmer_list = []
ddaShimmer_list = []
f1_mean_list = []
```

```
f2_mean_list = []
f3_mean_list = []
f4_mean_list = []
f1_median_list = []
f2_median_list = []
f3_median_list = []
f4_median_list = []

# Go through all the wave files in the folder and measure all the acoustics
for wave_file in glob.glob("/Users/ashkan/Downloads/1/*.wav"):
    sound = parselmouth.Sound(wave_file)
    (duration, meanF0, stdevF0, hnr, localJitter, localabsoluteJitter, rapJitter, ppq5Jitter, ddpJitter,
     localShimmer, localdbShimmer, apq3Shimmer, aqpq5Shimmer, apq11Shimmer, ddaShimmer) = measurePitch(
        sound, 75, 300, "Hertz")
    (f1_mean, f2_mean, f3_mean, f4_mean, f1_median, f2_median, f3_median, f4_median) = measureFormants(
        sound, wave_file, 75, 300)
    file_list.append(wave_file) # make an ID list
    duration_list.append(duration) # make duration list
    mean_F0_list.append(meanF0) # make a mean F0 list
    sd_F0_list.append(stdevF0) # make a sd F0 list
    hnr_list.append(hnr) #add HNR data

    # add raw jitter and shimmer measures
    localJitter_list.append(localJitter)
    localabsoluteJitter_list.append(localabsoluteJitter)
    rapJitter_list.append(rapJitter)
    ppq5Jitter_list.append(ppq5Jitter)
    ddpJitter_list.append(ddpJitter)
    localShimmer_list.append(localShimmer)
    localdbShimmer_list.append(localdbShimmer)
    apq3Shimmer_list.append(apq3Shimmer)
    aqpq5Shimmer_list.append(aqpq5Shimmer)
    apq11Shimmer_list.append(apq11Shimmer)
    ddaShimmer_list.append(ddaShimmer)

    # add the formant data
    f1_mean_list.append(f1_mean)
    f2_mean_list.append(f2_mean)
    f3_mean_list.append(f3_mean)
    f4_mean_list.append(f4_mean)
    f1_median_list.append(f1_median)
    f2_median_list.append(f2_median)
    f3_median_list.append(f3_median)
```

```
    f4_median_list.append(f4_median)
```

This block of code adds all of that data we just generated to a Pandas data frame

In [ ]:
```
# Add the data to Pandas
df = pd.DataFrame(np.column_stack([file_list, duration_list, mean_F0_list, sd_F0_list, hnr_list,
                                   localJitter_list, localabsoluteJitter_list, rapJitter_list,
                                   ppq5Jitter_list, ddpJitter_list, localShimmer_list,
                                   localdbShimmer_list, apq3Shimmer_list, aqpq5Shimmer_list,
                                   apq11Shimmer_list, ddaShimmer_list, f1_mean_list,
                                   f2_mean_list, f3_mean_list, f4_mean_list,
                                   f1_median_list, f2_median_list, f3_median_list,
                                   f4_median_list]),
                                   columns=['voiceID', 'duration', 'meanF0Hz', 'stdevF0Hz', 'HNR',
                                            'localJitter', 'localabsoluteJitter', 'rapJitter',
                                            'ppq5Jitter', 'ddpJitter', 'localShimmer',
                                            'localdbShimmer', 'apq3Shimmer', 'apq5Shimmer',
                                            'apq11Shimmer', 'ddaShimmer', 'f1_mean', 'f2_mean',
                                            'f3_mean', 'f4_mean', 'f1_median',
                                            'f2_median', 'f3_median', 'f4_median'])

#pcaData = runPCA(df) # Run jitter and shimmer PCA
#df = pd.concat([df, pcaData], axis=1) # Add PCA data
# reload the data so it's all numbers
df.to_csv("processed_results.csv", index=False)
df = pd.read_csv('processed_results.csv', header=0)
df.sort_values('voiceID').head(20)
```

Next we calculate the vocal-tract length estimates

Formant position

Puts, D. A., Apicella, C. L., & Cárdenas, R. A. (2012). Masculine voices signal men's threat potential in forager and industrial societies. Proceedings of the Royal Society of London B: Biological Sciences, 279(1728), 601-609.

In [ ]:
```
df['pF'] = (zscore(df.f1_median) + zscore(df.f2_median) + zscore(df.f3_median) + zscore(df.f4_median)) /
```

Formant Dispersion

Fitch, W. T. (1997). Vocal tract length and formant frequency dispersion correlate with body size in rhesus macaques. The Journal of the Acoustical Society of America, 102(2), 1213-1222.

In [ ]:
```
df['fdisp'] = (df['f4_median'] - df['f1_median']) / 3
```

Fn (Average Formant)

Pisanski, K., & Rendall, D. (2011). The prioritization of voice fundamental frequency or formants in listeners' assessments of speaker size, masculinity, and attractiveness. The Journal of the Acoustical Society of America, 129(4), 2201-2212.

In [ ]:
```
df['avgFormant'] = (df['f1_median'] + df['f2_median'] + df['f3_median'] + df['f4_median']) / 4
```

MFF

Smith, D. R., & Patterson, R. D. (2005). The interaction of glottal-pulse rate and vocal-tract length in judgements of speaker size, sex, and age. The Journal of the Acoustical Society of America, 118(5), 3177-3186.

In [ ]:
```
df['mff'] = (df['f1_median'] * df['f2_median'] * df['f3_median'] * df['f4_median']) ** 0.25
```

Fitch VTL

Fitch, W. T. (1997). Vocal tract length and formant frequency dispersion correlate with body size in rhesus macaques. The Journal of the Acoustical Society of America, 102(2), 1213-1222.

In [ ]:
```
# reload the data again
df.to_csv("processed_results.csv", index=False)
df = pd.read_csv('processed_results.csv', header=0)

df['fitch_vtl'] = ((1 * (35000 / (4 * df['f1_median']))) +
                   (3 * (35000 / (4 * df['f2_median']))) +
                   (5 * (35000 / (4 * df['f3_median']))) +
                   (7 * (35000 / (4 * df['f4_median'])))) / 4
```

ΔF

Reby,D.,& McComb,K.(2003). Anatomical constraints generate honesty: acoustic cues to age and weight in the roars of red deer stags. Animal Behaviour, 65, 519e-530.

In [ ]:
```
xysum = (0.5 * df['f1_median']) + (1.5 * df['f2_median']) + (2.5 * df['f3_median']) + (3.5 * df['f4_media
xsquaredsum = (0.5 ** 2) + (1.5 ** 2) + (2.5 ** 2) + (3.5 ** 2)
df['delta_f'] = xysum / xsquaredsum
```

VTL(ΔF)

Reby,D.,&McComb,K.(2003).Anatomical constraints generate honesty: acoustic cues to age and weight in the roars of red deer stags. Animal Behaviour, 65, 519e-530.

In [ ]:
```
df['vtl_delta_f'] = 35000 / (2 * df['delta_f'])
```

Save the final data

In [ ]:
```
# Write out the final dataframe
df.to_csv("processed_results_finalhc.csv", index=False)
```

Run this to tell you when it's done

In [ ]:
```
print("finished")
```

4. Intensity Standard Deviation Extraction from the Audio Files

In [ ]:
```
pip install librosa numpy
```

In [ ]:
```
import os
import librosa
import numpy as np

def extract_intensity_std(file_path):
    # Load the audio file
    y, sr = librosa.load(file_path)

    # Extract intensity (amplitude) envelope
    envelope = np.abs(librosa.amplitude_to_db(librosa.stft(y), ref=np.max))

    # Calculate standard deviation of intensity
    intensity_std = np.std(envelope)

    return intensity_std

# Folder path containing all voice WAV files
folder_path = "/Users/ashkan/Downloads/pd-post/others"

# Get a list of all WAV files in the folder
wav_files = [os.path.join(folder_path, file) for file in os.listdir(folder_path) if file.endswith(".wav")]

# Process each WAV file
for file in wav_files:
    intensity_std = extract_intensity_std(file)
    print(f"Intensity Std for {file}: {intensity_std}")
```

C. Sample Part of MDS-UPRDS Questionnaire

Patient Name or Subject ID	Site ID	(mm-dd-yyyy) Assessment Date	Investigator's Initials

MDS **UPDRS**

Part I: Non-Motor Aspects of Experiences of Daily Living (nM-EDL)

Part 1A: Complex behaviors: [completed by rater]

Primary source of information:

☐ Patient ☐ Caregiver ☐ Patient and Caregiver in Equal Proportion

To be read to the patient: I am going to ask you six questions about behaviors that you may or may not experience. Some questions concern common problems and some concern uncommon ones. If you have a problem in one of the areas, please choose the best response that describes how you have felt MOST OF THE TIME during the PAST WEEK. If you are not bothered by a problem, you can simply respond NO. I am trying to be thorough, so I may ask questions that have nothing to do with you.

1.1 COGNITIVE IMPAIRMENT	**SCORE**
Instructions to examiner: Consider all types of altered level of cognitive function including cognitive slowing, impaired reasoning, memory loss, deficits in attention and orientation. Rate their impact on activities of daily living as perceived by the patient and/or caregiver.	
Instructions to patients [and caregiver]: Over the past week have you had problems remembering things, following conversations, paying attention, thinking clearly, or finding your way around the house or in town? [If yes, examiner asks patient or caregiver to elaborate and probes for information]	
0: Normal: No cognitive impairment.	
1: Slight: Impairment appreciated by patient or caregiver with no concrete interference with the patient's ability to carry out normal activities and social interactions.	☐
2: Mild: Clinically evident cognitive dysfunction, but only minimal interference with the patient's ability to carry out normal activities and social interactions.	
3: Moderate: Cognitive deficits interfere with but do not preclude the patient's ability to carry out normal activities and social interactions.	
4: Severe: Cognitive dysfunction precludes the patient's ability to carry out normal activities and social interactions.	

	SCORE
1.13 FATIGUE Over the past week, have you usually felt fatigued? This feeling is <u>not</u> part of being sleepy or sad 0: Normal: No fatigue. 1: Slight: Fatigue occurs. However it does not cause me troubles doing things or being with people. 2: Mild: Fatigue causes me some troubles doing things or being with people. 3: Moderate: Fatigue causes me a lot of troubles doing things or being with people. However, it does not stop me from doing anything. 4: Severe: Fatigue stops me from doing things or being with people.	☐
Part II: Motor Aspects of Experiences of Daily Living (M-EDL)	
2.1 SPEECH Over the past week, have you had problems with your speech? 0: Normal: Not at all (no problems). 1: Slight: My speech is soft, slurred or uneven, but it does not cause others to ask me to repeat myself. 2: Mild: My speech causes people to ask me to occasionally repeat myself, but not everyday. 3: Moderate: My speech is unclear enough that others ask me to repeat myself every day even though most of my speech is understood. 4: Severe: Most or all of my speech cannot be understood.	☐

	SCORE
3.1 SPEECH Instructions to examiner: Listen to the patient's free-flowing speech and engage in conversation if necessary. Suggested topics: ask about the patient's work, hobbies, exercise, or how he got to the doctor's office. Evaluate volume, modulation (prosody) and clarity, including slurring, palilalia (repetition of syllables) and tachyphemia (rapid speech, running syllables together). 0: Normal: No speech problems. 1: Slight: Loss of modulation, diction or volume, but still all words easy to understand. 2: Mild: Loss of modulation, diction, or volume, with a few words unclear, but the overall sentences easy to follow. 3: Moderate: Speech is difficult to understand to the point that some, but not most, sentences are poorly understood. 4: Severe: Most speech is difficult to understand or unintelligible.	☐
3.2 FACIAL EXPRESSION Instructions to examiner: Observe the patient sitting at rest for 10 seconds, without talking and also while talking. Observe eye-blink frequency, masked facies or loss of facial expression, spontaneous smiling and parting of lips. 0: Normal: Normal facial expression. 1: Slight: Minimal masked facies manifested only by decreased frequency of blinking. 2: Mild: In addition to decreased eye-blink frequency, Masked facies present in the lower face as well, namely fewer movements around the mouth, such as less spontaneous smiling, but lips not parted. 3: Moderate: Masked facies with lips parted some of the time when the mouth is at rest. 4: Severe: Masked facies with lips parted most of the time when the mouth is at rest.	☐

Part IV: Motor Complications

Overview and Instructions: In this section, the rater uses historical and objective information to assess two motor complications, dyskinesias and motor fluctuations that include OFF-state dystonia. Use all information from patient, caregiver, and the examination to answer the six questions that summarize function over the past week including today. As in the other sections, rate using only integers (no half points allowed) and leave no missing ratings. If the item cannot be rated, place UR for Unable to Rate. You will need to choose some answers based on percentages, and therefore you will need to establish how many hours generally are awake hours and use this figure as the denominator for "OFF" time and Dyskinesias. For "OFF dystonia", the total "Off" time will be the denominator. Operational definitions for examiner's use.

Dyskinesias: Involuntary random movements
Words that patients often recognize for dyskinesias include "irregular jerking", "wiggling", "twitching". It is essential to stress to the patient the difference between dyskinesias and tremor, a common error when patients are assessing dyskinesias.

Dystonia: contorted posture, often with a twisting component:
Words that patients often recognize for dystonia include "spasms", "cramps", "posture".

Motor fluctuation: Variable response to medication:
Words that patients often recognize for motor fluctuation include "wearing out", "wearing off", "roller-coaster effect", "on-off", "uneven medication effects".

OFF: Typical functional state when patients have a poor response in spite of taking mediation or the typical functional response when patients are on NO treatment for parkinsonism. Words that patients often recognize include "low time", "bad time", "shaking time", "slow time", "time when my medications don't work."

ON: Typical functional state when patients are receiving medication and have a good response:
Words that patients often recognize include "good time", "walking time", "time when my medications work."

A . DYSKINESIAS [exclusive of OFF-state dystonia]

SCORE

4.1 TIME SPENT WITH DYSKINESIAS

Instructions to examiner: Determine the hours in the usual waking day and then the hours of dyskinesias. Calculate the percentage. If the patient has dyskinesias in the office, you can point them out as a reference to ensure that patients and caregivers understand what they are rating. You may also use your own acting skills to enact the dyskinetic movements you have seen in the patient before or show them dyskinetic movements typical of other patients. Exclude from this question early morning and nighttime painful dystonia.

Instructions to patient [and caregiver]. Over the past week, how many hours do you usually sleep on a daily basis, including nighttime sleep and daytime napping? Alright, if you sleep ___ hrs, you are awake ____ hrs. Out of those awake hours, how many hours in total do you have wiggling, twitching or jerking movements? Do not count the times when you have tremor, which is a regular back and forth shaking or times when you have painful foot cramps or spasms in the early morning or at nighttime. I will ask about those later. Concentrate only on these types of wiggling, jerking and irregular movements. Add up all the time during the waking day when these usually occur. How many hours ____ (use this number for your calculation).

0: Normal:	No dyskinesias.
1: Slight:	≤ 25% of waking day.
2: Mild:	26 - 50% of waking day.
3: Moderate:	51 - 75% of waking day.
4: Severe:	> 75% of waking day.

1. Total Hours Awake: _____
2. Total Hours with Dyskinesia: _____
3. % Dyskinesia = ((2/1)*100): _____

D. Parkinson Disease: Feature Selections (Google Colab)


```
from google.colab import drive
drive.mount('/content/drive')
```

```
#Author: Maheshwor Tiwari
# Parkinson Disease: Feature Selections

"""  Data Loading """
import numpy as np
import pandas as pd
df = pd.read_csv('/content/drive/My Drive/All_subjects2.csv')


