**Western Papers in Linguistics / Cahiers linguistiques de Western**

Volume 3
Issue 1 *Proceedings of Western Interdisciplinary Student Symposium on Language Research (WISSLR) 2016*

Article 2

2016

# Effects of Multi-talker Noise on the Acoustics of Voiceless Stop Consonants in Parkinson's Disease

Daryn Cushnie-Sparrow
*Western University*, dcushni@uwo.ca

Scott Adams
*Western University*, sadams@uwo.ca

Thea Knowles
*Western University*, tknowle3@uwo.ca

Talia M. Leszcz
*University of Western Ontario*, talialeszcz@gmail.com

Mandar Jog
*The University of Western Ontario*, msjog@uwo.ca

Follow this and additional works at: http://ir.lib.uwo.ca/wpl_clw

## Recommended Citation

Cushnie-Sparrow, Daryn; Adams, Scott; Knowles, Thea; Leszcz, Talia M.; and Jog, Mandar (2016) "Effects of Multi-talker Noise on the Acoustics of Voiceless Stop Consonants in Parkinson's Disease," *Western Papers in Linguistics / Cahiers linguistiques de Western*: Vol. 3: Iss. 1, Article 2.
Available at: http://ir.lib.uwo.ca/wpl_clw/vol3/iss1/2

This Article is brought to you for free and open access by Scholarship@Western. It has been accepted for inclusion in Western Papers in Linguistics / Cahiers linguistiques de Western by an authorized administrator of Scholarship@Western. For more information, please contact jpater22@uwo.ca.

# EFFECTS OF MULTI-TALKER NOISE ON THE ACOUSTICS OF VOICELESS CONSONANTS IN PARKINSON'S DISEASE

*Daryn Cushnie-Sparrow, Scott Adams, Talia Leszcz,*
*Thea Knowles & Mandar Jog*
*University of Western Ontario*

## 1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease, with most studies reporting the prevalence to be between 1 and 3 per 100 people over the age of 65. PD is a progressive neurological disorder thought to result from the degeneration of dopaminergic neurons of the substantia nigra which leads to dopamine deficiency in the striatum (Wirdefeldt, 2011). Both the substantia nigra and striatum are part of the basal ganglia, a subcortical nuclei cluster which regulates cortically-initiated motor activity and autonomic activities (Bhatnagar, 2013). PD is primarily thought of as a motor disorder, but has many non-motor features. Primary symptoms include resting tremor, bradykinesia, rigidity of bodily movements, a shuffling gait and a loss of postural reflexes. In addition to these symptoms, many other features like dysphagia, anosmia, sleep disorders, cognitive abnormalities and paresthesias are associated with PD (Jankovic, 2008). In terms of the speech difficulties related to PD, hypophonia or reduced speech intensity, is a common problem throughout the disease course.

As well as reduced speech intensity, the dysarthria of Parkinson's disease is also associated with reduced stress and intonation patterns, breathy, hoarse or rough speech, distorted consonantal sounds, abnormal speech rate and reduced pitch and loudness variation. Consonant articulation has a tendency to become less precise, with stops, affricates and fricatives being distorted (Adams & Dykstra, 2009). Cramer (1940) found that stops sound almost like fricatives, with Logemann and Fisher (1981) adding that this spirantization of stops may be due to inadequate narrowing of the vowel tract due to increased stiffness of articulators. Weismer (1984) found a significant amount of voicing during the normally voiceless closure interval of voiceless stops, and also found that stop gaps were shorted in individuals with PD. Intensity levels during stop closures have been found to be higher in individuals with PD than in healthy controls, which is thought to be because of the voicing present (Ackermann & Ziegler, 1991). The distortion of consonants is problematic, because a high correlation between ratings of reduced intelligibility and the imprecision of consonant articulation has been found (Darley, Aronson & Brown, 1969).

Patterns in the acoustic characteristics of stop consonants have been established. For example, voice onset time (VOT) has been found to be the longest for velar stops, the shortest for bilabial stops and intermediate for alveolar stops, showing a trend of place of articulation with anterior articulators associated with shorter VOT (Fischer-Jorgensen, 1954). Explanations for this trend include extent of contact area, with more extensive contact leading to longer VOT (Stevens, Keyser & Kawasaki, 1986) and articulatory speed, with faster articulators leading to shorter VOT (Hardcastle, 1973). In individuals with PD, findings have been mixed but Weismer (1984) found shorter VOT in individuals with PD. Spectral moments are acoustic characteristics used to describe the distribution of intensity across different frequencies. Spectral templates describe patterns in these moments for the 3 consonants *p, t* and *k* (Blumstein & Stevens, 1979). The bilabial *p* is associated with lower kurtosis, positive skewness and a lower centre of gravity. Alveolar *t* is associated with lower kurtosis, negative skewness and a higher centre of gravity. Velar *k* is associated with higher kurtosis, intermediate skewness and intermediate centre of gravity (Blumstein et al., 1979). In individuals with PD, Dromey (2003) found lower centre of gravity and standard deviation and higher kurtosis and skewness relative to healthy controls.

*© 2016 Daryn Cushnie-Sparrow, Scott Adams, Talia Leszcz, Thea Knowles and Mandar Jog*

Multitalker background noise (MTN) has been found to increase speech intensity in individuals with PD and has been used as a treatment for hypophonia (Richardson, Sussman, Stathopoulos & Huber, 2014; Adams, Winnell & Jog, 2010). However, the effect of increased intensity on consonant articulation and the acoustic correlates of articulation in PD has received limited attention.

It is hypothesized that individuals with PD will differ from healthy geriatric controls on measures related to their production of stop consonants, particularly on intensity, spirantization and voicing. It is also suggested that there will be differences on these acoustic measures when speaking in the presence of multitalker background noise. In particular, we expected voicing in closure, percent voicing, voicing intensity and voicing ratio to be higher in individuals with PD, as increased voicing was found by Weismer (1984). Mean and peak intensity of the vowel and syllable are expected to be lower in individuals with PD, because hypophonia (quiet speech) is a common speech symptom in PD. Spirantization intensity and spirantization ratio are expected to be higher in individuals with PD because increased spirantization was previously found in studies by Logemann and Fisher (1981) and Cramer (1940). Voice onset time (VOT) is expected to be shorter in individuals with PD based on Weismer (1984). In addition, VOT is expected to show place of articulation trends similar to those found by Fischer-Jorgensen (1954), Stevens et al. (1986) and Hardcastle (1973) with the highest VOT for *k* and lowest for *p*. Spectral moments are expected to align with the templates presented by Blumstein et al. (1979), and to show the pattern of low centre of gravity and standard deviation and high kurtosis and skewness in individuals with PD found by Dromey (2003). Multitalker noise is expected to increase speech intensity (Richardson et al., 2014; Adams et al., 2010). Thus, the present study aims to examine the effects of Parkinson's disease, multitalker noise and other factors on the acoustic correlates of stop consonant production.