# finding number of rows and columns
df.shape
#Show first 5 rows of the dataset
df.head()
# Display basic information about the dataset
print(df.info())
# Check for any missing values in the entire dataset
print(df.isnull().sum().sum())
# Check for duplicate rows in the dataset
duplicate_rows = df[df.duplicated()]
print("Number of duplicate rows:", duplicate_rows.shape[0])
```

```
""" Bar Diagram: PD Indicator  """

import seaborn as sns
import matplotlib.pyplot as plt
sns.set(style="whitegrid")
plt.figure(figsize=(6, 4))

ax = sns.countplot(x='Group', data=df, palette=["#1f77b4", "#ff7f0e"])
plt.xlabel('Group')
plt.ylabel('Count')
plt.title('Distribution of Group')
plt.xticks([0, 1], ['Healthy', 'PD'])

# Adding integer count numbers on top of the bars
for p in ax.patches:
    ax.annotate(f'{int(p.get_height())}', (p.get_x() + p.get_width() / 2., p.get_height()),
                ha='center', va='center', fontsize=10, color='black', xytext=(0, 5),
                textcoords='offset points')

plt.show()
```

```
""" Divide the dataset into two groups based on Group """

df1 = df[df["Group"] == 0]
df2 = df[df["Group"] == 1]
print(df1)
print(df2)
df1.shape
df2.shape
# Calculate summary statistics for the DataFrame
df1.describe()
df2.describe()
```

```
"""Central Tendencies and Difference between them """
# Select the columns for comparison (excluding "Subject_ID" and "PD Indicator")
columns_to_compare = df1.columns.difference(["duration", "Group", "IntSD", "F0SD"])
# Calculate the differences between describe statistics for df2 and df1
differences = df2[columns_to_compare].describe() - df1[columns_to_compare].describe()
# Extract the desired statistics (mean, median, std, min, max) from the differences DataFrame
desired_statistics = ["mean", "50%", "std"]
differences = differences.loc[desired_statistics]
# Transpose the differences DataFrame for desired display format
differences = differences.transpose()
differences

# Display the differences
print("Differences between central tendencies of df2 and df1:")
print(differences)
# Calculate the absolute differences
absolute_differences = differences.abs()

# Sort the absolute differences DataFrame by mean values in descending order
sorted_absolute_differences = absolute_differences.sort_values(by=["mean"], ascending=False)

# Get the indices of the top 10 absolute differences
top_10_indices = sorted_absolute_differences.head(10).index

# Display the top 10 absolute differences with the original sign
print("Top 10 Absolute Differences between central tendencies \n of df2 and df1 by Mean:")
print(differences.loc[top_10_indices])
```

```
"""  Histograpm Plotting"""
import matplotlib.pyplot as plt
import seaborn as sns
# Select numeric columns for histograms
numeric_columns = df1.select_dtypes(include=['float64', 'int64']).columns

# Exclude specific columns
columns_to_exclude = ["Group", "duration"]
numeric_columns = numeric_columns.difference(columns_to_exclude)

# Set up the Seaborn style
sns.set(style="whitegrid")

# Define custom color palette for histograms
custom_color_palette = sns.color_palette(["#1f77b4", "#ff7f0e"])  # Blue and orange

# Define hatch patterns for healthy and unhealthy individuals
hatch_patterns = ["", "////"]  # No hatch for healthy, hatch for unhealthy

# Function to plot side-by-side histograms with hatch patterns
def plot_side_by_side_histograms(dataframe1, dataframe2, title):
    plt.figure(figsize=(40, 30))
    for i, column in enumerate(numeric_columns, start=1):
        plt.subplot(6, 5, i)
        sns.histplot(dataframe1[column], bins=10, kde=True, color=custom_color_palette[0], hatch=hatch_patterns[0])
        sns.histplot(dataframe2[column], bins=10, kde=True, color=custom_color_palette[1], hatch=hatch_patterns[1])
        plt.title(column, fontsize=25)  # Set individual histogram title font size
        plt.xlabel("Value", fontsize=25)
        plt.ylabel("Number of files", fontsize=25)
        plt.legend(labels=["Healthy", "PD"])

    plt.tight_layout()
    plt.suptitle(f"Histogram Comparison for {title}", fontsize=30)
    plt.subplots_adjust(top=0.92)
    plt.show()

# Plot side-by-side histograms for df1 (healthy) and df2 (unhealthy)
plot_side_by_side_histograms(df1, df2, "Healthy vs PD")
```

```
"""  Box Plotting """
import matplotlib.pyplot as plt
import seaborn as sns

# Select numeric columns for box plots
numeric_columns = df1.select_dtypes(include=['float64', 'int64']).columns

# Exclude specific columns
columns_to_exclude = ["Group", "duration"]
numeric_columns = numeric_columns.difference(columns_to_exclude)

# Set up the Seaborn style
sns.set(style="whitegrid")

# Create a 6 by 5 grid of axes for the box plots
fig, axes = plt.subplots(6, 5, figsize=(40, 30))
axes = axes.flatten()

# Create a box plot for each numeric column in df1 and df2
for i, column in enumerate(numeric_columns):
    sns.boxplot(data=df1, x="Group", y=column, ax=axes[i], color="blue")
    sns.boxplot(data=df2, x="Group", y=column, ax=axes[i], color="orange")

    # Add hatches for the boxes
    for patch in axes[i].artists:
        patch.set_hatch('//')

    axes[i].set_title(column, fontsize=20)
    axes[i].set_xlabel("Group", fontsize=15)
    axes[i].set_ylabel("Value", fontsize=15)
    axes[i].tick_params(axis="both", labelsize=12)

plt.tight_layout()
plt.suptitle("Box Plot Comparison for Healthy and PD Individuals", fontsize=30)
plt.subplots_adjust(top=0.92)
plt.legend(labels=["Healthy", "PD"])
plt.show()
```

```
"""  Confidence Interval """
import pandas as pd
import numpy as np
from scipy.stats import t
# List of features/columns in your dataset
features = df1.columns.difference(["Group", "duration"])

# Initialize empty lists to store results
selected_features = []
mean_differences = []
confidence_intervals = []
absolute_mean_differences = []  # New list to store absolute mean differences

# Loop through each feature
for feature in features:
    # Calculate mean and standard error for each group
    mean_healthy = df1[feature].mean()
    mean_unhealthy = df2[feature].mean()
    std_error_healthy = df1[feature].std() / np.sqrt(len(df1))
    std_error_unhealthy = df2[feature].std() / np.sqrt(len(df2))

    # Calculate the t-statistic
    t_statistic = (mean_unhealthy - mean_healthy) / np.sqrt(std_error_healthy**2 + std_error_unhealthy**2)

    # Calculate degrees of freedom for the t-distribution
    dof = len(df1) + len(df2) - 2

    # Calculate the critical value for the t-distribution
    t_critical = t.ppf(0.975, dof)  # 95% confidence level

    # Calculate the margin of error
    margin_of_error = t_critical * np.sqrt((std_error_healthy**2 + std_error_unhealthy**2) / 2)

    # Calculate the confidence interval
    ci_lower = (mean_unhealthy - mean_healthy) - margin_of_error
    ci_upper = (mean_unhealthy - mean_healthy) + margin_of_error

    # Check if confidence intervals do not overlap
    if ci_lower > 0 or ci_upper < 0:
        selected_features.append(feature)
        mean_difference = mean_unhealthy - mean_healthy
        mean_differences.append(mean_difference)
        confidence_intervals.append((ci_lower, ci_upper))
        absolute_mean_differences.append(abs(mean_difference))  # Add the absolute mean difference

# Create a DataFrame to store the results
feature_selection_results = pd.DataFrame({
    'Feature': selected_features,
    'Mean Difference': mean_differences,
    'Confidence Interval': confidence_intervals,
    'Absolute Mean Difference': absolute_mean_differences  # Add the absolute mean difference column
})

# Sort features based on larger absolute mean differences and narrower CIs
sorted_results = feature_selection_results.sort_values(by=['Absolute Mean Difference', 'Confidence Interval'], ascending=[False, True])

# Drop the "Absolute Mean Difference" column
sorted_results = sorted_results.drop(columns='Absolute Mean Difference')

# Print the sorted results with formatting
pd.options.display.float_format = '{:.3f}'.format
print(sorted_results.to_string(index=False))


# Define the file path where you want to save the top 10 results
output_file_path = '/content/drive/My Drive/sorted_results_All.csv'

# Save the top 10 rows of the sorted results to a CSV file
top_10_sorted_results = sorted_results.head(10)
top_10_sorted_results.to_csv(output_file_path, index=False)

print("Top 10 results saved to", output_file_path)
```

```
"""  Hypothesis Testing """
import numpy as np
from scipy.stats import norm
# List of features/columns in your dataset
features = df1.columns.difference(["Group"])
# Set the significance level
alpha = 0.05
# Initialize empty lists to store results
reject_results = []
fail_to_reject_results = []
# Loop through each feature
for feature in features:
    # Calculate sample means and standard deviations
    mean_healthy = df1[feature].mean()
    mean_unhealthy = df2[feature].mean()
    std_healthy = df1[feature].std()
    std_unhealthy = df2[feature].std()
    n_healthy = len(df1)
    n_unhealthy = len(df2)
    # Calculate the pooled standard error
    pooled_std = np.sqrt((std_healthy**2 / n_healthy) + (std_unhealthy**2 / n_unhealthy))
    # Calculate the z-score
    z_score = (mean_unhealthy - mean_healthy) / pooled_std
    # Calculate the critical z-value for two-tailed test
    critical_z = norm.ppf(1 - alpha / 2)
    # Perform the hypothesis test
    result_dict = {
        "Feature": feature,
        "Z-Score": z_score,
        "Critical Z-Value": critical_z,
        "Result": "Reject H0" if np.abs(z_score) > critical_z else "Fail to reject H0"
    }
    # Store the results in the appropriate list
```

E. T-test Python code

In [ ]:

```python
import pandas as pd
from scipy.stats import ttest_ind

def perform_t_test(csv_file, group_column, value_column):
    # Read the CSV file into a pandas DataFrame
    data = pd.read_csv(csv_file)

    # Split data into two groups based on the specified column
    group1 = data[data[group_column] == 'PD'][value_column]
    group2 = data[data[group_column] == 'HC'][value_column]

    # Perform t-test
    t_statistic, p_value = ttest_ind(group1, group2)

    return p_value

# Example usage
csv_file = '/Users/ashkan/Downloads/Monoloudnesschange_fort-test-2014-2019.csv'
group_column = 'Group'
value_column = 'Value'

p_value = perform_t_test(csv_file, group_column, value_column)
print("P-value:", p_value)
```

F. Plotting Python code

In [ ]:

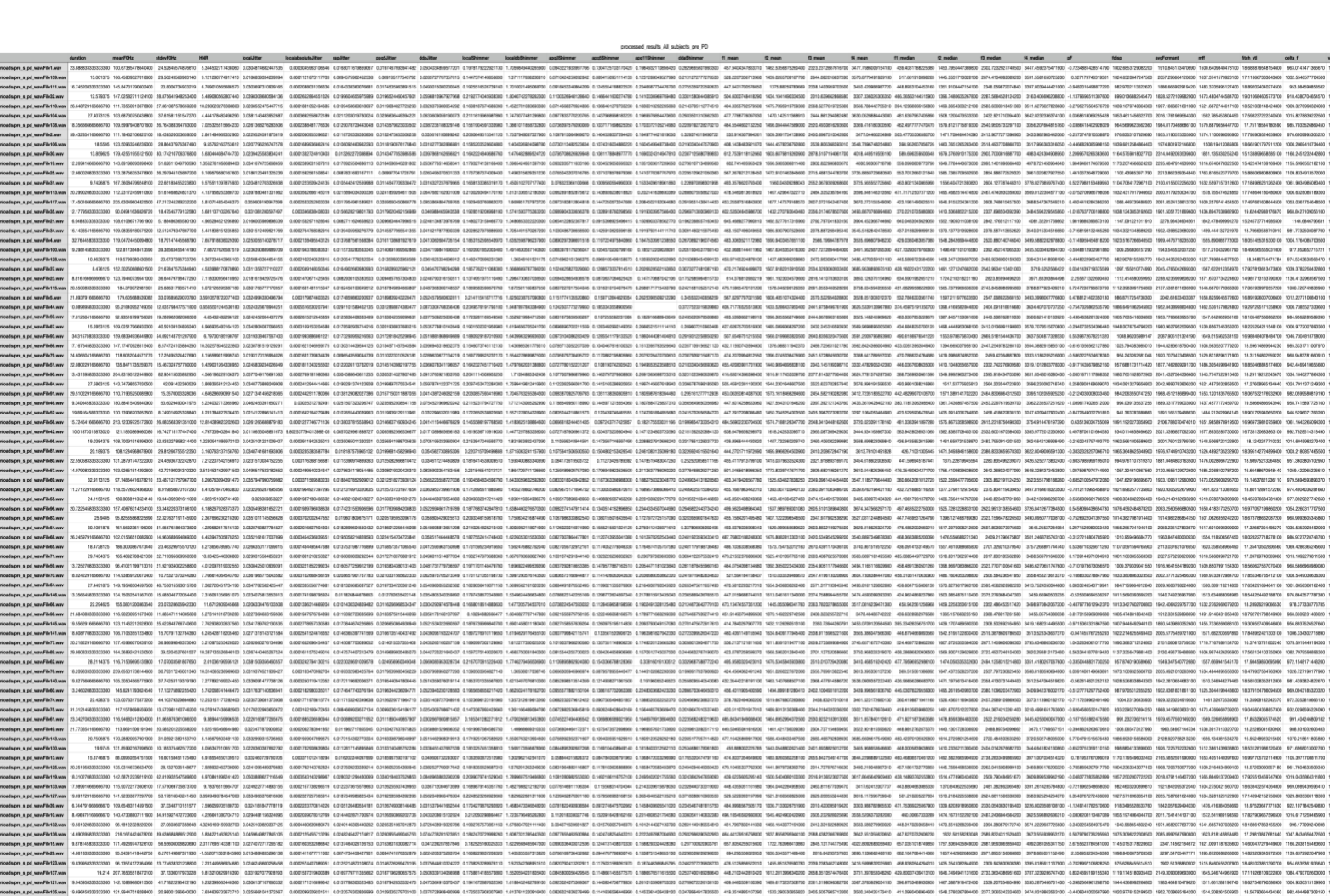
```
import pandas as pd
import matplotlib.pyplot as plt

# Read the data from CSV
data = pd.read_csv('/Users/ashkan/Downloads/Plotting/monoloudness-plotting-post.csv')

# Separate data for each group
group1_data = data[data['Group'] == 'PD']
group2_data = data[data['Group'] == 'HC']

# Extract time points and measurements for each group
time_points = ['TimeA', 'TimeB', 'TimeC', 'TimeD']
group1_measurements = group1_data[time_points].mean(axis=0)
group2_measurements = group2_data[time_points].mean(axis=0)

# Plotting
plt.plot(time_points, group1_measurements, label='PD')
plt.plot(time_points, group2_measurements, label='HC')

plt.xlabel('Time Points')
plt.ylabel('Mean IntSD')
plt.title('HC and PD Groups IntSD after Dance session')

plt.legend()
plt.grid(True)

# Save the plot as PNG
plt.savefig('intsd-hc-pd-post.png', dpi=300)  # specify the file name and dpi

plt.show()
```

In [ ]:

```
import pandas as pd
import matplotlib.pyplot as plt

# Read the data from CSV
data = pd.read_csv('/Users/ashkan/Downloads/Plotting/monoloudness-plotting.csv')

# Separate data for each group
group1_data = data[data['Group'] == 'PD']
group2_data = data[data['Group'] == 'HC']

# Extract time points and measurements for each group
time_points = ['TimeA', 'TimeB', 'TimeC', 'TimeD']
group1_measurements = group1_data[time_points]
group2_measurements = group2_data[time_points]

# Calculate mean and percentiles for each group
group1_mean = group1_measurements.mean()
group2_mean = group2_measurements.mean()
group1_25th_percentile = group1_measurements.quantile(0.25)
group2_25th_percentile = group2_measurements.quantile(0.25)
group1_75th_percentile = group1_measurements.quantile(0.75)
group2_75th_percentile = group2_measurements.quantile(0.75)

# Plotting
plt.plot(time_points, group1_mean, label='PD', color='blue')
plt.plot(time_points, group2_mean, label='HC', color='orange')

# Fill between the 25th and 75th percentiles
plt.fill_between(time_points, group1_25th_percentile, group1_75th_percentile, color='blue', alpha=0.2)
plt.fill_between(time_points, group2_25th_percentile, group2_75th_percentile, color='orange', alpha=0.2)

plt.xlabel('Time Points')
plt.ylabel('Mean IntSD')
plt.title('HC and PD Groups IntSD before Dance session')

plt.legend()
plt.grid(True)

# Save the plot as PNG
plt.savefig('intsd-hc-pd-pre2.png', dpi=300)  # specify the file name and dpi

plt.show()
```

Tables

1. Processed audio files for PwPD before the dance session



2. Processed audio files for healthy controls before the dance session

processed_results_All_subjects_pre_HC

voiceID	duration	meanF0Hz	stdevF0Hz	HNR	localJitter	localabsoluteJitter	rapJitter	ppq5Jitter
/Users/ashkan/Downloads/pre_s_hc_wav/File105.wav	25.442979166666700	178.9519064860180	35.54929612313910	7.113714894606380	0.0299408443537568	0.0001674271426824	0.0155133469320994	0.0176007786901625
/Users/ashkan/Downloads/pre_s_hc_wav/File27.wav	9.064520833333330	139.6139424988320	38.04246584857130	-0.7558172423604600	0.032902019299559	0.0002335644298238	0.0176327715450559	0.0225969840153043
/Users/ashkan/Downloads/pre_s_hc_wav/File33.wav	13.388354166666700	194.7848193913560	25.527466996467500	5.043467836396720	0.0185122579583017	9.4689333960383E-05	0.0099575299368733	0.0101964742548663
/Users/ashkan/Downloads/pre_s_hc_wav/File26.wav	11.645291666666700	136.9387691167500	41.14421610740300	5.784785708356950	0.0312785683199548	0.0002294841247447	0.015964704197894	0.0152418706481123
/Users/ashkan/Downloads/pre_s_hc_wav/File24.wav	18.422063492063500	158.93500739756100	22.586053277279100	3.4179581946984500	0.0092685070625176	5.84625659739377E-05	0.0040698448549165	0.0046708870542716
/Users/ashkan/Downloads/pre_s_hc_wav/File18.wav	6.671145833333330	103.89838379604300	17.64122970825430	4.567700126615630	0.0207076957928353	0.0001997162000802	0.0107156128480141	0.009968938923576
/Users/ashkan/Downloads/pre_s_hc_wav/File3.wav	23.038708333333300	167.96005961730900	36.448963812244000	5.0526462284877700	0.0334577326898421	0.0001980448781166	0.0181151773321427	0.0195822135876902
/Users/ashkan/Downloads/pre_s_hc_wav/File7.wav	24.171333333333300	98.82244603211870	33.0002785379311	6.05435514215304	0.0222293136538734	0.0002261124006206	0.0122182881992885	0.0138261810396051
/Users/ashkan/Downloads/pre_s_hc_wav/File103.wav	24.993395833333300	129.5180759380630	43.80226009311110	4.687435028679150	0.0348721133984212	0.0002681700111071	0.0191309662054171	0.019225990136317
/Users/ashkan/Downloads/pre_s_hc_wav/File20.wav	6.3290022675737000	110.6897698197760	3.468805413993760	-0.1538021580935410	0.0089132119393124	8.04298657076352E-05	0.0023687850952163	0.0038420415415042
/Users/ashkan/Downloads/pre_s_hc_wav/File102.wav	18.0400625	203.79670711813900	37.99423102590750	8.370925207440630	0.0351892937415518	0.0001728253554301	0.0191478287038689	0.0199825535536714
/Users/ashkan/Downloads/pre_s_hc_wav/File116.wav	16.176541666666700	134.79314654712200	18.02842030680620	7.88995257716643	0.0338460388606108	0.000252446677033	0.0175662996709359	0.0202020720730822
/Users/ashkan/Downloads/pre_s_hc_wav/File6.wav	31.287270833333300	185.31483334515000	39.66592835215190	7.165110244741080	0.0283688941454457	0.0001531923556432	0.0159539418281024	0.0169309883036238
/Users/ashkan/Downloads/pre_s_hc_wav/File22.wav	10.299251700680300	188.80105637712300	58.37291465201730	2.9388328378661000	0.0078935529553773	4.17447071695811E-05	0.0037741700897627	0.0035553464921708
/Users/ashkan/Downloads/pre_s_hc_wav/File36.wav	16.540916666666700	170.187240519007	60.35552535288640	4.358659216120790	0.0238309297625975	0.000139639711456	0.012667540188511	0.0143128350069867
/Users/ashkan/Downloads/pre_s_hc_wav/File129.wav	19.491270833333300	103.06799657233200	29.48458674081080	5.614788678708040	0.0219425298698438	0.0002132761918384	0.0102644861752558	0.0104986099905003
/Users/ashkan/Downloads/pre_s_hc_wav/File101.wav	23.3249375	158.28801769646000	32.00980061856410	7.05772565821222	0.0302317162836557	0.0001914648915109	0.0162723252058117	0.0170029395000282
/Users/ashkan/Downloads/pre_s_hc_wav/File78.wav	13.6611875	117.56618212721000	43.77504942124430	2.778202703526810	0.0303554104096757	0.0002579464589225	0.0153978511103664	0.0163223937354161
/Users/ashkan/Downloads/pre_s_hc_wav/File92.wav	19.202625	176.56025299110000	44.488394088020900	4.143177820805100	0.0357988302633588	0.0002018345998526	0.0189622413989482	0.0203608899508779
/Users/ashkan/Downloads/pre_s_hc_wav/File45.wav	20.8538125	189.99444248294500	49.76710348940460	10.335729712068300	0.0279340887557323	0.0001471671443743	0.0141660244402316	0.0154738876959803
/Users/ashkan/Downloads/pre_s_hc_wav/File53.wav	28.9724375	189.5162376906210	50.39787393562890	10.55137179906570	0.0295282963890901	0.000155592002614	0.0155203265997703	0.0164828617008622
/Users/ashkan/Downloads/pre_s_hc_wav/File47.wav	28.231958333333300	184.94163810568000	31.579557655971400	11.799325368868200	0.0255093388545626	0.0001376781775094	0.0127176377282771	0.0141577609958666
/Users/ashkan/Downloads/pre_s_hc_wav/File85.wav	6.547270833333330	161.38358706262500	26.99566102366060	8.270487561730180	0.0181371040377139	0.0001124329384816	0.0100482101357114	0.00979726001654
/Users/ashkan/Downloads/pre_s_hc_wav/File94.wav	27.127708333333300	134.75777237491700	12.078956802286200	4.798770811528820	0.0227479905197635	0.0001687419914199	0.0126387386287308	0.0130851069188979
/Users/ashkan/Downloads/pre_s_hc_wav/File43.wav	15.578145833333300	178.94409326386600	30.4525763874112	8.506978498959600	0.0239084487548209	0.0001344239251502	0.0120365545832787	0.0135370484135891
/Users/ashkan/Downloads/pre_s_hc_wav/File82.wav	14.4734375	111.1445952518670	21.72700971484930	9.093729974796910	0.0284481719213917	0.0002565851586771	0.0141167186413223	0.0149956577554084
/Users/ashkan/Downloads/pre_s_hc_wav/File97.wav	12.206791666666700	187.42813172665900	36.473919510977800	9.020445854450970	0.0223210975603604	0.0001187636589226	0.0117753458752998	0.0129800347254278
/Users/ashkan/Downloads/pre_s_hc_wav/File40.wav	5.814333333333330	157.92848080852700	29.520432157020300	4.797102658616680	0.018051748897679	0.0001144959117468	0.0104206113493174	0.0111648325344764
/Users/ashkan/Downloads/pre_s_hc_wav/File58.wav	23.875041666666700	175.3665028157530	30.011009512835100	10.81630783772150	0.0205036438816809	0.0001165559204404	0.0098970853623721	0.0107117130456937
/Users/ashkan/Downloads/pre_s_hc_wav/File144.wav	20.211583333333300	188.09683903642400	56.01481841022550	6.121872861626910	0.0448178606413463	0.0002392739402499	0.0238761612140365	0.0257193624790481
/Users/ashkan/Downloads/pre_s_hc_wav/File72.wav	26.485520833333300	184.1965578101580	33.78778124254650	7.4774313105957000	0.0261544315872431	0.0001418103544276	0.013241997546019	0.0143426216449422
/Users/ashkan/Downloads/pre_s_hc_wav/File99.wav	11.7735625	147.55694076525200	38.05445226343340	3.3708086417581800	0.0384805880654105	0.0002609038272509	0.0205798308942554	0.0221670520424215
/Users/ashkan/Downloads/pre_s_hc_wav/File67.wav	12.1084375	151.6844299160560	34.14681028417640	8.858842299671140	0.0285780386954316	0.0001884614486224	0.0147890613968508	0.0161220773515279
/Users/ashkan/Downloads/pre_s_hc_wav/File73.wav	26.330020833333300	213.47096130359500	54.92097304786090	8.73637490772066	0.0388307253240984	0.0001823482834134	0.0204352947245313	0.0207619742904911
/Users/ashkan/Downloads/pre_s_hc_wav/File63.wav	8.713645833333330	132.79018048992200	11.746020346103900	10.357622781815400	0.0229259682696953	0.0001730011333864	0.0117866545444512	0.0130320997728449
/Users/ashkan/Downloads/pre_s_hc_wav/File88.wav	20.147354166666700	154.73698930503200	59.55680814311050	3.550215163325430	0.0455886250758041	0.0002935385372963	0.0244980710405664	0.0253850280882163
/Users/ashkan/Downloads/pre_s_hc_wav/File142.wav	20.136520833333300	130.73845044269700	14.876908015594500	7.096516088248160	0.0282999550448862	0.0002171030154177	0.0138469205828524	0.0159686030913198
/Users/ashkan/Downloads/pre_s_hc_wav/File48.wav	20.224458333333300	190.7542511920850	56.62302697013300	6.62763964886429	0.0393161667556899	0.0002063375316852	0.021639720084237	0.0219050595546516
/Users/ashkan/Downloads/pre_s_hc_wav/File8.wav	29.310395833333300	164.50531941678500	47.78501476500760	5.215900001033080	0.0402840625492111	0.0002445116653142	0.0216232837050957	0.0243384417340452
/Users/ashkan/Downloads/pre_s_hc_wav/File118.wav	20.221875	174.61400590913000	53.90761845500900	6.287213727250900	0.0399466991007377	0.0002282607588591	0.0210262262915234	0.0223055732464021
/Users/ashkan/Downloads/pre_s_hc_wav/File124.wav	29.78225	180.28687186455800	37.47390915588420	9.41858131649922	0.0260443394976712	0.0001448633553917	0.0132021949277197	0.0148269120816401
/Users/ashkan/Downloads/pre_s_hc_wav/File12.wav	16.799979166666700	130.77946032959500	18.58816090092440	8.971220050566090	0.04624072844022	0.000352937778445	0.0240328562061469	0.0240147622779995
/Users/ashkan/Downloads/pre_s_hc_wav/File131.wav	16.975020833333300	147.47569347407500	54.494465940589700	9.13324787273688	0.0297793784476436	0.0002012452071712	0.0143886403363215	0.0144474175143619
/Users/ashkan/Downloads/pre_s_hc_wav/File11.wav	6.953145833333330	141.65175855193900	20.25742440796910	4.5770147300153100	0.018230007963758	0.0001285908881645	0.0097758256737038	0.0100157449869169
/Users/ashkan/Downloads/pre_s_hc_wav/File38.wav	18.813625	171.64380854389000	55.243942072107500	10.715977758452900	0.0195476381669672	0.0001134675093307	0.0095534591914625	0.0098824337732655
/Users/ashkan/Downloads/pre_s_hc_wav/File126.wav	19.157395833333300	118.70940997060800	34.66420344042340	4.866767065064410	0.0279072737611297	0.0002353750098344	0.0147934029829477	0.0165366113900477
/Users/ashkan/Downloads/pre_s_hc_wav/File122.wav	11.5703125	122.674791253029	16.16027342488450	5.5579421580138600	0.0324413042294848	0.0002655185692582	0.0176232277782194	0.0185248669698647
/Users/ashkan/Downloads/pre_s_hc_wav/File28.wav	10.9569375	192.53461157852500	35.888236737632600	5.825119545327650	0.0279357358967346	0.0001447874520364	0.0149748834933259	0.0154309970650118
/Users/ashkan/Downloads/pre_s_hc_wav/File14.wav	14.016166666666700	143.74277211740100	35.270952450849200	4.993325926751080	0.0554406291619701	0.0003839087243247	0.0310300468085717	0.031852250770827
/Users/ashkan/Downloads/pre_s_hc_wav/File16.wav	5.922395833333330	192.68751473992900	30.80558314575450	7.76404415279677	0.0224138652060535	0.0001160647327446	0.0106686500934855	0.0104543724842129
/Users/ashkan/Downloads/pre_s_hc_wav/File134.wav	19.457041666666700	160.02320223781700	37.56908164591880	7.4063276590716700	0.0274901622712602	0.0001723055332178	0.0141956655765769	0.0155023846266185
/Users/ashkan/Downloads/pre_s_hc_wav/File120.wav	19.578604166666700	176.51235330291400	36.50748378373170	5.8902280555609100	0.0389006544663264	0.0002194413175208	0.0199082595546151	0.0210388223961515

voiceID	ddpJitter	localShimmer	localdbShimmer	apq3Shimmer	apq5Shimmer	apq11Shimmer	ddaShimmer	f1_mean	f2_mean	f3_mean	f4_mean
/Users/ashkan/Downloads/pre_s_hc_wav/File105.wav	0.0465400407962983	0.1929921183713610	1.673710610087720	0.0849233454186456	0.1280036815148330	0.2234018138348970	0.2547700362559370	512.9768593943760	1561.9654277801700	2562.238556904280	3709.151343371270
/Users/ashkan/Downloads/pre_s_hc_wav/File27.wav	0.0528983146351678	0.1890332121867700	1.6225210585861600	0.0949332294621467	0.1575029013799290		0.2847996883864400	523.0118642311350	1802.661086815220	2717.713709208970	4024.168913879950
/Users/ashkan/Downloads/pre_s_hc_wav/File33.wav	0.02987258981062	0.1459041354659420	1.3672970702180400	0.0734306781408261	0.0936774867705797	0.128003469980946	0.2202920344224780	669.2115951335430	1692.8244197038600	2605.029542804540	4017.648453574200
/Users/ashkan/Downloads/pre_s_hc_wav/File26.wav	0.0478941125936821	0.1789127413903940	1.5460603460167500	0.0892754867189557	0.1311752155762940	0.2056860165334570	0.2678264601568670	501.7385311077260	1557.3331839721400	2562.119539217490	3777.02841996798
/Users/ashkan/Downloads/pre_s_hc_wav/File24.wav	0.0122095345647495	0.1556495408586910	1.3965137060490900	0.075155063799284	0.1005978577386310	0.136391551157733	0.2254651913978520	641.1726163997970	1653.150121773670	2561.3574895605500	3571.720113945470
/Users/ashkan/Downloads/pre_s_hc_wav/File18.wav	0.0321468385440424	0.2008491495427940	1.752279004466170	0.1123716375217700	0.1134520672327240	0.145590300034243	0.3371149125653090	428.0438171608000	1478.422229769630	2291.3864534617700	3531.183484320230