## 2. Method

### 2.1 Data

The speech samples used in the present acoustic study were collected for a previous phonetic study conducted by Talia Leszcz as part of her Master's thesis at Western University (Leszcz, 2012). Ten individuals with mild-moderate PD and ten geriatric controls read aloud the University of Western Ontario Distinctive Features Differences Test (DFD) (Cheesman & Jamieson, 1996) which required participants to produce each consonant in the environments "*aCil*, point to the word *aCil*, point to the word *aCil*" where C represents the consonant in question. In Leszcz's (2012) study, participants produced 21 consonants in the DFD but for the purpose of this study, we analyzed only the 3 voiceless stops *p*, *t* and *k*. As the participants read aloud the DFD, they were recorded using an AKG c420 headset microphone positioned 6 cm from their mouth while sitting in an audiometric booth. The participants produced the DFD twice – once in low ambient noise and once in the presence of 65 dB multitalker noise presented through a loudspeaker 120 cm from the participant. Before starting the speech tasks, the participants were calibrated at 70 dBA using a vowel prolongation of 1-2 seconds and a sound level meter placed 15 cm from their mouth.

### 2.2 Analysis

Nineteen measures were obtained using Praat (Boersma & Weenink, 2008). These included several durational measures, intensity measures and spectral measures.

### 2.2.1 Durational Measures

Several measures of the duration of important components of the speech signal were measured. The total word duration, calculated as the time from the onset of voicing of the first vowel to the offset of the *l* in *aCil*, was used as an index of rate of speech. The closure duration, or the duration of the stop gap, was measured as the interval from the end of the vowel (determined by a marked decrease in intensity and periodic complexity on the waveform) until the burst. Voicing into closure was measured as the interval from the end of the vowel until the offset of voicing (determined by the absence of periodicity on the waveform). Percent voicing was calculated as the proportion of the closure interval that had voicing as illustrated below.

(1) $$percent\ voicing = \frac{voicing\ into\ closure}{closure\ duration}$$

Voice onset time (VOT) was calculated as the time from the burst to the beginning of the following vowel (determined by the end of the aperiodicity of the burst). The transient duration was defined as the time from the burst to the end of the 3rd cycle of the following vowel. This duration was chosen to be consistent with Forrest, Weismer, Milenkovic and Dougall (1988) and was used to determine the spectral characteristics of the consonant.

### 2.2.2 Intensity Measures

The mean and peak intensity of the vowel (referred to as vowel mean intensity and vowel peak intensity) and of the *il* portion of *aCil* (referred to as syllable mean intensity and syllable peak intensity for simplicity) were obtained. The intensity of the closure interval was taken and called closure intensity. The closure interval was then put through 2 band-pass filters. The first passed 500 Hz – 10 kHz, and the intensity of this signal was determined and called spirantization intensity. The second passed 70 Hz – 500 Hz, and the intensity of this signal was obtained and called voicing intensity. The 70 Hz floor was to remove the effects of electrical noise that may have entered the signal. The band-pass filter to separate the spirantization and voicing energy in the closure interval was adapted from Hualde, Shosted and Scarpace's (2011) work on spirantization of Spanish voiced stops. This was done because it was expected that there may be differences in the effects of spirantization and voicing on the overall intensity of the closure interval. The filter would allow clarification of Ackermann and Ziegler's (1991) finding of increased intensity of the closure interval in individuals with PD. Using these spirantization and voicing intensity measures, ratio measures were calculated that compared the intensity of spirantization and voicing, respectively, to the total intensity of the closure interval, as illustrated in the following formulas.

(2)

a. $$spirantization\ ratio = \frac{spirantization\ intensity}{closure\ intensity}$$

b. $$voicing\ ratio = \frac{voicing\ intensity}{voicing\ ratio}$$

### 2.2.3 Spectral Measures

Centre of gravity (mean), standard deviation, skewness and kurtosis were taken from the transient duration (as per Forrest et al., 1988) using Praat's (Boersma & Weenink, 2008) default settings.

### 2.2.4 Statistical Analysis

A series of independent *t*-tests investigated group differences. Matched pair *t*-tests examined noise effects and one-way repeated measures ANOVAs investigated the effects of context and consonant. One-tailed *t*-tests were used on measures for which, based on extant literature, we predicted the direction of our results. Given the exploratory nature of this study, a statistical correction for multiple comparisons was not performed.

## 3. Results

The exact *p*-values for all measures are provided in Table 1. Significant values are marked with an asterisk (*), and those italicized are *p*-values of one-tailed *t*-tests.

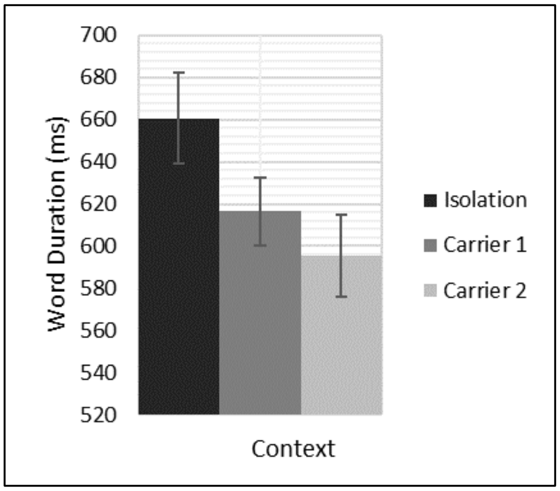
Table 1: The *p*-values obtained for the statistical tests related to each acoustic measure across the group, noise, consonant, and context factors.

| | Group | Noise | Consonant | Context |
|---|---|---|---|---|
| Word Duration | 0.658 | 0.102 | 0.363 | 0.005* |
| Closure Duration | 0.474 | 0.102 | 0.002* | 0.002* |
| Voicing in Closure | *0.218* | 0.882 | 0.826 | 0.649 |
| Percent Voicing | *0.074* | 0.250 | 0.037* | 0.416 |
| Voice Onset Time | 0.866 | 0.040* | 0.000* | 0.070 |
| Transient Duration | 0.673 | 0.000* | 0.000* | 0.235 |
| Vowel Mean Intensity | *0.375* | 0.000* | 0.003* | 0.042* |
| Vowel Peak Intensity | *0.385* | 0.000* | 0.006* | 0.042* |
| Syllable Mean Intensity | *0.110* | 0.000* | 0.316 | 0.000* |
| Syllable Peak Intensity | *0.069* | 0.000* | 0.402 | 0.000* |
| Closure Intensity | 0.822 | 0.000* | 0.323 | 0.507 |
| Spirantization Intensity | *0.499* | 0.000* | 0.032* | 0.503 |
| Voicing Intensity | *0.474* | 0.000* | 0.542 | 0.893 |
| Spirantization Ratio | *0.094* | 0.000* | 0.002* | 0.745 |
| Voicing Ratio | *0.144* | 0.000* | 0.921 | 0.773 |
| Spectral Centre of Gravity | 0.237 | 0.178 | 0.000* | 0.132 |
| Spectral Standard Deviation | 0.232 | 0.267 | 0.621 | 0.326 |
| Spectral Skewness | 0.609 | 0.061 | 0.000* | 0.115 |
| Spectral Kurtosis | 0.294 | 0.058 | 0.000* | 0.610 |