/Users/ashkan/Downloads/pre_s_hc_wav/File3.wav	0.0543455319964283	0.1883637941795760	1.6540918778652300	0.0888510439977413	0.1264896136915750	0.1788869940318170	0.2665531319632240	518.7393638075710	1665.0592757767700	2654.4339204491900	3642.976478421910
/Users/ashkan/Downloads/pre_s_hc_wav/File7.wav	0.0366548645978657	0.1891680175934740	1.6367934432452800	0.0870360563674084	0.125820723531215	0.1746921093890030	0.2611081691022250	496.9260853741570	1465.3062661833500	2483.4915050860100	3493.5593237469200
/Users/ashkan/Downloads/pre_s_hc_wav/File103.wav	0.0573928986162514	0.1793296935064020	1.6281621516664700	0.0820756189514447	0.1069406549910470	0.1716477041358230	0.2462268508543340	492.8231159752160	1715.2405246198600	2689.6053119732800	3860.4207588719400
/Users/ashkan/Downloads/pre_s_hc_wav/File20.wav	0.0071063552856489	0.143007745548581	1.3205648569783700	0.0647455426440847	0.0835969556759858	0.0674394470525742	0.1942366279322540	580.9797903124390	1825.2272527890100	2698.2441775678900	3380.981186630280
/Users/ashkan/Downloads/pre_s_hc_wav/File102.wav	0.0574434861116068	0.1733887779601840	1.5851616340542300	0.0897795245207435	0.110350169242179	0.1638279890477160	0.2693385735622310	507.9535241279690	1618.8159620761600	2573.693714413920	3621.714472811010
/Users/ashkan/Downloads/pre_s_hc_wav/File116.wav	0.0526988990128078	0.1999073150821240	1.7249606142164200	0.0889510672282066	0.1304645038835980	0.2565923567139780	0.26685320168462	440.2198189258610	1440.4789281760600	2418.6032111539500	3386.4603415739400
/Users/ashkan/Downloads/pre_s_hc_wav/File6.wav	0.0478618254843073	0.1871502275476100	1.6539093734057000	0.0895264706192358	0.1254039618235280	0.2007575049466920	0.2685794118577070	566.6616998170920	1647.4626301422100	2636.926360727680	3703.041580063670
/Users/ashkan/Downloads/pre_s_hc_wav/File22.wav	0.0113225102692881	0.1492691476469140	1.3230618008445400	0.0754367114049396	0.0918076625495893	0.1301843020666910	0.2263101342148190	630.08917485995	1745.9322296414000	2684.197778950730	3556.579552506640
/Users/ashkan/Downloads/pre_s_hc_wav/File36.wav	0.0380026205655332	0.1646068550410360	1.454477013437500	0.0780127671469472	0.1055620602643600	0.1462527675140060	0.2340383014408420	678.7635695414540	1661.2120717686400	2875.4243787518300	4004.9486963586900
/Users/ashkan/Downloads/pre_s_hc_wav/File129.wav	0.0307933985257676	0.1810075572238920	1.593232001291030	0.087499034610906	0.1191172485753210	0.1643232048614090	0.2624971038327180	511.0988623042810	1474.6255367866300	2550.4950637730400	3650.220277964040
/Users/ashkan/Downloads/pre_s_hc_wav/File101.wav	0.0488169756174351	0.1898546374770230	1.623513659824630	0.0858973052902129	0.124278188237001	0.2207638276028520	0.2576919158706390	496.2903873241610	1486.6158594339800	2561.930843149690	3648.470611663630
/Users/ashkan/Downloads/pre_s_hc_wav/File78.wav	0.0461935533310994	0.2155038009370360	1.831315069059860	0.1067806027692340	0.131767512110617	0.2081822474442640	0.3203418083077020	491.506190316966	1533.5278639814800	2615.290892796340	3774.635352047590
/Users/ashkan/Downloads/pre_s_hc_wav/File92.wav	0.0568867241968446	0.204946117842589	1.7092309977836200	0.1070356650161400	0.1450665110251100	0.2121659224844980	0.3211069950484190	488.1357266213550	1574.8832532101100	2564.950360016490	3592.99836889634
/Users/ashkan/Downloads/pre_s_hc_wav/File45.wav	0.042498073320695	0.1842576222218010	1.6186009564917400	0.0823434741627814	0.1205480683021390	0.2216624796432820	0.2470304224883440	512.5997809007480	1582.4202958857800	2632.341330578430	3504.569349173660
/Users/ashkan/Downloads/pre_s_hc_wav/File53.wav	0.0465609797993109	0.1549310533041140	1.496653403777510	0.0740381013948938	0.0986436584107153	0.1612436411477470	0.2221143041846820	561.5829227664700	1516.24830376973	2561.3169921657400	3550.905258691340
/Users/ashkan/Downloads/pre_s_hc_wav/File47.wav	0.0381529131848314	0.1540102668658000	1.4237330506948800	0.0649395274688639	0.1031510993036080	0.1856683353196350	0.1948185824065920	502.9303760753940	1535.0650536265300	2558.005780404890	3683.704405608640
/Users/ashkan/Downloads/pre_s_hc_wav/File85.wav	0.0301446304071342	0.1748063727079100	1.5366072667204400	0.089234725896912	0.1188430401923100	0.1837887354045750	0.267704177690736	535.5671385669440	1598.0513428274400	2631.598947504780	3561.8349110652000
/Users/ashkan/Downloads/pre_s_hc_wav/File94.wav	0.0379162158861925	0.1890907514181500	1.6419880652036700	0.0956428061090181	0.1283200020970730	0.1970612867226110	0.2869284183270540	505.5731121922320	1542.4547297769500	2526.4356600939700	3399.500264739970
/Users/ashkan/Downloads/pre_s_hc_wav/File43.wav	0.0361096637498363	0.1582633119066070	1.4735809213096000	0.062995830140633	0.0994269324755353	0.1804065350768630	0.188987490421899	581.4289056821200	1554.7007621487100	2701.0718596642300	3934.526698941190
/Users/ashkan/Downloads/pre_s_hc_wav/File82.wav	0.0423501559239671	0.1674193049660690	1.5635595107393300	0.070014247475903	0.0951868470551971	0.1915258600101890	0.210042742427709	485.217349381332	1443.1895461138800	2517.1862157187900	3326.614455978160
/Users/ashkan/Downloads/pre_s_hc_wav/File97.wav	0.0353260376258996	0.1629433263232890	1.458198226699430	0.0778696933562917	0.1034563110498540	0.1514291484158850	0.2336090800688750	544.4290675308550	1443.3004127524100	2535.795852903900	3547.770784864110
/Users/ashkan/Downloads/pre_s_hc_wav/File40.wav	0.0312618340479522	0.1453473358204660	1.3441583479014900	0.0703353007004298	0.0932354407713367	0.1536044608715280	0.2110059021012900	680.9544943342460	1705.9308561343000	2814.869351399300	3942.475652511920
/Users/ashkan/Downloads/pre_s_hc_wav/File58.wav	0.0296912560871163	0.159994689649744	1.506936430875930	0.0724002357198647	0.102262817342503	0.1906587276959560	0.2172007071595940	507.7192612301990	1481.0974939042600	2487.281970626700	3654.7654937255700
/Users/ashkan/Downloads/pre_s_hc_wav/File144.wav	0.0716284836421096	0.2008509943207270	1.6748634961718600	0.1041849033014160	0.1325725605634160	0.2343340251575860	0.3125547099042480	490.3217208993910	1610.1574049074700	2672.9218816170000	3704.3322755127400
/Users/ashkan/Downloads/pre_s_hc_wav/File72.wav	0.0397259926380572	0.1717068865010980	1.5114394876396400	0.0817330786777578	0.117251822011579	0.1891245825788010	0.2451992360332740	530.4485471109690	1606.4353618307200	2600.7968846903100	3717.169955446900
/Users/ashkan/Downloads/pre_s_hc_wav/File99.wav	0.0617394926827663	0.2085688229219490	1.7369077932043300	0.1029761350868680	0.1407268546656330	0.2432093213064590	0.3089284052606040	534.3165438246180	1532.7786901074300	2625.377962045440	3575.8874983957400
/Users/ashkan/Downloads/pre_s_hc_wav/File67.wav	0.0443671841905524	0.1537818935323370	1.448639611086450	0.0659877665086946	0.1014347197551690	0.2070927233497100	0.1979632965260840	479.4832178316710	1634.6639162569900	2565.4411424154100	3838.856829939170
/Users/ashkan/Downloads/pre_s_hc_wav/File73.wav	0.0613058841735941	0.1401359968362080	1.3326515910801200	0.0712249439479957	0.088535764538301	0.1252186960685420	0.2136748318439670	484.4001356409790	1551.730904656180	2681.677864602840	3721.9010782460300
/Users/ashkan/Downloads/pre_s_hc_wav/File63.wav	0.0353599636333537	0.1530681826705930	1.4336798429902500	0.0660888719258287	0.0982536069467963	0.1562716807184510	0.1982666157774860	405.6070073203570	1491.022634760290	2393.2043245427800	3493.140821180970
/Users/ashkan/Downloads/pre_s_hc_wav/File88.wav	0.0734942131216993	0.2156534728028310	1.812867659674540	0.1120579581456160	0.134864387246456	0.1598350123808100	0.3361738744368490	466.1390374525410	1665.4851987496800	2666.047517406110	3762.369805008260
/Users/ashkan/Downloads/pre_s_hc_wav/File142.wav	0.0415407617485573	0.1746257313140150	1.543633405677820	0.0798550940752085	0.1128336981687150	0.1791975144579480	0.2395652822256250	460.4823257455700	1569.9756974161300	2548.546479143990	3457.1438241451300
/Users/ashkan/Downloads/pre_s_hc_wav/File48.wav	0.0649191602527111	0.1645194967277620	1.4956727264500200	0.0860860756965055	0.1093481548672930	0.1724227729995720	0.2582582270895170	448.6449921728460	1625.6039896293300	2622.2347433767200	3695.64711585116
/Users/ashkan/Downloads/pre_s_hc_wav/File8.wav	0.0648698511152873	0.2006378922426060	1.7284865232917500	0.1092908761530830	0.149704644321965	0.2443050805829540	0.3278726284592480	566.7041908919570	1669.371654050490	2573.9083320004300	3726.7060169020600
/Users/ashkan/Downloads/pre_s_hc_wav/File118.wav	0.0630786788745704	0.1981366913955940	1.7648106256914200	0.0900669734276105	0.134648182509164	0.3333239228822810	0.2702009202826320	508.1219118247430	1620.3139647479100	2564.754520980820	3779.099161884410
/Users/ashkan/Downloads/pre_s_hc_wav/File124.wav	0.0396065847831593	0.172334378042470	1.5183135870038900	0.0793750295038041	0.1133875973773330	0.1749590847073660	0.2381250885114120	531.5139996796500	1565.109658285930	2530.3676268036900	3622.292508652060
/Users/ashkan/Downloads/pre_s_hc_wav/File12.wav	0.0720985686184407	0.2014513715587360	1.74531050571517	0.1080022105276470	0.1422700875961320	0.2125629181510130	0.3240066315829420	565.0421388178460	1618.267400923460	2626.1012821526800	3697.065256704390
/Users/ashkan/Downloads/pre_s_hc_wav/File131.wav	0.0431659210089647	0.1643143103160760	1.5058464330159300	0.0826274300086643	0.1045253598680790	0.1437448786732640	0.2478822900259930	514.999121024129	1619.0908406078300	2610.3047405518300	3782.0800718086000
/Users/ashkan/Downloads/pre_s_hc_wav/File11.wav	0.0293274770211115	0.1652080923218150	1.4549618282313000	0.0829781104821595	0.1116379205861510	0.1771227287437980	0.2489343313864790	642.604431588154	1698.4210766486900	2791.646683788680	3966.111437830460
/Users/ashkan/Downloads/pre_s_hc_wav/File38.wav	0.0286603775743875	0.1227174435013980	1.2926431683352500	0.0534618399096181	0.0766856556198167	0.1347378192271480	0.1603855197268540	627.0645920686880	1709.5691183699200	2607.9991422853500	3730.0907447657100
/Users/ashkan/Downloads/pre_s_hc_wav/File126.wav	0.0443802089488433	0.1814877442929400	1.5020299970000500	0.0935168482213624	0.111504815704111	0.1336830626856830	0.2805505446640670	520.6054198203780	1602.6933509432100	2612.784060177990	3551.676039971500
/Users/ashkan/Downloads/pre_s_hc_wav/File122.wav	0.0526966833346584	0.1925625738371820	1.6474572847725800	0.0948466886921855	0.1265756045272350	0.1828206241893250	0.2845400660765570	471.9595221397310	1546.641960016140	2449.6919193723400	3504.899546525730
/Users/ashkan/Downloads/pre_s_hc_wav/File28.wav	0.0449246504799778	0.168625784579068	1.5618495941440800	0.0796714401120432	0.1033707863811660	0.1799271694280680	0.2390143203361300	676.7476725176990	1666.7043302260600	2600.145154996800	4075.427834422640
/Users/ashkan/Downloads/pre_s_hc_wav/File14.wav	0.0930901404257152	0.2285742769268830	1.8796686483125700	0.1049661475329510	0.1760494168701530	0.1779409724011270	0.3148984425968540	509.8492047464200	1424.919992001430	2374.4883536109700	3604.4467740994000
/Users/ashkan/Downloads/pre_s_hc_wav/File16.wav	0.0320059502804565	0.1699834934866740	1.5190832525928200	0.0823160569506189	0.1196908931123430	0.1685991099652220	0.2469481708518570	529.7697433590830	1456.5823038245500	2417.9181680173700	3655.869117126350
/Users/ashkan/Downloads/pre_s_hc_wav/File134.wav	0.0425869967297309	0.1661680054725520	1.5169938865124200	0.0793807896387137	0.1032609194378510	0.1681993763825980	0.2381423689161410	472.9122974674610	1600.3263060396900	2464.8333210447200	3583.530934126620
/Users/ashkan/Downloads/pre_s_hc_wav/File120.wav	0.0597247786638453	0.2026240176186480	1.736356599751840	0.0989403442216785	0.1531486174560290	0.2672210098391400	0.2968210326650360	496.7131874657250	1524.403287788310	2585.994669647550	3675.157391697270

voiceID	f1_median	f2_median	f3_median	f4_median	pF	fdisp	avgFormant	mff	fitch_vtl	delta_f	vtl_delta_f
/Users/ashkan/Downloads/pre_s_hc_wav/File105.wav	493.1064189194480	1605.7945125003700	2624.3950883556200	3793.5911777410300	0.0761826593599964	1100.16158627386	2129.221799379120	1675.627935191930	16.726963958516600	1071.1334200568100	16.33783399184010
/Users/ashkan/Downloads/pre_s_hc_wav/File27.wav	507.7160460703010	1873.1715639258000	2798.5236796983000	4052.868306646530	1.3188727646798900	1181.7174201920800	2308.098990852300	1812.2682458326700	15.498426158144000	1154.52207816345	15.157787218619500
/Users/ashkan/Downloads/pre_s_hc_wav/File33.wav	674.5099798166740	1725.154403887200	2862.0666656497300	4063.2106489410700	1.7207005298376600	1129.5668897081300	2331.235424573670	1917.9680071308600	14.637213168147400	1157.209072912250	15.12259142244650
/Users/ashkan/Downloads/pre_s_hc_wav/File26.wav	493.1283051760670	1542.522689234130	2614.883194771220	3877.534465690310	0.0191468463925721	1128.13538683080	2132.017163717930	1666.4790688571800	16.822176903265000	1079.4727049182600	16.211618802649800
/Users/ashkan/Downloads/pre_s_hc_wav/File24.wav	635.3792463065530	1564.4212014056000	2556.070115299270	3532.899212460200	0.0634089929781148	965.8399887178810	2072.1924438679000	1730.9028069302500	16.250956520232900	1019.9830455771700	17.15714793092220