### 3.1 Durational Measures

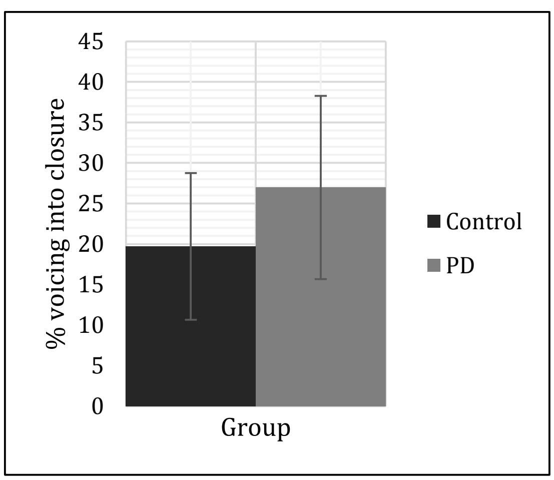
The results of the group analysis on word duration did not reach significance, but individuals with PD showed a tendency for slower rate of speech. Word duration was significantly ($p$ = 0.005) longer in isolation than on the last carrier phrase production, indicating that participants increased their rate of speech as they progressed across the three speech contexts (see Figure 1).

Figure 1: Average word duration obtained for the contexts related to the word in isolation, and two carrier phrases.




Word duration showed a tendency to be longer in noise, and this effect was approaching significance ($p = 0.102$). Closure duration was found to be somewhat shorter in individuals with PD but this effect did not reach significance and a significant effect of noise was not found. There were significant effects of consonant ($p = 0.002$) and context ($p = 0.002$). The *k* and *t* sounds were found to have shorter stop gaps than *p*. These stop gaps were longer in isolation than in the final carrier phrase. Duration of voicing of closure was longer in individuals with PD but this effect was not significant, and no other effects on voicing into closure were found. Percent voicing was approaching significance ($p = 0.074$) for a one-tailed *t*-test related to the group effect, with individuals with PD showing more voicing than controls (see Figure 2).

Figure 2: Average percent voicing of the stop closures for the Parkinson's disease and control groups.

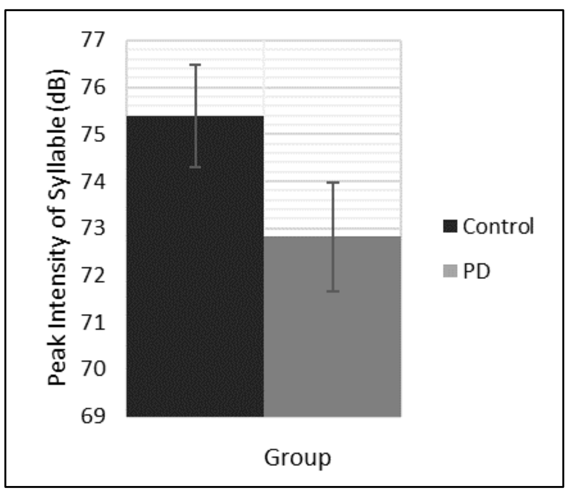


There was a significant effect of consonant type ($p = 0.037$) with the least voicing for *k*, the most for *t* and an intermediate value for *p*. VOT was significantly longer in the absence of noise ($p = 0.04$) and a significant effect of consonant type ($p < 0.001$) was found, with the longest VOT for *k*, shortest for *p* and intermediate for *t*. Individuals with PD showed a shorter transient duration but this effect was not significant. Noise effects on transient duration were significant ($p < 0.001$), with longer duration in the presence of noise. A significant effect of consonant ($p < 0.001$) was found with *k* having the longest transient duration, *p* the shortest and *t* intermediate.

## 3.2 Intensity Measures

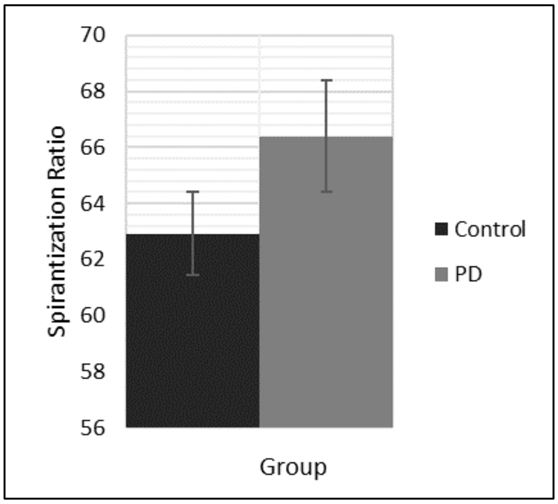
Significant effects of noise the condition ($p < 0.001$) were found for all intensity measures (see Figure 3). Significant effects of context were found for vowel mean intensity ($p = 0.042$) and vowel peak intensity ($p = 0.042$), with intensity being higher in sounds produced in isolated words as opposed to a carrier phrase. Significant effects of consonant type were also found for vowel mean intensity ($p = 0.003$) and vowel peak intensity ($p = 0.006$) with both showing the trend of *t* having the highest intensity, *k* the lowest and *p* intermediate. A significant context effect was found for syllable mean intensity ($p < 0.001$) and syllable peak intensity ($p < 0.001$) with a higher intensity in isolation. For the measures of vowel mean intensity, vowel peak intensity, syllable mean intensity and syllable peak intensity, no group effects reached significance but syllable peak intensity was approaching significance ($p = 0.069$) for a one-tailed *t*-test with lower intensity for individuals with PD (see Figure 3).

Figure 3: Average syllable peak intensity for the Parkinson's disease and control groups.



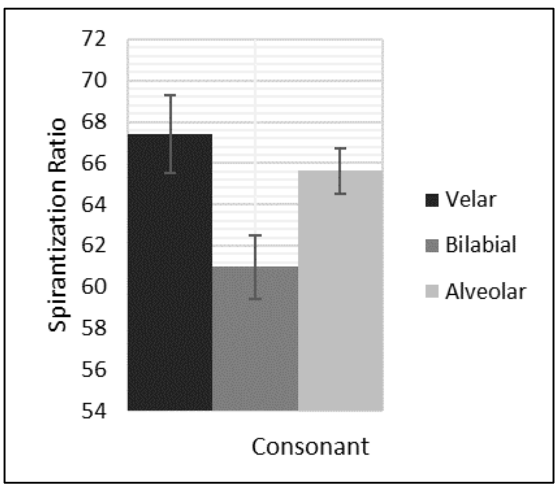

No group effects reached significance for closure intensity, spirantization intensity, voicing intensity or voicing ratio. The effect of group on spirantization ratio was approaching significance ($p = 0.094$) for a one-tailed *t*-test with more spirantization by individuals with PD (see Figure 4).

Figure 4: Average spirantization ratio for the Parkinson's disease and control groups.




Spirantization intensity did show a significant effect of consonant type ($p = 0.032$), with *p* having less spirantization energy than *k* and *t*. Similarly, a significant consonant type effect was seen for spirantization ratio ($p = 0.002$) but with a different trend in that spirantization intensity *k* showed the highest spirantization energy and *p* the least (see Figure 8).

Figure 5: Average spirantization ratio for the velar, bilabial and alveolar place of stop articulation.




## 3.3 Spectral Measures

No significant effect of group was found for any of the spectral measures, but PDs were found to have higher values on all four moments. The effect of noise condition was not significant, but approached significance for skewness ($p = 0.061$) and kurtosis ($p = 0.058$) with higher values for each moment value in the 65 dB noise. A significant effect of consonant type was found for centre of gravity ($p < 0.001$), skewness ($p < 0.001$) and kurtosis ($p < 0.001$). For centre of gravity, *t* showed the highest centre of gravity, *p* the lowest and *k* intermediate. For skewness, *p* showed the highest skewness, *t* the lowest and *k* intermediate. For kurtosis, *p* showed the highest skewness, *t* the lowest and *k* intermediate.

# 4. Discussion

## 4.1 Comparisons between the Parkinson's Disease and Control Groups

### 4.1.1 Intensity

Individuals with PD were expected to exhibit lower speech intensity due to their hypophonia. This finding was supported, with the difference in syllable peak intensity approaching significance. Vowel mean intensity, vowel peak intensity and syllable mean intensity differences did not reach significance but the intensity values of individuals with PD were lower for each of these measures. The failure to observe significantly lower intensity values in these hypohonic PD participants may be related to the relatively short duration of the speech segments that were measured. Most of the previous studies that have found a significant reduction in speech intensity in PD, have measured intensity across complete sentences or paragraphs instead of across an isolated vowel or syllable. Additional studies are required to determine if there is a minimum utterance length that is required to obtain a consistent and significant measure of reduced speech intensity in individuals with hypophonia and PD.

### 4.1.2 Spirantization

Based on studies by Cramer (1940) and Logemann and Fisher (1981) we expected to find more spirantization in the stop consonants of individuals with PD. While these findings did not reach significance, spirantization ratio approached significance. Logemann and Fisher (1981) also found higher intensity in the closure interval of individuals with PD. These findings were not supported in the present study. It should be noted that the study by Logemann and Fisher (1981) included 90 individuals with PD who were selected because they demonstrated marked articulation errors across a fairly wide range of severity levels.  The present study was limited to only 10 PD participants who were selected on the basis of their hypophonia symptom rather than their articulatory errors. Future studies attempting to examine the effect of changes in speech intensity on stop consonant spirantization should consider selecting PD participants with a wide range in the severity of spirantization errors.

### 4.1.3 Voicing

Weismer (1984) found significant voicing in the closure interval of voiceless stops produced by individuals with PD and it was expected that voicing in closure, percent voicing into closure, voicing intensity and voicing ratio would be higher in individuals with PD. Percent voicing into closure was approaching significance with individuals with PD exhibiting voicing further into the closure interval than geriatric controls and this is consistent with Weismer's (1984) findings.

Weismer (1984) also found shorter VOT in individuals with PD. This was not strongly supported by this study, as group differences in VOT measures did not reach significance, but VOT was slightly shorter for individuals with PD. As previously mentioned, the small number of participants and the inclusion of PD participants with fairly mild articulation errors may explain some of these non-significant group effects on the voicing measures.

## 4.2 Effects of Noise

Findings of previous studies indicate that multitalker noise is effective in increasing the speech intensity of individuals with hypophonia (Richardson et al., 2014; Adams et al., 2010). These findings were supported in all intensity measures. Both PD and control participants increased their speech intensity measures during the multi-talker noise condition. This effect has been referred to as the Lombard effect and has been previously described in both non-neurologically impaired individuals and individuals with PD (Lane & Tranel, 1971; Adams & Lang, 1992). A significant interaction between noise and group was not found. This indicates that, despite the presence of hypophonia, individuals with PD appear to show a Lombard response that is equivalent to that of control participants. This finding of an apparently normal Lombard effect has been described in previous studies of the multi-talker noise and PD (Adams et al, 2010). In addition to the numerous significant intensity measures, several of the durational and spectral measures were found to be significantly longer or approaching significance during the noise condition. These preliminary results suggest that additional detailed studies are required to examine the potential effects of background noise on the temporal and spectral characteristics of stop consonants.

## 4.3 Effects of Place of Articulation

### 4.3.1 Voice Onset Time

VOT findings (i.e. k > t > p) of this study followed the expected trends presented in the literature (Fischer-Jorgensen, 1954; Stevens et al., 1986; Hardcastle, 1973), with significant differences emerging between velar, bilabial and alveolar plosives. As previously mentioned, explanations for place-related pattern include extent of contact area, with more extensive contact leading to longer VOT (Stevens, Keyser & Kawasaki, 1986) and articulatory speed, with faster articulators (i.e. tongue tip faster than tongue dorsum movements) leading to shorter VOT (Hardcastle, 1973).

### 4.3.2 Moments

Spectral moment findings generally support Blumstein et al.'s (1979) spectral templates of high skewness and low COG for *p*, low skewness and high centre of gravity for *t* and intermediate centre of gravity and skewness but high kurtosis for *k.* The divergence of our findings from Blumstein et al.'s (1979) templates was in kurtosis. Our findings showed a different pattern of kurtosis, with higher kurtosis for *p* than for *k*. Further investigation is needed to determine the reasons for this inconsistency.

Dromey (2003) found lower centre of gravity and standard deviation and higher kurtosis and skewness in individuals with PD. None of the spectral moments revealed significant effects for group, but the trends in the results of the post-hoc comparisons, partially supported Dromey's (2003) findings. For example, higher kurtosis and skewness were found in accordance with his findings, but centre of gravity and standard deviation were also found to be higher in individuals with PD. These inconsistencies, indicate that additional studies of the spectral moments of stop consonant production in individuals with PD are required.

### 4.4 Limitations

Many of the group effects did not reach significance and there are several factors that may have contributed to this. A relatively small number of Parkinson's patients were studied, and a fairly large amount of individual variability was found in the PD group. Thus, this exploratory study may not have had sufficient power to detect PD-related group differences. Richardson et al. (2014) encountered a similar concern about insufficient statistical power in their study of VOT in individuals with PD. By dividing participants into a group which showed improvement in voicing proficiency and one that did not, the effects became clearer and stronger. Further investigation is needed to indicate if a subset of the participants in this study would have shown stronger effects. Also, the patients who participated in this study had mild-moderate PD and were not selected exclusively for hypokinetic dysarthria, which may be more closely related to imprecise consonant articulation than hypophonia. Investigation of a larger number of patients and patients with more severe dysarthria may result in stronger PD-related group effects being revealed.

Another potential concern relates to the method that was used to present the 65 dB multitalker noise. Presenting the noise via a loudspeaker, may have produced an artifact in the recordings and the intensity measures. Despite the short mouth–to-microphone distance (6cm) and the uni-directional properties of the headset microphone, it is possible that some of the multitalker noise signal was added to the speech recordings and that this produced an artifact in the intensity measures. Future investigations should compare the effects of presenting multitalker noise via loudspeakers versus headphones on the measures of speech intensity.