/Users/ashkan/Downloads/pre_s_hc_wav/File18.wav	410.28153814053000	1467.16870399992	2375.7666118807100	3389.999976888320	-1.435849023143800	993.2394795825980	1910.8042077273700	1483.8546939330100	18.925344254887100	962.3957273276690	18.183788126941400
/Users/ashkan/Downloads/pre_s_hc_wav/File3.wav	483.1706074134730	1679.668866880380	2692.3591980354400	3584.846080366520	0.0884301424477058	1033.891824317680	2110.011188173950	1672.9460018721900	16.768281261404400	1049.4737085904200	16.67502468785510
/Users/ashkan/Downloads/pre_s_hc_wav/File7.wav	474.5711705356230	1427.1394825966500	2415.7884330690300	3442.902447072930	-1.1598698821176200	989.443758845768	1940.1003833185600	1540.592740371020	18.18284674237090	974.6487836471710	17.955185799867700
/Users/ashkan/Downloads/pre_s_hc_wav/File103.wav	460.2951707620650	1691.1694507781900	2712.060640261310	3900.567727845360	0.4288463090750060	1146.7575190277600	2191.0232474117300	1693.9972096835700	16.591458062656500	1104.716209983830	15.841172458450900
/Users/ashkan/Downloads/pre_s_hc_wav/File20.wav	517.1937933755090	1944.5748556037400	2645.766804244890	3267.647218331870	0.3242144225742490	916.8178083187880	2093.7956678890000	1717.181393853710	16.42438503844020	1010.7924502317700	17.31314870425410
/Users/ashkan/Downloads/pre_s_hc_wav/File102.wav	496.0167341248190	1646.596309837890	2606.9282844838900	3612.774426651490	-0.0651996188394198	1038.9192308422200	2090.5789387745200	1665.3800165701100	16.82961077255740	1041.901620776630	16.79621151462990
/Users/ashkan/Downloads/pre_s_hc_wav/File116.wav	423.2273195175460	1481.5730741231000	2405.48886383498	3321.669185232880	-1.3817192104016400	966.1472885717760	1907.9896106771200	1496.1120632115700	18.754804746524800	955.8827418498060	18.30768485905950
/Users/ashkan/Downloads/pre_s_hc_wav/File6.wav	555.2158126180650	1686.5450048193800	2729.336220046490	3684.673486666640	0.5393260908174550	1043.1525580161900	2163.9426310376500	1751.7775336178700	15.994112760296200	1072.7201508069300	16.31366762972000
/Users/ashkan/Downloads/pre_s_hc_wav/File22.wav	630.2908676718650	1779.4166408803500	2676.8790342107400	3547.7023351816500	0.7469773503561010	972.4704891699270	2158.57221948615	1806.544424079470	15.560715040415000	1052.0679120866200	16.633907183131700
/Users/ashkan/Downloads/pre_s_hc_wav/File36.wav	692.6516723758660	1711.302741773870	2902.8468619983600	4050.990902003690	1.817477764859760	1119.4464096759400	2339.4480445379500	1932.2209279166700	14.54074315002170	1159.4697743265500	15.093105820860600
/Users/ashkan/Downloads/pre_s_hc_wav/File129.wav	508.15514915399900	1428.290633151650	2524.3829749895500	3689.0767241885200	-0.555614487597985	1060.3071916781700	2037.476370370930	1612.3950723081800	17.38295024637100	1029.487595068480	16.998747807967400
/Users/ashkan/Downloads/pre_s_hc_wav/File101.wav	477.3913696441610	1482.9387420109500	2612.2850031153600	3692.9714841588200	-0.3781409588876640	1071.860038504890	2066.39664948232	1616.5850989604900	17.34086622743670	1043.7722142706100	16.76611023050570
/Users/ashkan/Downloads/pre_s_hc_wav/File78.wav	481.7053873410830	1550.4893765051000	2687.570789516250	3833.591405209150	0.0821616032969488	1117.295339289360	2138.339239642920	1665.535938881850	16.837648630558400	1081.0992214500500	16.18722838087670
/Users/ashkan/Downloads/pre_s_hc_wav/File92.wav	478.9445573549640	1545.5892822670300	2593.54313778912	3610.6986764253500	-0.3679392961833250	1043.9180396901300	2057.193913459120	1622.6169772599000	17.271360640752700	1032.3409244780700	16.951764271912000
/Users/ashkan/Downloads/pre_s_hc_wav/File45.wav	497.1709081673340	1581.7179212517500	2661.1158589701000	3485.984458466440	-0.242195840115379	996.2711834330360	2056.4972867139100	1643.4480986646500	17.05157307988430	1022.614170858050	17.1130036124144
/Users/ashkan/Downloads/pre_s_hc_wav/File53.wav	514.6068241093450	1518.6859972866400	2571.8357376926200	3551.051941125920	-0.408473685370584	1012.1483723388600	2039.0451250536300	1634.503840401130	17.136889188238500	1018.7430260074700	17.178031704996100
/Users/ashkan/Downloads/pre_s_hc_wav/File47.wav	478.648387725766	1535.8779192626900	2654.7472362627600	3738.9025803585600	-0.1290321704541570	1086.751397544260	2102.0440309024400	1643.5584592507800	17.058392109852000	1060.2937235556600	16.5048605034786
/Users/ashkan/Downloads/pre_s_hc_wav/File85.wav	512.997626766127	1651.5699904915200	2688.199195052490	3597.7095618521000	0.1402608835347960	1028.2373116953300	2112.6190935405600	1691.9010951429000	16.56253324025950	1049.8254882492300	16.669437154916400
/Users/ashkan/Downloads/pre_s_hc_wav/File94.wav	493.22995363421500	1541.5180865158000	2524.398292136220	3367.7586611349500	-0.7325304895809300	958.1762358335800	1981.7262483553000	1594.4989104527900	17.571726256518300	983.6687214716050	17.79054230149700
/Users/ashkan/Downloads/pre_s_hc_wav/File43.wav	535.5382805773710	1628.363461327810	2796.6909929284500	4031.048372946090	0.8666941075356430	1165.170030789570	2247.9123769449300	1770.726213827410	15.824294911762400	1133.844386662520	15.434216728374400
/Users/ashkan/Downloads/pre_s_hc_wav/File82.wav	480.64916188752400	1469.8156040726400	2552.3540578701	3305.5202437312500	-0.948036844795322	941.6236939479090	1952.0847668903800	1562.49251569104	17.936445309248000	971.2025707041600	18.018897939398800
/Users/ashkan/Downloads/pre_s_hc_wav/File97.wav	522.2018909597450	1449.8263072559900	2629.5388348281100	3643.050699577270	-0.3156563959694530	1040.282936205840	2061.1544331552800	1641.0613043509900	17.078079797469000	1036.2078543787900	16.88850352373690
/Users/ashkan/Downloads/pre_s_hc_wav/File40.wav	664.9737812357700	1790.388663123340	2912.386080178870	4056.1459129038300	1.9124606631145000	1130.3907105560200	2355.973609360450	1936.5494419264400	14.485655724041800	1166.4545609958800	15.002727568795400
/Users/ashkan/Downloads/pre_s_hc_wav/File58.wav	481.9302879795150	1508.292899252400	2580.534187086960	3682.512696333880	-0.3795566358038740	1066.8608027847900	2063.3175178631900	1621.1789065536400	17.286613354926700	1040.1683046549700	16.824200393036300
/Users/ashkan/Downloads/pre_s_hc_wav/File144.wav	452.7413801077410	1639.508897369380	2721.40967280253	3772.409935362730	0.1638164473803340	1106.556185085000	2146.5174714105900	1661.476462132080	16.91253291107780	1080.5996662801800	16.194711645841400
/Users/ashkan/Downloads/pre_s_hc_wav/File72.wav	501.4328314079100	1652.4411289464700	2680.428325298180	3789.682909334990	0.3054325887360820	1096.0833593090300	2155.996298746890	1703.2816139682300	16.454975786711500	1080.6828145257900	16.19346561708680
/Users/ashkan/Downloads/pre_s_hc_wav/File99.wav	522.4647399331060	1522.8367422749400	2707.9421648141500	3528.2533879706800	-0.1428807094638300	1001.9295493458600	2070.3742587482200	1660.4559975045700	16.875268080809600	1031.629988252940	16.96344638995830
/Users/ashkan/Downloads/pre_s_hc_wav/File67.wav	474.20124360653800	1668.2948569621100	2613.329133637530	3900.318763436120	0.2436745822431860	1142.039173276530	2164.0359994105700	1685.1261883568200	16.65791328141440	1091.6181625412700	16.031246839631100
/Users/ashkan/Downloads/pre_s_hc_wav/File73.wav	430.8593154873190	1572.786421549820	2703.3008554345000	3781.371033191770	-0.0790546263696067	1116.8372392348200	2122.0794064158500	1622.3226374985500	17.345030910772200	1074.6504783250400	16.28436440774280
/Users/ashkan/Downloads/pre_s_hc_wav/File63.wav	378.36953927256400	1474.895689062730	2353.1948267046400	3432.065225239500	-1.525994708085420	1017.898561988980	1909.6313201448600	1457.0441869750700	19.340388063157200	966.5116027990580	18.10635273215480
/Users/ashkan/Downloads/pre_s_hc_wav/File88.wav	470.21379855671200	1690.8421483900600	2709.9813207756000	3815.973674148970	0.3628244666243740	1115.2532918640900	2171.752735467840	1693.333598146320	16.582084153099300	1090.5824420630400	16.046471431261500
/Users/ashkan/Downloads/pre_s_hc_wav/File142.wav	429.12933092987600	1560.982530840070	2519.717024444540	3396.779697340820	-0.8898768825882850	989.8834554703140	1977.152145888830	1547.623290680420	18.14767245267550	988.145712549012	17.70993870413820
/Users/ashkan/Downloads/pre_s_hc_wav/File48.wav	415.8430606562090	1604.9811475087400	2659.7399318452400	3726.2266207040500	-0.2076473910066810	1103.4611866826100	2101.6976901785600	1603.7141383413100	17.57086028141930	1062.2160120794500	16.47499171636570
/Users/ashkan/Downloads/pre_s_hc_wav/File8.wav	550.426452557626	1701.9966308760800	2591.992388459660	3811.514029795200	0.4424191529225570	1087.0291924125300	2163.9823754221400	1744.2041258103800	16.067116138834800	1078.4994403821600	16.226248567916800
/Users/ashkan/Downloads/pre_s_hc_wav/File118.wav	487.35696858297900	1649.0413784377500	2610.702329815560	3844.7960717695700	0.1807663754765500	1119.1463677288600	2147.974187151470	1685.300501486030	16.6402228322795	1080.9896489371700	16.18886916928950
/Users/ashkan/Downloads/pre_s_hc_wav/File124.wav	490.1924104845180	1571.4779977005200	2582.8324789561600	3631.687901324550	-0.2693974050676430	1047.165163613350	2069.0478971164400	1639.5320526226700	17.08958940171040	1036.6810501816700	16.88079472170330
/Users/ashkan/Downloads/pre_s_hc_wav/File12.wav	379.4056610303680	1471.5653835059300	2486.898609192220	3595.2186142823200	-1.093146538675400	1071.937651083990	1983.2723670027100	1494.7437308122200	18.882308576752200	1009.4078847020400	17.338896476854600
/Users/ashkan/Downloads/pre_s_hc_wav/File131.wav	495.2409563130840	1654.473079590540	2671.033069667780	3859.77175063384	0.3501736423401950	1121.510264740250	2170.129714031310	1704.8229639807400	16.445622527524600	1091.2435189623900	16.036750455406300
/Users/ashkan/Downloads/pre_s_hc_wav/File11.wav	632.7279153713720	1773.4209630289200	2876.6932555080500	4093.2372064426900	1.7382593389854300	1153.5030970237700	2344.019835087760	1906.5461635923900	14.70076242600450	1166.4075601669600	15.003332109288400
/Users/ashkan/Downloads/pre_s_hc_wav/File38.wav	588.9171229730740	1731.0763754751300	2731.518519749180	3968.185284593040	1.0795561141114300	1126.42272053999	2254.924325697610	1823.2307030070100	15.368438247136700	1124.2151390546600	15.566415530318800
/Users/ashkan/Downloads/pre_s_hc_wav/File126.wav	503.4991502507140	1579.6029747973800	2599.183568208360	3513.3491115148	-0.3093676772664620	1003.283320421360	2048.908701192820	1641.633613773550	17.06554934645050	1019.8016594354400	17.160199572226700
/Users/ashkan/Downloads/pre_s_hc_wav/File122.wav	447.99606030744400	1531.2767772764100	2381.7699531072800	3423.932772383240	-1.1167417080187900	991.9789040252650	1946.243890768590	1537.935893796640	18.232864372694700	974.2429896275170	17.96266453679160
/Users/ashkan/Downloads/pre_s_hc_wav/File28.wav	654.683836593484	1725.6883010015600	2854.1417564035800	4121.0776892942700	1.7031549112169100	1155.4646175669300	2338.897895823220	1909.2820022330800	14.691942442170000	1165.4762225399000	15.015321343804500
/Users/ashkan/Downloads/pre_s_hc_wav/File14.wav	442.69479660239000	1381.9293016541000	2399.2885876353500	3626.353232456440	-1.1904101407468200	1061.219478618020	1962.5664795870700	1518.92282752868	18.471327889404300	999.2713873080120	17.512760019221700
/Users/ashkan/Downloads/pre_s_hc_wav/File16.wav	499.15725465803300	1436.7859997473000	2465.8959957406100	3696.0510916908400	-0.6708143762240270	1065.631279010940	2024.4724854592000	1598.9523862162000	17.52831581362770	1024.0797827247400	17.088512335863400
/Users/ashkan/Downloads/pre_s_hc_wav/File134.wav	479.4262628256280	1587.332815359830	2496.343232367990	3591.4437504359100	-0.4813596979495420	1037.339162536760	2038.6365152473400	1616.1839724664200	17.342053519404100	1020.5535029475300	17.147557823835500
/Users/ashkan/Downloads/pre_s_hc_wav/File120.wav	478.5736617239030	1536.5686350514000	2643.8280406540100	3659.476407034110	-0.2387033501538140	1060.3009151034000	2079.6116861158500	1633.1957021691400	17.163089522713900	1045.8036814139700	16.73354216571430

3. Processed audio files for PwPD after the dance session

processed_results_All_subjects_post_PD

voiceID	duration	meanF0Hz	stdevF0Hz	HNR	localJitter	localabsoluteJitter	rapJitter	ppq5Jitter	ddpJitter	localShimmer	localdbShimmer	apq3Shimmer	apq5Shimmer	apq11Shimmer	ddaShimmer	f1_mean	f2_mean	f3_mean	f4_mean	f1_median	f2_median	f3_median	f4_median	pF	fdisp	avgFormant	mff	fitch_vtl	delta_f	vtl_delta_f
/Users/ashkan/Downloads/post_pd/File80-2.wav	22.1422708333333300	142.99416356869400	17.337588707977100	8.950191184042480	0.0242025655806478	0.0001692639499859	0.0122185953163013	0.0135188172321181	0.0366557859489041	0.1685760372728400	1.5122507695675000	0.0783668810629237	0.1115127560301150	0.1884238329307250	0.2351006431887710	445.6096922667000	1400.3545031296000	2402.3604686178700	3468.4119815549600	429.6334433993440	1381.6960307392100	2391.2819205391200	3444.6680465855400	-0.8856387397837400	1005.0115343954000	1911.8198603158000	1487.0384110971300	18.8603295976991000	967.709701533603	18.08393568057280