One potential reason for the differences between our findings and the spectral templates laid out by Blumstein et al. (1979) and findings of Dromey (2003) may be that Forrest et al.'s (1988) method for determining the spectral moments of the transient of a stop was not exactly replicated in this study. While we used the same analysis window, Forrest et al. (1988) divided this window into 20 ms windows overlapping by 10 ms. Moments were calculated for each of these windows and then averaged. Further investigation is needed to determine if these two methods produce different values for the spectral moments.

### 4.5 Summary and Conclusions

This study examined the effect of increased speech intensity on stop consonant acoustics in Parkinson's disease (PD). Acoustic analyses focused on measures of spirantization, voicing during closure, stop closure durations, and voice onset time. Ten individuals with Parkinson's disease and ten age-matched controls were audio recorded while they read aloud words from the Distinctive Features Differences Test (DFD) during two conditions: no noise and 65 dB of multi-talker background noise. When compared to controls, the participants with PD had values that approached a significant difference for the measures related to greater percent voicing into closure ($p=0.074$), lower mean syllable intensity ($p=0.069$) and greater spirantization ratio ($p=0.094$). When compared to the no noise condition, the 65 dB multi-talker noise condition was associated with significant changes in voice onset time (VOT), syllable intensity, spirantization ratio and other measures. In addition, the place of stop consonant production had a significant effect on measures of closure duration, VOT, spectral skewness and other measures. These preliminary findings suggest that additional studies of the effect of changes in speech intensity on stop production in PD are warranted. The results of the present study identified several acoustic measures of stop production that may be useful in future evaluations of treatment outcome in PD.

# References


Ackermann, H. & Ziegler, W. 1991. Articulatory deficits in parkinsonian dysarthria: an acoustic analysis. *Journal of Neurology, Neurosurgery, and Psychiatry 54*: 1093–1098.

Adams, S. & Dykstra, A.D. 2009. Hypokinetic dysarthria. In M. R. McNeil (Ed.), *Clinical Management of Sensorimotor Speech Disorders, Second Edition*. New York: Thieme.

Adams, S.G. & Lang, A.E. 1992. Can the Lombard effect be used to improve the low voice intensity in Parkinson disease? *European Journal of Disorders of Communication 27:* 121-127.

Adams, S. G., Winnell, J., Jog, M. 2010. Effects of interlocutor distance, multi-talker background noise, and a concurrent manual task on speech intensity in Parkinson's disease. *Journal of Medical Speech-Language Pathology 18*: 1-8.

Bhatnagar, S. C. 2013. *Neuroscience for the study of communicative disorders.* 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins.

Blumstein, S. E. & Stevens, K. N. 1979. Acoustic invariance in speech production: Evidence from measurements of the spectral characteristics of stop consonants. *Journal of the Acoustical Society of America 66*: 1001 – 1017.

Boersma, P. & Weenink, D. 2008. PRAAT (version 5.0.20) [Software]. Available from http://www.fon.hum.uva.nl/praat

Cheesman, M. F., & Jamieson, D. G. 1996. Development, evaluation and scoring of a nonsense word test suitable for use with speakers of Canadian English. *Canadian Acoustics 24*: 3-11.

Cho, T., & Ladefoged, P. 1999. Variation and universals in VOT: evidence from 18 languages. *Journal of Phonetics 27*: 207-229.

Cramer, W. 1940. De spaak bij patienten met Parkinsonisme. *Logopaedica Phoniatrica, 22*: 17–23.

Darley, F.L., Aronson, A.E., & Brown, J.R. 1969. Clusters of deviant speech dimensions in the dysarthrias. *Journal of Speech and Hearing Research 12*: 462–496.

Dromey, C. 2003. Spectral measures and perceptual ratings of hypokinetic dysarthria. *Journal of Medical Speech-Language Pathology 11*: 85-91.

Fischer-Jorgensen, E. 1954. Acoustic analysis of stop consonants. *Miscellanea Phonetica 2*: 42-59.

Flint, A. J., Black, S. E., Campbell-Taylor, L., Gailey, G. F. & Levinton, C. 1992. Acoustic analysis in the differentiation of Parkinson's disease and major depression. *Journal of Psycholinguistic Research 21*: 383-389.

Forrest, K., Wesimer, G., Milenkovic, P., Dougall, R. N. 1988. Statistical analysis of word-initial voiceless obstruents: Preliminary data. *Journal of the Acoustical Society of America, 84:* 115-123.

Hardcastle, W. J. 1973. Some observations on the tense-lax distinction in initial stops in Korean. *Journal of Phonetics 1*: 263-271.

Hualde, J. I., Shosted, R., Scarpace, D. 2011. Acoustics and articulation of Spanish /d/ spirantization. In *Proceedings from ICPHS 2011: The International Congress of Phonetic Sciences:* 906-909.

Jankovic, J. 2008. Parkinson's disease: clinical features and diagnosis. *Journal of Neurology, Neurosurgery and Psychiatry 79:* 368-376.

Kuehn, D. P. & Moll, K. 1976. A cineradiographic study of VC and CV articulatory velocities. *Journal of Phonetics 4*: 303-320.

Leszcz, T. M. 2012. The effect of multitalker background noise on speech intelligibility in Parkinson's disease and controls. Master's thesis. University of Western Ontario.

Lane, H. & Tranel, B. 1971. Lombard sign and role of hearing in speech. *Journal of Speech and Hearing Research 14:* 677-709.Logemann, J.A. & Fisher, H.B. 1981. Vocal tract control in Parkinson's disease: Phonetic feature analysis of misarticulations. *Journal of Speech and Hearing Disorders 46*: 348–352.

Richardson K., Sussman J.E., Stathopoulos E.T., & Huber J.E. 2014. The effect of increased vocal intensity on interarticulator timing in speakers with parkinson's disease: A preliminary analysis. *Journal of Communication Disorders 52*: 44-64.

Stevens, K. N., Keyser, S. J., Kawasaki, H. 1986. Toward a phonetic and phonological theory of redundant features. In J. S. Perkell & D. H. Klatt (eds.), *Invariance and variability in speech processes:* 426-463. New Jersey: Lawrence Erlbaum Associates.

Weismer, G. 1984. Articulatory characteristics of parkinsonian dysarthria: segmental and phrase-level timing, spirantization, and glottal-supraglottal coordination. In M. R. McNeil, J. C. Rosenbek, & A. E. Aronson (Eds.), *The Dysarthrias: Physiology, Acoustics, Perception, Management*: 101–130. San Diego: College-Hill.

Wirdefeldt, K., Adami, H. O., Cole, P., Trichopoulos, D. & Mandel, J. 2011. Epidemiology and etiology of Parkinson's disease: a review of the evidence. *European Journal of Epidemiology 26*: 51-58.