/Users/ashkan/Downloads/post_pd/File145-2.wav	13.0944791666666700	133.46602936784400	24.534835327787000	5.344727598587570	0.044108756867602	0.0003280163906649	0.0234893493917866	0.0248965584200644	0.0704680481753599	0.2207215040772260	1.8610383066356700	0.1074400076838480	0.1584262301054850	0.3170839767673230	0.3223200230515430	404.3361490498570	1518.28435748722	2419.7319191717000	3446.374376384970	390.6497852311500	1526.8730243602600	2397.0816300676400	3393.3013535246200	-0.7546354621412450	1000.8838560978200	1926.9764482959200	1484.1368266180300	18.9730516407749000	969.280630555297	18.0546267492979
/Users/ashkan/Downloads/post_pd/File100-2.wav	17.6915625	123.18580730079100	10.71233912587280	10.28327783314330	0.0174093745655903	0.0001414223904005	0.0091105017961908	0.0102315557644498	0.0273315053945725	0.1600579752796750	1.4377306736830800	0.0708987024784393	0.1051229898656050	0.1705672007550600	0.212696107435318	427.4625885332460	1472.3447530010200	2436.4906138948200	3425.8792603809000	433.3843667641550	1466.0866369146300	2405.7366782600200	3344.7358608232300	-0.7494517361158300	970.45049801969	1912.485885695510	1503.6982633094200	18.6481984173450000	958.8923498731120	18.25022381533830
/Users/ashkan/Downloads/post_pd/File64-2.wav	6.589104166666670	168.56730526607200	44.68530464706100	6.423106138665240	0.033305762163176	0.0001963077766724	0.0173323834480141	0.0187700797674945	0.0519971503440423	0.1799696100368380	1.5721711777303900	0.0867909893711327	0.1200888328917200	0.2250386888148750	0.2603729681133980	518.3061506257020	1602.2059693559400	2617.3938793023400	3614.218543154660	498.7941181502340	1657.1304807361800	2676.6684238087300	3641.483565508330	0.8294901336657510	1047.5631491193700	2118.519147050870	1684.7588244054200	16.6369892012263000	1055.8074437609700	16.574992062626500
/Users/ashkan/Downloads/post_pd/File21-2.wav	8.5176458333333330	134.13424695029300	31.84241558241810	6.8470744817368000	0.0165665612514306	0.0001236653761462	0.0071763338234927	0.0068403575394342	0.0215290014704781	0.1464268260196010	1.3359790653052700	0.065098512779042	0.0908225169839217	0.1334894983964080	0.1952955383371260	597.6199902277200	1547.190861438390	2783.3067438967300	3770.962234262690	579.3151166844090	1659.331730966570	2856.6653532453600	4051.8550759469200	1.9943683507247600	1157.5133197541700	2286.791819211570	1826.3766140374500	15.3388140270841000	1147.7053001773400	15.2478169627756000
/Users/ashkan/Downloads/post_pd/File119-2.wav	19.7067083333333300	114.14784657017300	46.9308271600862	2.760832359232480	0.0469565679272216	0.0004141227117403	0.0275808271977584	0.0286714341515331	0.0827424815932754	0.2329776500352620	1.9116455615153200	0.1226362790324220	0.1618232933250580	0.2337096016505520	0.3679088370972650	454.4594141640080	1490.486742657530	2430.358934762640	3569.1894297263200	452.7520275239590	1503.572423109540	2415.222615828320	3552.319889079180	-0.2956243625141980	1033.1892871850700	1980.9667388852500	1554.5815081357000	18.0352997458023000	997.7576571321060	17.539291897162000

4. Processed audio files for healthy controls after the dance session

processed_results_All_subjects_post_HC

voiceID	duration	meanF0Hz	stdevF0Hz	HNR	localJitter	localabsoluteJitter	rapJitter	ppq5Jitter
/Users/ashkan/Downloads/post_hc/File38-2.wav	27.506958333333300	205.82922527469400	43.75790840038250	9.82786786222866	0.0131369931178563	6.38181196875686E-05	0.0070365566100726	0.0072616560595739
/Users/ashkan/Downloads/post_hc/File99-2.wav	11.980166666666700	161.7739862113190	63.48740690433920	4.596838146179810	0.0418149140508165	0.0002611934103449	0.0224331383372594	0.0236213261146509
/Users/ashkan/Downloads/post_hc/File124-2.wav	19.269458333333300	180.16567790680400	30.79806087498500	7.839507252609230	0.0281650321681337	0.0001566199133367	0.014325029415866	0.0151862607441681
/Users/ashkan/Downloads/post_hc/File126-2.wav	14.524395833333300	113.98207969400400	37.01585011738520	5.808653294111530	0.0329060019171478	0.0002905817066656	0.0162057554128315	0.0180963641050084
/Users/ashkan/Downloads/post_hc/File102-2.wav	24.909979166666700	207.3387211652910	31.588732297346300	8.988895472990190	0.0293224184487555	0.0001408968094111	0.0157766079545221	0.0160938473088323
/Users/ashkan/Downloads/post_hc/File82-2.wav	10.101708333333300	116.8017703358970	26.38940210989050	5.645220713398120	0.0302370485275773	0.0002606952283233	0.0162685933457528	0.0176059696617658
/Users/ashkan/Downloads/post_hc/File27-2.wav	9.861354166666670	135.1722509595580	51.18742848719280	4.312698859616960	0.0290442620540682	0.0002139621905808	0.0149906271705612	0.017633405134613
/Users/ashkan/Downloads/post_hc/File18-2.wav	7.413	126.16987907074800	24.846794363803500	2.413423407443630	0.0387985441746343	0.0003058870439159	0.0204603526492144	0.0209118435797694
/Users/ashkan/Downloads/post_hc/File120-2.wav	20.810604166666700	178.42150789631800	39.48767517431280	6.578467511325600	0.0361314853114649	0.000201987968455	0.0196415668400805	0.0208976569153606
/Users/ashkan/Downloads/post_hc/File8-2.wav	24.9710625	203.52175704006500	46.13988330915950	8.020140990452920	0.0270431578603772	0.0001318551570218	0.0141710972872826	0.0140752078450515
/Users/ashkan/Downloads/post_hc/File22-2.wav	7.565600907029480	210.4345167092100	23.51756746637120	7.785985127705020	0.0127874186296891	6.0637203353017E-05	0.0065562943377396	0.006754669122383
/Users/ashkan/Downloads/post_hc/File67-2.wav	15.209854166666700	178.1808816246030	54.025542911497	5.420476532424860	0.0346467172424428	0.0001947191534334	0.0190069882843994	0.0185615964676043
/Users/ashkan/Downloads/post_hc/File103-2.wav	20.082104166666700	147.06568349667100	59.88053280163060	5.698362604119900	0.0366938962434704	0.0002489710853789	0.0197287353038708	0.0197908579868631
/Users/ashkan/Downloads/post_hc/File43-2.wav	11.445791666666700	177.52525811159600	29.027826732493100	7.658947954909580	0.0179617032566947	0.000101166903006	0.0091334357929898	0.0095870420097293
/Users/ashkan/Downloads/post_hc/File101-2.wav	23.371791666666700	181.84878175341000	33.19973844647720	7.076536268640010	0.0325879602388273	0.0001793615990666	0.0171621959962697	0.020358472361509
/Users/ashkan/Downloads/post_hc/File144-2.wav	20.162270833333300	203.33999166070900	51.94716191287980	5.572311585774870	0.0424967904947252	0.0002085344361807	0.023495525165764	0.0252218100100114
/Users/ashkan/Downloads/post_hc/File58-2.wav	21.697854166666700	170.54501049548300	37.82724705615440	8.720782172934260	0.027325243627153	0.0001597498645503	0.014033980402733	0.0143484705375344
/Users/ashkan/Downloads/post_hc/File20-2.wav	11.715215419501100	115.76503904465400	6.484906517657170	4.759626862211750	0.0159569916639689	0.0001379415176078	0.008363803456065	0.0091770001629936
/Users/ashkan/Downloads/post_hc/File118-2.wav	20.349208333333300	156.9803921600620	50.45291745652330	6.65440887220482	0.0382464164511478	0.0002468365256662	0.0206250130162372	0.0226671317728483
/Users/ashkan/Downloads/post_hc/File24-2.wav	16.710566893424000	173.02887216274500	25.971817889555700	7.491770750533360	0.0104970836474264	6.08029699459625E-05	0.0052561218117687	0.005791918928498
/Users/ashkan/Downloads/post_hc/File45-2.wav	17.22683333333330	178.34958227561700	36.03240533939270	19.08608850541020	0.0156377045196684	8.76269109763882E-05	0.0078282436802803	0.0073352439041832
/Users/ashkan/Downloads/post_hc/File105-2.wav	28.374604166666700	187.22259486014	39.31929283548970	7.067411127922230	0.0329423695046214	0.0001754124996309	0.0173976313136505	0.0197353688510568
/Users/ashkan/Downloads/post_hc/File78-2.wav	20.558354166666700	135.1139121331630	39.65416528704660	6.196937341690760	0.0431938703256084	0.0003163526989917	0.0225355983767111	0.0204830658626179
/Users/ashkan/Downloads/post_hc/File85-2.wav	20.881208333333300	176.44508753968100	32.19808060696470	9.658577821878250	0.024720319958087	0.00014029434804	0.0128963017611522	0.0140711914857353
/Users/ashkan/Downloads/post_hc/File9-2.wav	12.822333333333300	111.54219281215700	25.531046461440900	6.056257537242680	0.0313918832734259	0.0002805493799674	0.0158896415526575	0.0157231209968021
/Users/ashkan/Downloads/post_hc/File107-2.wav	14.315	138.99862235333100	25.364770244711600	7.228430296553920	0.0354207432742611	0.0002556867140327	0.019579409702992	0.0209549157512494
/Users/ashkan/Downloads/post_hc/File142-2.wav	19.174083333333300	129.2272817280970	24.63895271568300	6.159430389727920	0.027384195028979	0.0002125545591919	0.0143956825709795	0.0156905356566931
/Users/ashkan/Downloads/post_hc/File47-2.wav	22.1046875	165.09031842668000	34.2623474834148	9.08674182125812	0.02854370291873	0.0001726632446161	0.014368731857384	0.0160874436638706
/Users/ashkan/Downloads/post_hc/File26-2.wav	8.950020833333330	123.39196082346300	42.84846048617520	3.435892734762570	0.0331719893313725	0.0002641817916974	0.017101329290479	0.016225369264111
/Users/ashkan/Downloads/post_hc/File63-2.wav	20.019520833333300	127.38737141872700	20.81382629080070	8.018530101818740	0.0279711678200538	0.0002207848680214	0.0147846934047803	0.0169183250819788
/Users/ashkan/Downloads/post_hc/File92-2.wav	12.402291666666700	155.06516833291100	54.48987553778470	4.723964426802460	0.0453319065395472	0.0002936255907107	0.0244461341333312	0.0248275396418237
/Users/ashkan/Downloads/post_hc/File112-2.wav	19.305520833333300	144.58494574076100	49.16104761786400	7.000732974427650	0.0299794698249617	0.0002072491110051	0.0159020778376419	0.0172178094433643
/Users/ashkan/Downloads/post_hc/File33-2.wav	12.499916666666700	192.18182835796300	45.841088102657100	8.597068048690470	0.0183280698663226	9.50390839302743E-05	0.0092870651527236	0.0091041384091856
/Users/ashkan/Downloads/post_hc/File7-2.wav	11.5649375	104.7965623821400	47.561428178726700	3.251739192420170	0.033066045008826	0.0003169940361974	0.0174262860727694	0.0169944239858316
/Users/ashkan/Downloads/post_hc/File134-2.wav	15.271166666666700	150.112116293804	26.71838256865590	7.138133876954770	0.0302710546611678	0.0002010069112254	0.0158534839562776	0.0158386088199112
/Users/ashkan/Downloads/post_hc/File28-2.wav	15.959479166666700	150.5601509976330	45.15050104223990	5.44006106616444	0.0224120226610815	0.0001492924374694	0.0114901621336584	0.0121672926482673
/Users/ashkan/Downloads/post_hc/File94-2.wav	27.4986875	143.23568449554100	10.90201454847890	7.439110419412660	0.0238396668631769	0.0001665799074315	0.0132825343223941	0.0131685231768145
/Users/ashkan/Downloads/post_hc/File129-2.wav	19.622270833333300	100.4950620439330	33.95916440494020	4.675589264842070	0.0339658488700406	0.000340959606016	0.0160190489247072	0.0163087062579503
/Users/ashkan/Downloads/post_hc/File3-2.wav	29.0160625	168.31413491121700	28.784549307967400	7.251550308224920	0.0250090945456365	0.0001482938966237	0.0133665285586064	0.0150386990372091
/Users/ashkan/Downloads/post_hc/File72-2.wav	16.085270833333300	172.9040176734280	21.01447674787350	10.1703662580991	0.02580023994204	0.0001492315892303	0.0123657769250964	0.0135078492082012
/Users/ashkan/Downloads/post_hc/File116-2.wav	22.308479166666700	131.58989512092000	24.13417686466080	7.61625175412942	0.0280543821136523	0.0002136901427074	0.015150988846938	0.0171538842748328
/Users/ashkan/Downloads/post_hc/File48-2.wav	27.752833333333300	169.8774505519580	64.24400657936740	6.668047649825230	0.0307139244093131	0.0001798143129768	0.0150910354743825	0.0141388706978177
/Users/ashkan/Downloads/post_hc/File88-2.wav	17.066666666666700	125.55851922595200	39.69528738389160	3.854011520070250	0.0382581007674334	0.0003021906490785	0.0209263410104259	0.0223219070512496
/Users/ashkan/Downloads/post_hc/File14-2.wav	12.342416666666700	150.8505982536390	44.55441635111600	3.447977166142530	0.0308418557439613	0.0002044549870852	0.016864952084586	0.017204140334079
/Users/ashkan/Downloads/post_hc/File16-2.wav	6.957041666666670	169.29101265374100	34.72477878404470	6.475211942306830	0.0205280547931008	0.0001207246534184	0.0106267712533742	0.0111471383439612
/Users/ashkan/Downloads/post_hc/File53-2.wav	23.838208333333300	183.91007205473	44.89958057298480	7.729799478976040	0.0319480621748788	0.0001740953915503	0.0171331869672858	0.0174805246226899
/Users/ashkan/Downloads/post_hc/File6-2.wav	30.5443125	198.99080698692500	39.098713821948200	6.498027551889640	0.0311092567278844	0.0001560646930411	0.0175613042197371	0.0183556637751261
/Users/ashkan/Downloads/post_hc/File36-2.wav	15.543041666666700	183.88514789738100	54.34350359464490	5.109441541259820	0.0358174486332412	0.0001952733033968	0.0184126541297861	0.0207595713290908
/Users/ashkan/Downloads/post_hc/File73-2.wav	25.690833333333300	180.11136335264800	59.712930695313800	7.420656457185210	0.0428270158484131	0.0002383806188862	0.0230892425284561	0.0248221727436891
/Users/ashkan/Downloads/post_hc/File97-2.wav	19.27025	165.94496358631000	27.555872491861800	11.210755496778800	0.0247928460102558	0.0001491751062197	0.0128557209336564	0.0131827986488151
/Users/ashkan/Downloads/post_hc/File12-2.wav	18.9921875	121.43186916904900	18.941191154684900	7.314626077819640	0.0402314099852475	0.0003330213744409	0.0205545823867947	0.0220029976947981
/Users/ashkan/Downloads/post_hc/File131-2.wav	17.472416666666700	153.71084548009300	42.7113666521492	7.66805113425034	0.0332038369612151	0.0002148963771006	0.0161369991000302	0.017052922483784

voiceID	ddpJitter	localShimmer	localdbShimmer	apq3Shimmer	apq5Shimmer	apq11Shimmer	ddaShimmer	f1_mean	f2_mean	f3_mean	f4_mean	f1_median