Appendix A. Mean and standard deviation (parentheses) for each acoustic measure obtained from the Parkinson disease (PD) and control (C) groups in the noise conditions (no noise; 65 dB noise), speech contexts (isolated word, carrier phrase 1 & 2), and stop consonant test items (p, t, k).

| Measure | | No Noise | | | | | | | | | 65 dB Multitalker Noise | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Isolated | | | Carrier 1 | | | Carrier 2 | | | Isolated | | | Carrier 1 | | | Carrier 2 | | |
| | | p | t | k | p | t | k | p | t | k | p | t | k | p | t | k | p | t | k |
| Word Duration (ms) | C | 607.23 (134.98) | 629.56 (109.40) | 614.06 (95.20) | 630.79 (153.77) | 584.06 (56.58) | 609.06 (63.07) | 543.36 (69.17) | 540.91 (52.47) | 537.54 (88.11) | 634.66 (157.96) | 626.100 (59.85) | 635.28 (84.67) | 603.33 (99.48) | 611.47 (59.85) | 622.49 (103.80) | 543.22 (94.38) | 586.03 (100.52) | 567.94 (67.17) |
| | PD | 636.23 (72.47) | 634.93 (99.85) | 675.46 (152.54) | 545.68 (60.21) | 588.96 (63.74) | 597.25 (41.87) | 598.70 (80.66) | 642.06 (128.34) | 660.04 (73.24) | 673.59 (104.00) | 682.01 (145.80) | 680.50 (81.700) | 627.02 (69.94) | 653.17 (104.48) | 627.59 (86.56) | 576.27 (81.22) | 662.67 (71.12) | 677.75 (94.88) |
| Closure Duration (ms) | C | 119.21 (43.08) | 116.54 (30.03) | 102.95 (24.84) | 160.13 (165.20) | 94.30 (21.65) | 91.22 (19.67) | 112.20 (29.35) | 97.30 (26.93) | 95.48 (35.79) | 144.76 (75.78) | 107.30 (27.69) | 110.84 (21.57) | 102.86 (29.39) | 91.17 (29.85) | 92.92 (18.50) | 100.01 (23.94) | 96.78 (37.89) | 87.21 (22.11) |
| | PD | 163.97 (81.35) | 118.31 (28.66) | 92.702 (33.72) | 114.67 (27.03) | 96.32 (21.03) | 102.81 (22.43) | 109.86 (43.39) | 95.10 (13.05) | 92.34 (25.59) | 137.54 (49.68) | 110.14 (52.04) | 102.69 (30.53) | 102.83 (35.29) | 101.46 (35.08) | 92.28 (17.03) | 99.04 (40.00) | 99.81 (28.03) | 91.60 (24.66) |
| Voicing in Closure (ms) | C | 22.91 (11.16) | 20.84 (9.19) | 21.11 (5.83) | 22.76 (7.25) | 17.14 (4.43) | 16.67 (9.18) | 17.63 (7.47) | 18.64 (5.25) | 18.58 (9.56) | 25.36 (14.55) | 16.93 (4.41) | 21.97 (11.68) | 25.39 (14.80) | 12.34 (2.51) | 32.13 (33.18) | 28.00 (11.25) | 18.57 (8.84) | 24.34 (9.98) |
| | PD | 40.27 (33.30) | 25.16 (12.79) | 23.05 (6.71) | 36.45 (20.35) | 33.32 (26.15) | 32.27 (13.75) | 23.84 (10.03) | 31.92 (21.15) | 22.99 (7.56) | 27.76 (14.28) | 46.63 (45.12) | 23.68 (15.26) | 19.12 (3.26) | 25.51 (19.25) | 33.34 (17.60) | 24.03 (15.44) | 33.98 (36.24) | 13.10 (8.41) |
| Percent Voicing (%) | C | 18.98 (8.81) | 20.95 (7.54) | 19.08 (8.60) | 16.94 (10.44) | 25.15 (13.34) | 17.18 (5.54) | 21.02 (11.31) | 18.32 (8.12) | 17.81 (11.34) | 17.87 (12.43) | 20.08 (7.44) | 15.98 (4.43) | 31.69 (27.96) | 22.07 (10.56) | 15.70 (7.56) | 26.95 (9.25) | 26.82 (13.21) | 19.98 (9.38) |
| | PD | 27.48 (18.31) | 18.87 (4.44) | 26.48 (15.39) | 27.81 (14.24) | 26.80 (18.70) | 26.80 (11.63) | 17.23 (xx) | 29.59 (18.92) | 18.663 (13.49) | 24.57 (9.38) | 49.29 (46.39) | 20.26 (7.32) | 23.37 (14.08) | 39.36 (38.34) | 33.18 (19.54) | 28.56 (24.53) | 30.69 (28.04) | 16.68 (10.96) |
| Voice Onset Time (ms) | C | 66.34 (52.84) | 66.68 (17.45) | 79.82 (28.24) | 56.45 (19.18) | 66.43 (14.48) | 76.47 (21.45) | 55.42 (16.80) | 59.69 (11.80) | 67.67 (20.56) | 45.69 (18.83) | 71.84 (28.18) | 68.68 (15.46) | 50.53 (13.30) | 62.93 (21.04) | 66.64 (15.61) | 52.29 (17.40) | 60.97 (27.76) | 62.16 (15.02) |