/Users/ashkan/Downloads/post_hc/File38-2.wav	0.021109669832218	0.1286516941762440	1.283882753110140	0.0614355512891642	0.0773471656906572	0.1192490851012630	0.1843066538674930	631.0219125559900	1702.3961450263300	2731.4040725367200	3919.8018742209600	604.5857551518670
/Users/ashkan/Downloads/post_hc/File99-2.wav	0.0672994150117784	0.1989737670756510	1.6850563501063000	0.0998490411952848	0.1365379309738360	0.1810745104611070	0.2995471235858550	497.8230666623300	1573.412002492770	2547.4686181937600	3601.877862949160	505.1562976618080
/Users/ashkan/Downloads/post_hc/File124-2.wav	0.042975088247598	0.1755890465119070	1.5438629634839500	0.0833876710339771	0.1166548799882170	0.1775915194092240	0.2501630131019320	493.0335600378900	1540.943066618640	2532.5825058873700	3574.2172673537900	463.1361121033970
/Users/ashkan/Downloads/post_hc/File126-2.wav	0.0486172662384947	0.173717895144319	1.5146163228032800	0.0834271402542978	0.1186422233410020	0.20403891543289	0.252814207628930	497.3182211513500	1517.1778791218600	2598.3864893587200	3417.0534065455900	488.3024303071580
/Users/ashkan/Downloads/post_hc/File102-2.wav	0.0473298238635665	0.1657546394359940	1.49435955619080	0.08689085918325	0.1125157195480730	0.1608932622940290	0.2606725775497500	506.8621343623380	1529.4815565367500	2488.0781171641600	3712.905284854830	492.3988961961460
/Users/ashkan/Downloads/post_hc/File82-2.wav	0.0488057800372586	0.2048148590217960	1.7381572148006800	0.1127003183121910	0.1393833181592810	0.1574950184473900	0.3381009549365740	482.1983677997290	1448.1706545488600	2495.6926576905800	3390.601787787080	477.6661255296620
/Users/ashkan/Downloads/post_hc/File27-2.wav	0.0449718815116838	0.1731583896260440	1.5753085886514700	0.0878750407624116	0.1263327909133430	0.1877567893301120	0.263625122287235	637.18524864532	1683.7100640681500	2779.5417124999900	4061.4407393004800	627.814607127044
/Users/ashkan/Downloads/post_hc/File18-2.wav	0.0613810579476434	0.216938632324132	1.8398291284431700	0.1087664542587230	0.1499615082102050	0.1549288943670690	0.3262993627761680	457.1129638225650	1440.9621161716300	2469.1290132094500	3493.5442365023	432.9543778262010
/Users/ashkan/Downloads/post_hc/File120-2.wav	0.0589247005202417	0.1996299831408080	1.7030526983308700	0.0971320806241969	0.1386659392341180	0.2310998581312990	0.2913962418725910	474.0851346371570	1636.8119969576800	2613.21558123871	3775.481493957510	471.879681714751
/Users/ashkan/Downloads/post_hc/File8-2.wav	0.0425132918618479	0.1748917442033690	1.565848406260450	0.0857305867650951	0.1187102110310360	0.2068143028425960	0.2571917602952850	573.5107305565590	1560.2327228628900	2453.198522992830	3648.140951541360	553.0763016710480
/Users/ashkan/Downloads/post_hc/File22-2.wav	0.0196688830132168	0.1509097272093030	1.3920711492718100	0.0809744273326582	0.0934819313089717	0.1304053107876200	0.2429232819979690	672.6001942442310	1799.868547721200	2728.3147742638400	3561.658639028720	616.6831768267510
/Users/ashkan/Downloads/post_hc/File67-2.wav	0.0570209648531964	0.178334807362698	1.47603913572982	0.0820625883813583	0.0982714192466742	0.1370458973199730	0.2461877651440690	466.8534833689620	1682.9764261867900	2698.799385136940	3853.269121607560	453.682657279144
/Users/ashkan/Downloads/post_hc/File103-2.wav	0.0591862059116126	0.1931461912556900	1.6531886671621800	0.0904809113384629	0.1302768089635520	0.2654250935121220	0.2714427340153890	507.245134968291	1674.979505443250	2675.104037183740	3934.56627508812	498.132419916089
/Users/ashkan/Downloads/post_hc/File43-2.wav	0.0274003073789694	0.1586664014861660	1.4127430823206900	0.0667603004254476	0.1030546624538730	0.1629898697518820	0.2002809012763430	570.0435414875070	1601.1086297972600	2622.985289636310	3923.0061118362400	545.186989276606
/Users/ashkan/Downloads/post_hc/File101-2.wav	0.0514865879688091	0.1842860873517770	1.6186978283761900	0.0792451944113802	0.1245199024759500	0.2555074243928810	0.2377355832341410	473.9766877660870	1574.810726079090	2604.705619267250	3661.099595692690	452.3809545823490
/Users/ashkan/Downloads/post_hc/File144-2.wav	0.0704865754972920	0.1991267661635910	1.6891209658574900	0.1084521487898490	0.1496979857283560	0.2274780962762410	0.3253564463695470	496.2892967554450	1526.9417416040200	2629.157373889720	3634.8956866111800	480.8139907765570
/Users/ashkan/Downloads/post_hc/File58-2.wav	0.0421019412081992	0.1593625017506260	1.4563739594610800	0.0725624426457528	0.1047428981328010	0.1718451512306579	0.2176873279402580	493.4720586037320	1581.763715071110	2572.5741495505000	3740.45886414711	471.6676552004120
/Users/ashkan/Downloads/post_hc/File20-2.wav	0.0250914103681952	0.1656910786128510	1.4635720180712900	0.0809970622065433	0.1075061922398280	0.1907988887907730	0.2429911866196300	598.6757711303890	1770.236673801750	2560.36420847276	3504.388686003190	572.3220889541970
/Users/ashkan/Downloads/post_hc/File118-2.wav	0.0618750390487118	0.2087895896097960	1.7903828231209700	0.0949590432826575	0.1397715538257410	0.1770837168519730	0.2848771298479730	510.1512207557340	1612.7839592418500	2721.5652364266700	3885.824331667880	490.2799903881420
/Users/ashkan/Downloads/post_hc/File24-2.wav	0.0157683654353063	0.1541413142274420	1.3781791151561500	0.0729384090063924	0.0934337937514674	0.1425867995566150	0.2188152270191770	696.8965943826100	1718.650311023430	2640.8606588392400	3544.1332926470000	654.2303946492780
/Users/ashkan/Downloads/post_hc/File45-2.wav	0.023484731040841	0.1232614768101390	1.310344823134510	0.0594982054674083	0.0726695256332849	0.1166114199952770	0.1784946164022250	514.4220798681630	1565.2000620359000	2721.5289443248200	3661.2629735858400	472.2678163140360
/Users/ashkan/Downloads/post_hc/File105-2.wav	0.0521928939409517	0.2065993338552930	1.7316461894269600	0.0982580588679562	0.1430424649892360	0.2181263475883080	0.2947741766038690	497.8221078604600	1566.7005797523900	2587.6436664625700	3652.51400991351	480.2236389128170
/Users/ashkan/Downloads/post_hc/File78-2.wav	0.0676067951301334	0.2119687681087430	1.7123757160331300	0.0908118437851049	0.1350294978990880	0.2191606754971130	0.2814355313553150	507.2821273268750	1563.8117350193200	2632.032382532530	3737.843562413480	487.0684322009670
/Users/ashkan/Downloads/post_hc/File85-2.wav	0.0386889052834568	0.1684265437241890	1.504075964701470	0.0752206220284345	0.1113590297470620	0.1848176774880150	0.2256618660853040	506.711076004052	1595.290509746490	2648.875854644960	3611.0993284973500	490.0786127423490
/Users/ashkan/Downloads/post_hc/File9-2.wav	0.0476689246579727	0.1907149031405300	1.6446367953253000	0.0962940021978649	0.1291908803292580	0.2143983830868150	0.288882006505950	502.8401455850040	1535.6086188297400	2533.2322238033600	3360.163565596390	483.6929440831180
/Users/ashkan/Downloads/post_hc/File107-2.wav	0.056738229108976	0.1879386455235180	1.661822495879290	0.0900349363494385	0.1245118002153700	0.1695902390379690	0.2701048090483160	427.385649675252	1516.6741034177000	2435.6398470689000	3516.919565029810	419.3579101997300
/Users/ashkan/Downloads/post_hc/File142-2.wav	0.0431870477129087	0.1981732737243500	1.7067030915869400	0.0935642424190599	0.1378388954092780	0.2556854900256770	0.2806927272571800	429.5440634413240	1554.7996018352900	2422.2763624140900	3428.2878327755800	415.6467320570620
/Users/ashkan/Downloads/post_hc/File47-2.wav	0.043106195572152	0.1610092930547350	1.4540291419814800	0.0753261780856058	0.1055109829829780	0.1531183789188240	0.2259785342568180	486.3113367438000	1577.858384861010	2594.729947947340	3750.825635039110	448.7293329137600
/Users/ashkan/Downloads/post_hc/File26-2.wav	0.0513039878714371	0.2105930627042970	1.685368235937520	0.1125280947389200	0.1410718942684770	0.2037340084443240	0.3375842842167610	466.2854814775750	1459.1673923089000	2528.4532898325200	3753.1600070992700	447.7763108643080
/Users/ashkan/Downloads/post_hc/File63-2.wav	0.0443540802143409	0.1825230968380630	1.6348425115138900	0.0841576622654573	0.1258984469408000	0.2213417109209900	0.2524729867963720	483.4877136337560	1567.9657632539100	2538.857961231850	3496.6074829569600	403.745677843107
/Users/ashkan/Downloads/post_hc/File92-2.wav	0.0733384023999636	0.2108385212643790	1.73564699905322	0.1072669556822930	0.1490974975461000	0.2299554577735320	0.3218008670468790	489.0531751541730	1640.5139436710100	2619.645769028780	3594.943134975640	472.0177805041800
/Users/ashkan/Downloads/post_hc/File112-2.wav	0.0477062329129258	0.2034291139181190	1.7129002232298100	0.0943854922032922	0.1342569879313300	0.2171447276869250	0.2831564766098770	519.0507828573670	1555.8457863913400	2665.975839249900	3793.952617290760	499.5179667589470
/Users/ashkan/Downloads/post_hc/File33-2.wav	0.0278611954581708	0.1424347658546660	1.3752629686486400	0.0653685062810679	0.0839369983554377	0.1378557993782310	0.1961055188432040	620.9177672209300	1568.9910525880400	2686.214520253010	3941.871177651960	601.8808258508880
/Users/ashkan/Downloads/post_hc/File7-2.wav	0.0522788582183084	0.2029900332398570	1.7443653434108200	0.0944174349268721	0.1202076471525440	0.1995381302385830	0.2832523047806160	475.2538580280210	1437.7545163120500	2471.42920923453	3531.06719386974	461.4792839600400
/Users/ashkan/Downloads/post_hc/File134-2.wav	0.0475604518688328	0.1735316331577590	1.5122589251747500	0.0872295531639577	0.1174283579289360	0.191306131796782	0.2616886594918730	459.1747387328620	1533.7258196492900	2480.6100298959500	3624.13596705606	431.7309914443410
/Users/ashkan/Downloads/post_hc/File28-2.wav	0.0344704864009752	0.1433689682879120	1.3004342952873000	0.0685328568082577	0.0843649108246406	0.119208591284874	0.205598570424773	681.0754361046780	1719.1443199752600	2759.1766157197300	4079.792918364910	700.2364213932490
/Users/ashkan/Downloads/post_hc/File94-2.wav	0.0398476029671824	0.1741456264232270	1.5664787489731800	0.0881085824885067	0.1178380677744080	0.1574669749694400	0.2643257474655200	501.6222054749360	1559.9302115535600	2511.6001015969200	3412.112424131630	486.8657127834530
/Users/ashkan/Downloads/post_hc/File129-2.wav	0.0480571467741216	0.183457800669733	1.5755845946801300	0.0921573418337627	0.1213447152938140	0.1226532723919910	0.2764720255012880	478.7449603915510	1579.533030550350	2680.9062169644200	3542.837609437610	472.2863367272850
/Users/ashkan/Downloads/post_hc/File3-2.wav	0.0400965856758192	0.1774215093216260	1.5707088862080600	0.0772134221992308	0.1112632081949720	0.1815321316159430	0.2316402665976930	516.2945074541260	1662.9636975013600	2613.6233243981900	3598.5190947671800	496.0782682372780
/Users/ashkan/Downloads/post_hc/File72-2.wav	0.0370973307752893	0.1461278883996740	1.3895283966645900	0.0619647606409851	0.0883107777738526	0.1466543405720830	0.1858942819229560	473.5529533701300	1614.615821396960	2496.86349587157	3704.8216564976700	436.7724727745240
/Users/ashkan/Downloads/post_hc/File116-2.wav	0.045452966540814	0.1946348554400470	1.6666319110176500	0.0896171044309541	0.1352558190558610	0.2250777196225400	0.2688513132928620	445.6004617022860	1507.633861306990	2503.2732831775300	3547.700077165740	429.0631195889120
/Users/ashkan/Downloads/post_hc/File48-2.wav	0.0452731064231475	0.1514316208579960	1.361099615420140	0.0786878600483177	0.0959417574106029	0.132736756665235	0.2360635801449530	519.0059232733380	1605.385869202960	2651.121269000650	3692.973482967970	480.9149984488770
/Users/ashkan/Downloads/post_hc/File88-2.wav	0.0627790230312777	0.2159999649976160	1.7898018517684000	0.1108242696509860	0.1515817271248470	0.2442889529256630	0.3324728089529570	494.5959022434080	1691.8080608492900	2646.931732627470	3796.4140818245300	463.0920380742030
/Users/ashkan/Downloads/post_hc/File14-2.wav	0.0505948562537581	0.2224281916830530	1.8020137628927400	0.1239625125597300	0.1592382204584730	0.3015876057239670	0.3718875376791890	504.1441052757800	1439.6099545753000	2452.597673686850	3515.633339458900	471.9949117707710
/Users/ashkan/Downloads/post_hc/File16-2.wav	0.0318803137601226	0.1611742473864850	1.4748403239720600	0.0791718635659778	0.1050668777491640	0.1646702513484500	0.2375155906979330	561.58889529969	1471.9769404358400	2573.338723992720	3817.4775377532100	546.5987048021120
/Users/ashkan/Downloads/post_hc/File53-2.wav	0.0513995609018574	0.1827745481001820	1.6377094396125700	0.090426008199213	0.1213075539590370	0.21742617881268	0.271278024597639	514.6761928508600	1553.60000943169	2593.9266148191700	3545.767323092740	498.3911440774680
/Users/ashkan/Downloads/post_hc/File6-2.wav	0.0526839126592113	0.1907219001727430	1.671388484538230	0.0920111946462681	0.1241547565653320	0.1921150541418930	0.2760335839388040	562.3460557600520	1611.883068697680	2612.928897919920	3625.7604321527800	528.3790311565840
/Users/ashkan/Downloads/post_hc/File36-2.wav	0.0552379623893584	0.1748212043796910	1.5916808989385100	0.0802242760906838	0.1067668436526020	0.1686678246192140	0.2406728282720520	717.5873352227250	1708.5019188114700	2883.573561376820	4017.04572051382	744.1949457657760
/Users/ashkan/Downloads/post_hc/File73-2.wav	0.0692677275853685	0.1800194099222990	1.565574852994070	0.0964653433204132	0.1200920433183910	0.1792281228535140	0.2893960299612400	479.4574349464060	1545.8076290755100	2660.4231984904700	3714.362917050570	430.2090929785210