| | PD | 76.85 (29.67) | 89.52 (29.20) | 129.53 (47.19) | 64.41 (25.36) | 86.39 (29.05) | 96.57 (23.13) | 92.43 (64.68) | 89.95 (35.63) | 103.19 (45.02) | 78.64 (27.62) | 90.61 (15.09) | 102.23 (22.21) | 68.52 (25.48) | 82.70 (32.81) | 89.15 (26.11) | 63.29 (23.28) | 86.21 (26.04) | 92.74 (30.17) |
| Transient Duration (ms) | C | 85.05 (53.18) | 85.02 (16.50) | 98.79 (27.77) | 77.56 (18.76) | 87.23 (14.05) | 96.73 (19.97) | 84.33 (20.27) | 82.94 (12.33) | 88.26 (18.70) | 62.64 (17.21) | 88.23 (27.04) | 84.61 (14.76) | 69.46 (14.04) | 80.86 (19.52) | 84.46 (14.81) | 73.15 (19.53) | 80.19 (26.72) | 80.38 (14.91) |
| | PD | 89.38 (30.95) | 101.18 (29.16) | 142.19 (47.23) | 77.76 (26.31) | 99.53 (29.08) | 109.67 (23.92) | 97.04 (51.74) | 102.98 (35.80) | 117.34 (44.45) | 90.42 (28.14) | 101.99 (15.01) | 118.12 (19.97) | 80.84 (26.15) | 94.26 (32.93) | 102.14 (25.51) | 76.05 (24.21) | 98.23 (25.70) | 105.54 (28.97) |
| Vowel Mean Intensity (dB) | C | 70.02 (3.80) | 69.34 (3.19) | 68.48 (2.49) | 68.32 (3.32) | 67.38 (2.74) | 66.90 (2.90) | 67.33 (66.35) | 67.07 (3.31) | 66.32 (3.40) | 73.37 (3.55) | 74.74 (3.35) | 73.43 (3.00) | 72.38 (2.63) | 73.05 (3.18) | 71.77 (2.19) | 71.47 (3.00) | 72.14 (3.50) | 71.20 (0.66) |
| | PD | 64.69 (9.47) | 68.09 (4.40) | 66.25 (6.95) | 66.10 (6.45) | 67.84 (4.40) | 65.963 (5.84) | 66.35 (5.83) | 65.68 (66.60) | 62.09 (9.78) | 71.54 (6.54) | 71.37 (6.27) | 71.10 (7.13) | 73.61 (6.44) | 73.18 (6.03) | 72.82 (3.48) | 71.46 (7.08) | 71.80 (6.95) | 72.61 (2.03) |
| Vowel Peak Intensity (dB) | C | 71.94 (4.38) | 71.09 (3.68) | 70.09 (2.73) | 69.87 (3.56) | 69.16 (2.76) | 68.45 (2.67) | 69.02 (3.66) | 68.51 (3.04) | 68.00 (3.23) | 75.14 (1.50) | 76.54 (3.71) | 75.57 (3.32) | 74.06 (2.76) | 74.80 (2.67) | 73.57 (2.31) | 73.55 (2.53) | 73.85 (2.63) | 72.90 (74.13) |
| | PD | 67.71 (8.58) | 70.05 (4.44) | 68.63 (5.42) | 67.37 (6.05) | 70.03 (4.28) | 67.65 (5.09) | 67.28 (6.35) | 67.54 (6.23) | 63.77 (8.67) | 73.71 (6.24) | 69.15 (6.85) | 73.37 (6.63) | 75.28 (6.48) | 75.01 (4.87) | 74.29 (4.94) | 73.78 (5.98) | 73.44 (5.30) | 74.13 (4.43) |
| Syllable Mean Intensity (dB) | C | 72.78 (4.00) | 71.85 (3.29) | 72.01 (3.6) | 68.21 (3.96) | 69.78 (3.47) | 70.04 (3.29) | 68.21 (3.96) | 68.42 (3.96) | 67.64 (3.57) | 76.88 (2.69) | 77.30 (3.05) | 76.44 (3.37) | 74.75 (3.16) | 75.14 (2.90) | 74.83 (2.57) | 72.79 (3.54) | 72.74 (3.33) | 72.91 (3.56) |
| | PD | 69.70 (4.61) | 70.71 (1.91) | 66.90 (7.40) | 63.81 (5.58) | 68.00 (3.60) | 67.14 (3.17) | 63.81 (5.58) | 63.31 (7.18) | 63.30 (5.78) | 74.34 (5.53) | 74.73 (4.47) | 74.35 (4.50) | 73.79 (3.81) | 72.69 (3.68) | 73.12 (3.22) | 71.60 (4.39) | 70.19 (5.35) | 70.53 (5.83) |
| Syllable Peak Intensity (dB) | C | 76.04 (3.68) | 75.56 (3.21) | 75.76 (3.55) | 73.57 (3.72) | 72.80 (3.58) | 73.74 (3.29) | 72.11 (3.67) | 71.86 (3.64) | 71.49 (3.36) | 80.24 (2.50) | 80.52 (3.08) | 80.02 (3.29) | 77.46 (2.80) | 78.15 (3.22) | 77.66 (2.32) | 75.96 (3.27) | 76.76 (2.90) | 76.84 (2.96) |
| | PD | 72.91 (4.42) | 74.04 (2.24) | 70.69 (5.99) | 71.26 (3.81) | 70.37 (3.92) | 69.18 (3.10) | 67.99 (5.29) | 67.31 (6.19) | 67.13 (5.09) | 76.97 (5.44) | 77.45 (4.23) | 77.87 (4.14) | 76.02 (3.56) | 75.20 (3.73) | 75.47 (4.84) | 74.38 (4.48) | 73.36 (5.20) | 73.70 (5.46) |