/Users/ashkan/Downloads/post_hc/File97-2.wav	0.0385671628009692	0.1482566700083120	1.4130128314864700	0.0711747875984632	0.0960318233389404	0.1474402960044900	0.2135243627953900	489.3115885424020	1456.1546995272700	2573.9323837704800	3668.9167858829400	459.9046313173820
/Users/ashkan/Downloads/post_hc/File12-2.wav	0.0616637471603841	0.1932982726456690	1.6678570144337700	0.0897406010695839	0.134101322026087	0.3012782084755330	0.2692218032087520	517.8730794364930	1559.318388255020	2502.805237305480	3599.987358401980	388.2505077449200
/Users/ashkan/Downloads/post_hc/File131-2.wav	0.0484109973000907	0.1933494290914550	1.5973127665604800	0.0948904298318584	0.1345797748407140	0.2104819550348590	0.2846712894955750	490.9816433260140	1531.9472276337000	2601.0748166025800	3711.9203396554000	465.4025681266330

voiceID	f2_median	f3_median	f4_median	pF	fdisp	avgFormant	mff	fitch_vtl	delta_f	vtl_delta_f
/Users/ashkan/Downloads/post_hc/File38-2.wav	1772.2360236093600	2811.747140226250	4073.8521653554400	1.6314339826361300	1156.4221367345200	2315.605271085730	1871.7172780220600	14.969786692870700	1154.690349633320	15.155578294698100
/Users/ashkan/Downloads/post_hc/File99-2.wav	1540.7057242067200	2600.0178809962000	3605.368672333880	-0.2571922016787220	1033.4041248906900	2062.8121437996500	1643.49304592626	17.043594945734000	1032.4986567047700	16.94917459045810
/Users/ashkan/Downloads/post_hc/File124-2.wav	1524.422535963650	2579.361401769480	3541.1396120180600	-0.5579589549439620	1026.0011666382200	2027.0149154636500	1593.5559382777900	17.592705883762100	1017.1711431659100	17.20457773264380
/Users/ashkan/Downloads/post_hc/File126-2.wav	1552.6807893780800	2608.9907845168700	3376.5002020225900	-0.5227585099182240	962.732590571812	2006.6185515561800	1607.5985198586000	17.433821882741000	995.8761936948550	17.572465443794100
/Users/ashkan/Downloads/post_hc/File102-2.wav	1549.8125011522400	2549.0747604352600	3757.119131125510	-0.2093934109740850	1088.240078309790	2087.10132222729	1644.2143805643300	17.043288173730600	1052.072479040660	16.633834976804500
/Users/ashkan/Downloads/post_hc/File82-2.wav	1469.1830167292800	2510.4508557455600	3362.5156114821400	-0.9871551107553870	961.616495317492	1954.9539023716600	1560.10595340402	17.956996128110800	975.5971127338150	17.937732463108200
/Users/ashkan/Downloads/post_hc/File27-2.wav	1697.565748743890	2822.05356962631	4133.529619307700	1.6059614416011400	1168.5716707268800	2320.2408862012300	1877.7426983100700	14.930323422434900	1161.0830246820000	15.072134918855500
/Users/ashkan/Downloads/post_hc/File18-2.wav	1414.4988857071500	2472.470274234020	3398.0917952329100	-1.3194605043757400	988.3791391355700	1929.5038332500700	1506.0962689411900	18.62186658341840	972.03440411305	18.003477990028700
/Users/ashkan/Downloads/post_hc/File120-2.wav	1653.663516090970	2702.188776091500	3839.13719814661	0.3840926204254860	1122.4191721439500	2166.7172930109600	1686.774144150050	16.640348150992400	1090.8993927969400	16.041809277326700
/Users/ashkan/Downloads/post_hc/File8-2.wav	1569.668560789630	2437.051201346860	3612.371806314030	-0.3319124457522050	1019.7651682143300	2043.04196753039	1662.6947553734200	16.862879966839200	1017.4747770231500	17.19944355888620
/Users/ashkan/Downloads/post_hc/File22-2.wav	1852.9743622355200	2755.331285554560	3556.104571985220	1.1913470439778100	979.8071317194890	2195.273349150510	1829.2369466059600	15.364358409518300	1067.7379669034000	16.389788963041800
/Users/ashkan/Downloads/post_hc/File67-2.wav	1686.3705757603200	2745.906223175370	3947.889293481350	0.6140722339776910	1164.735545400730	2208.462187424050	1697.027832961220	16.575002826071700	1116.1321560668200	15.679146868834000
/Users/ashkan/Downloads/post_hc/File103-2.wav	1720.1370353952600	2717.9250809095600	3937.9102650403500	0.7889154558206270	1146.592615041420	2218.526200315320	1740.214519094910	16.119198869379100	1114.6081139507600	15.700585507107700
/Users/ashkan/Downloads/post_hc/File43-2.wav	1673.174250813160	2735.97968560818	4031.9078280528700	0.9715744244360680	1162.2402795920900	2246.562238437700	1781.0558480758100	15.730053981605100	1130.18961824112	15.484127369029200
/Users/ashkan/Downloads/post_hc/File101-2.wav	1624.6293747566000	2644.9577149840100	3682.211980996570	-0.0478593735875824	1076.6103421380700	2101.0450063298800	1635.6731833764400	17.168641743437900	1055.3938457321000	16.581487632098800
/Users/ashkan/Downloads/post_hc/File144-2.wav	1530.9015421168500	2700.6791060060200	3675.623767997680	-0.0884803984134922	1064.9365924070400	2097.0046017242800	1644.11464607364	17.052133071104000	1054.911441027170	16.589070247413600
/Users/ashkan/Downloads/post_hc/File58-2.wav	1591.8327118157600	2643.7765425940200	3788.881847234700	0.0510939759979964	1105.7380640114300	2124.0396892112200	1656.0266898641400	16.938910142137000	1071.1481293871600	16.33760963575820
/Users/ashkan/Downloads/post_hc/File20-2.wav	1809.904634265250	2469.3224541716800	3372.0273733871500	0.1519770371744670	933.2350948109850	2055.8941376945700	1713.725560159500	16.418419478151100	998.877139912341	17.519672140595500
/Users/ashkan/Downloads/post_hc/File118-2.wav	1687.1419355535900	2798.4628803562800	3934.8430483217400	0.8328434267838860	1148.1876859778700	2227.681963654940	1737.2434723360700	16.151360878987500	1121.1409889781500	15.609098384628800
/Users/ashkan/Downloads/post_hc/File24-2.wav	1729.3599306289900	2647.2557451340200	3538.048018874250	0.7667735235045910	961.2725414083240	2142.2235223216300	1804.2384461734800	15.597968423573200	1043.9267867696700	16.76362770051340
/Users/ashkan/Downloads/post_hc/File45-2.wav	1611.2119774091600	2719.5197571971300	3692.3553392429200	0.1458665329847800	1073.3625076429600	2123.8387225408100	1662.586252050440	16.873858288569200	1065.4759502197000	16.42458470920100
/Users/ashkan/Downloads/post_hc/File105-2.wav	1562.338705004110	2664.3720892371100	3657.3537622640800	-0.1017199114978300	1059.0433744504200	2091.0720488545300	1644.3533331458500	17.047468020425000	1049.7756318085500	16.67022882770770
/Users/ashkan/Downloads/post_hc/File78-2.wav	1606.4989156395600	2662.689699985370	3812.9629852805100	0.2069775253392610	1108.6315176931800	2142.305058276600	1678.8558178924300	16.699719437771100	1078.8275137145300	16.221314137368900
/Users/ashkan/Downloads/post_hc/File85-2.wav	1616.319890429220	2713.0656017130500	3658.862478620420	0.1705987776516680	1056.261288626030	2119.5816458762600	1674.556719509940	16.740180180722400	1059.9143724509100	16.510767713748000
/Users/ashkan/Downloads/post_hc/File9-2.wav	1533.384237356920	2515.579147561460	3287.814807936350	-0.8734275978286960	934.707287951078	1955.1177842344600	1573.7709336873100	17.807500484399700	968.486786893229	18.069425661590700
/Users/ashkan/Downloads/post_hc/File107-2.wav	1542.02425202801	2406.319639095610	3482.761520377850	-1.0733065978136200	1021.1345367260400	1962.6158304253000	1525.7671987935600	18.414055345438400	987.0561786763520	17.729487315977900
/Users/ashkan/Downloads/post_hc/File142-2.wav	1564.235833966030	2353.6568770993100	3344.621144536690	-1.2877795793173300	976.3248041598750	1919.5401469156000	1504.1085174607300	18.683492454262900	959.2615864575810	18.24319898457010
/Users/ashkan/Downloads/post_hc/File47-2.wav	1615.343782355310	2659.9085544216100	3864.715027289550	0.149215288856944	1138.6618981252600	2147.174174245060	1652.1839599445700	17.011591614873300	1086.8406819789200	16.10171600140700
/Users/ashkan/Downloads/post_hc/File26-2.wav	1429.0718478084000	2584.119262639820	3854.6476344772000	-0.4980098796487340	1135.6237745376300	2078.90376394743	1588.9239227416800	17.682453665855500	1062.8124192578300	16.465746619916600
/Users/ashkan/Downloads/post_hc/File63-2.wav	1535.13323269299	2473.992357502120	3456.9831390458000	-1.039688663416960	1017.745820400900	1967.463601771000	1517.355676263950	18.543319916713700	989.9521223036490	17.677622589744
/Users/ashkan/Downloads/post_hc/File92-2.wav	1612.345238159880	2636.156353717470	3619.381102904640	-0.0992744904370532	1049.121107466820	2084.975118821540	1641.5551176448300	17.084246193131200	1043.464356759610	16.771056803842100
/Users/ashkan/Downloads/post_hc/File112-2.wav	1551.0941159664900	2731.3532849947700	3899.925365763840	0.3404139297006720	1133.4691330016300	2170.472683371010	1694.9459722835800	16.540888744205700	1097.8343880947400	15.940473526586600
/Users/ashkan/Downloads/post_hc/File33-2.wav	1616.4477383186700	2781.6939290034000	4007.2417287164300	1.0846598972433700	1135.1203009551800	2251.816055472350	1814.7080468084200	15.447432182971800	1128.8187092104500	15.502932275316700
/Users/ashkan/Downloads/post_hc/File7-2.wav	1424.0767803661800	2407.265274461500	3509.0182663741000	-1.201216228504820	1015.8463274713500	1950.4599012904600	1534.9661367809200	18.255733450345400	984.1229490948770	17.782330974087300
/Users/ashkan/Downloads/post_hc/File134-2.wav	1538.8115239121900	2529.752194001080	3613.6479068356500	-0.6471357085243670	1060.638971797100	2028.4856540483100	1569.840820738800	17.89242122427890	1023.6300447865700	17.096020275224400
/Users/ashkan/Downloads/post_hc/File28-2.wav	1726.427503520500	2816.64394973431	4177.984381865650	1.9708524866029400	1159.2493201574700	2355.323064128430	1942.1060959954900	14.473359318610800	1171.6340322306200	14.936404643933600
/Users/ashkan/Downloads/post_hc/File94-2.wav	1550.7856741466700	2550.26993371816	3380.9950409847300	-0.6442744048778070	964.709776067094	1992.2290904082600	1597.342010750840	17.542505177811400	989.4651831120820	17.686322165433600
/Users/ashkan/Downloads/post_hc/File129-2.wav	1535.4148646837100	2705.9752785839100	3528.8510631339600	-0.259980534021947	1018.854908802230	2060.631885782220	1622.1726281869400	17.287024999885500	1031.1991610865600	16.970533588836900
/Users/ashkan/Downloads/post_hc/File3-2.wav	1688.2903140023800	2635.8959723392500	3591.2701522513800	0.1487978908777710	1031.7306280047000	2102.883676707570	1678.0056484787600	16.709909622932500	1044.7457175642900	16.750487420804400
/Users/ashkan/Downloads/post_hc/File72-2.wav	1646.8004715024000	2539.5932885770100	3788.307600155440	-0.135301199945835	1117.178375793640	2102.868458252340	1621.9087322970900	17.342162911641100	1061.7450840775000	16.482299058822600
/Users/ashkan/Downloads/post_hc/File116-2.wav	1539.1665103311700	2510.456803730070	3517.851020954950	-0.8009228788441300	1029.5959671220100	1999.1343636512700	1554.0294578914400	18.071564993542500	1005.3286622837500	17.407242682454000
/Users/ashkan/Downloads/post_hc/File48-2.wav	1596.9846993906100	2750.3407310523200	3750.667486050000	0.2654733579790080	1089.9174958670400	2144.7269787354500	1677.7066860243300	16.717314259805100	1078.0534560531500	16.23296127083440
/Users/ashkan/Downloads/post_hc/File88-2.wav	1654.2643263610700	2670.444048556020	3867.410056634670	0.3237147878726520	1134.7726726534900	2163.802617406490	1677.1387021995500	16.745832105552000	1091.66087056670	16.03054286240870
/Users/ashkan/Downloads/post_hc/File14-2.wav	1450.99808093279	2448.0205848928000	3417.418943352480	-1.1165235825482200	981.8080105272370	1947.108130237210	1547.1390954961900	18.105949872544600	975.8815400595360	17.932504388731800
/Users/ashkan/Downloads/post_hc/File16-2.wav	1488.4504033289900	2651.3639614047200	3936.0982947105800	0.2231481330772840	1129.8331966361600	2155.6278410616000	1707.0040937553700	16.426478639631500	1090.9870901139700	16.040519781193600
/Users/ashkan/Downloads/post_hc/File53-2.wav	1572.051064197770	2622.747473701000	3534.0553177188300	-0.2341218905603930	1011.8880578804500	2056.811249923770	1641.5975547977400	17.066691890399600	1025.3968792668500	17.066562570887100
/Users/ashkan/Downloads/post_hc/File6-2.wav	1649.4079569668700	2643.0022555962500	3571.0454456491800	0.1517169807006840	1014.2221381642	2097.958672334720	1693.5251188378800	16.549670835636000	1040.2126737960200	16.82348277505380
/Users/ashkan/Downloads/post_hc/File36-2.wav	1734.769955648520	2897.139244882880	4051.5381467457600	2.1634536667597400	1102.4477336600000	2356.9105732607400	1973.0108676184700	14.277045023960800	1161.784953913000	15.063028610465600
/Users/ashkan/Downloads/post_hc/File73-2.wav	1565.091274857880	2714.063498933770	3748.8814691258400	-0.0670340735284729	1106.2241253824400	2114.561333974000	1617.8387836897600	17.392269811519500	1069.9516832405200	16.355878750523100
/Users/ashkan/Downloads/post_hc/File97-2.wav	1454.0732531234800	2613.444308247040	3749.084053153630	-0.4510136102149010	1096.3931406120800	2069.126561460380	1599.919471785120	17.539025881365400	1050.7841500952000	16.654229128232000
/Users/ashkan/Downloads/post_hc/File12-2.wav	1500.5019993919800	2348.9221489322300	3493.2734258541300	-1.3909535745193500	1035.0076393697400	1932.737020480820	1478.640010179290	19.047600662730700	978.2686007514510	17.888747514289500
/Users/ashkan/Downloads/post_hc/File131-2.wav	1540.474732712660	2647.774697984310	3792.906435570770	-0.091119102532649	1109.1679558147100	2111.6396085985900	1638.0763041274000	17.128251109134200	1068.4772691709900	16.37844856875420