Appendix A continued. Mean and standard deviation (parentheses) for each acoustic measure obtained from the Parkinson disease (PD) and control (C) groups in the noise conditions (no noise; 65 dB noise), speech contexts (isolated word, carrier phrase 1 & 2), and stop consonant test items (p, t, k).

| Measure | | No Noise | | | | | | | | | 65 dB Multitalker Noise | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Isolated | | | Carrier 1 | | | Carrier 2 | | | Isolated | | | Carrier 1 | | | Carrier 2 | | |
| | | p | t | k | p | t | k | p | t | k | p | t | k | p | t | k | p | t | k |
| Closure Intensity (dB) | C | 53.11 | 50.29 | 47.91 | 47.23 | 49.57 | 49.27 | 47.94 | 48.70 | 49.27 | 54.81 | 55.31 | 52.99 | 55.09 | 55.07 | 53.60 | 54.50 | 55.66 | 53.79 |
| | | (8.63) | (7.12) | (5.63) | (6.54) | (7.82) | (6.60) | (10.39) | (6.08) | (6.82) | (3.29) | (3.45) | (3.26) | (5.45) | (4.02) | (5.96) | (6.63) | (6.18) | (3.76) |
| | PD | 50.34 | 44.34 | 48.30 | 49.55 | 48.00 | 43.39 | 47.99 | 44.19 | 45.43 | 53.64 | 56.01 | 54.06 | 56.82 | 55.47 | 53.45 | 54.54 | 54.06 | 55.52 |
| | | (5.41) | (3.57) | (6.39) | (2.82) | (2.96) | (4.18) | (8.50) | (2.72) | (3.19) | (6.82) | (7.63) | (4.24) | (5.71) | (4.85) | (4.58) | (7.74) | (5.41) | (4.09) |
| Spirantization Intensity (dB) | C | 26.06 | 29.44 | 27.12 | 25.72 | 25.80 | 30.63 | 25.20 | 25.17 | 28.72 | 41.82 | 43.17 | 40.00 | 40.82 | 43.41 | 41.49 | 41.52 | 43.25 | 41.35 |
| | | (9.89) | (9.29) | (7.01) | (7.75) | (6.73) | (9.19) | (7.20) | (7.30) | (11.08) | (3.47) | (4.07) | (3.41) | (4.03) | (4.23) | (3.20) | (4.55) | (3.69) | (4.68) |
| | PD | 21.09 | 24.89 | 25.82 | 23.14 | 23.44 | 27.61 | 20.50 | 22.61 | 24.99 | 43.93 | 44.04 | 45.03 | 44.00 | 45.39 | 43.79 | 43.32 | 45.59 | 43.00 |
| | | (3.51) | (7.10) | (8.27) | (9.38) | (5.66) | (7.49) | (5.65) | (5.59) | (5.19) | (5.69) | (7.39) | (4.98) | (7.76) | (4.13) | (4.87) | (6.59) | (4.41) | (7.62) |
| Voicing Intensity (dB) | C | 40.73 | 42.28 | 36.65 | 38.86 | 41.54 | 41.47 | 37.80 | 40.71 | 39.36 | 48.58 | 50.62 | 48.62 | 51.10 | 51.07 | 49.12 | 50.53 | 52.30 | 50.36 |
| | | (11.02) | (40.53) | (7.12) | (8.79) | (10.55) | (10.80) | (10.60) | (9.35) | (11.52) | (4.43) | (5.65) | (4.58) | (6.15) | (5.31) | (7.27) | (7.84) | (6.32) | (4.18) |
| | PD | 42.25 | 34.28 | 37.59 | 40.54 | 36.66 | 35.13 | 38.74 | 35.93 | 37.24 | 50.53 | 53.58 | 50.77 | 52.43 | 52.83 | 51.29 | 53.00 | 49.03 | 52.46 |
| | | (41.24) | (3.34) | (10.20) | (9.13) | (8.42) | (5.40) | (7.43) | (4.74) | (5.22) | (7.55) | (8.76) | (2.57) | (7.87) | (5.09) | (4.95) | (8.11) | (8.79) | (5.97) |
| Spirantization Ratio | C | 45.033 | 54.75 | 54.27 | 50.19 | 48.42 | 59.26 | 49.55 | 47.97 | 55.10 | 75.32 | 77.47 | 74.32 | 73.18 | 77.81 | 76.50 | 75.26 | 77.01 | 76.25 |
| | | (13.13) | (12.18) | (16.39) | (10.74) | (9.06) | (15.55) | (10.05) | (9.34) | (19.27) | (5.69) | (7.74) | (5.82) | (8.38) | (5.62) | (5.91) | (6.67) | (6.36) | (4.58) |
| | PD | 43.01 | 56.27 | 52.80 | 46.77 | 49.43 | 62.97 | 43.64 | 51.21 | 55.25 | 82.26 | 81.57 | 83.63 | 77.24 | 82.05 | 82.07 | 79.53 | 84.59 | 77.49 |
| | | (8.73) | (14.31) | (10.88) | (14.63) | (13.38) | (12.88) | (9.25) | (10.32) | (8.66) | (5.47) | (3.07) | (7.87) | (5.70) | (3.63) | (5.77) | (2.60) | (5.00) | (11.47) |
| Voicing Ratio | C | 74.27 | 82.11 | 74.75 | 80.15 | 81.59 | 81.95 | 77.23 | 81.61 | 77.01 | 88.14 | 91.25 | 91.34 | 92.34 | 92.22 | 90.96 | 92.19 | 93.59 | 93.14 |
| | | (10.21) | (10.32) | (9.60) | (10.74) | (9.87) | (13.57) | (9.95) | (11.62) | (16.78) | (5.34) | (7.24) | (5.79) | (4.52) | (4.27) | (4.16) | (5.45) | (3.04) | (3.99) |
| | PD | 84.45 | 77.85 | 77.04 | 81.53 | 75.97 | 80.94 | 81.49 | 81.50 | 82.22 | 94.09 | 95.46 | 94.14 | 92.15 | 95.29 | 95.96 | 97.13 | 90.33 | 94.32 |
| | | (13.33) | (11.25) | (11.05) | (13.92) | (12.83) | (8.41) | (10.89) | (10.04) | (10.12) | (3.63) | (3.63) | (2.77) | (7.19) | (3.96) | (2.57) | (2.45) | (7.14) | (4.65) |
| Spectral Centre of Gravity | C | 195.29 | 614.47 | 320.28 | 230.66 | 688.86 | 301.28 | 234.38 | 676.43 | 292.40 | 248.96 | 835.77 | 374.07 | 266.09 | 777.83 | 318.16 | 270.83 | 618.34 | 314.22 |
| | | (54.45) | (434.32) | (68.11) | (65.62) | (683.69) | (65.46) | (46.76) | (690.15) | (66.59) | (48.09) | (543.95) | (82.07) | (70.15) | (554.65) | (69.47) | (68.21) | (345.33) | (65.07) |
| | PD | 248.49 | 710.18 | 628.05 | 202.10 | 704.49 | 341.52 | 210.80 | 980.58 | 634.91 | 243.97 | 1624.49 | 694.12 | 228.11 | 1407.23 | 443.20 | 249.31 | 1350.90 | 421.60 |
| | | (80.76) | (506.11) | (504.48) | (32.30) | (549.40) | (84.45) | (47.84) | (752.25) | (749.65) | (65.44) | (1803.87) | (647.23) | (56.79) | (1802.52) | (289.29) | (81.58) | (1779.04) | (257.16) |
| Spectral Standard Deviation | C | 336.39 | 1303.27 | 650.50 | 308.93 | 1249.39 | 570.39 | 307.49 | 1208.50 | 515.29 | 358.95 | 1593.74 | 761.04 | 377.19 | 1527.32 | 584.25 | 363.83 | 1303.34 | 598.62 |
| | | (145.14) | (823.17) | (163.89) | (97.91) | (941.92) | (147.36) | (78.73) | (914.84) | (138.41) | (117.89) | (816.31) | (222.45) | (164.83) | (847.27) | (209.69) | (98.27) | (662.21) | (154.78) |
| | PD | 420.64 | 1354.57 | 1171.84 | 290.79 | 1416.87 | 794.67 | 404.52 | 1683.36 | 1119.28 | 458.23 | 1867.35 | 1195.75 | 456.09 | 1593.24 | 880.68 | 455.32 | 1562.81 | 823.17 |
| | | (212.72) | (709.33) | (719.66) | (137.07) | (901.74) | (277.65) | (295.71) | (1007.22) | (752.98) | (232.30) | (1190.28) | (833.57) | (233.88) | (1153.08) | (624.86) | (228.90) | (1085.77) | (546.53) |
| Spectral Skewness | C | 16.70 | 6.74 | 8.58 | 12.86 | 7.30 | 9.29 | 13.03 | 7.40 | 10.20 | 12.19 | 4.85 | 7.72 | 11.63 | 5.19 | 9.41 | 11.22 | 5.67 | 8.94 |
| | | (9.33) | (4.76) | (2.23) | (4.87) | (5.03) | (1.64) | (2.95) | (4.97) | (1.89) | (3.81) | (3.50) | (2.78) | (4.12) | (3.47) | (2.61) | (3.62) | (3.32) | (1.60) |
| | PD | 13.46 | 5.80 | 6.98 | 17.00 | 6.33 | 8.12 | 16.16 | 5.67 | 6.63 | 12.85 | 4.63 | 6.16 | 13.60 | 5.16 | 8.79 | 14.53 | 5.31 | 8.69 |
| | | (7.72) | (4.45) | (5.85) | (6.34) | (4.55) | (4.04) | (9.15) | (4.36) | (4.09) | (7.00) | (4.80) | (4.28) | (7.09) | (4.27) | (5.49) | (7.62) | (4.40) | (5.52) |
| Spectral Kurtosis | C | 507.44 | 75.21 | 97.58 | 289.042 | 94.65 | 111.25 | 280.04 | 98.79 | 139.89 | 247.77 | 37.91 | 81.51 | 225.14 | 42.90 | 124.29 | 208.31 | 48.95 | 105.86 |
| | | (634.40) | (94.13) | (50.70) | (203.26) | (102.52) | (42.78) | (128.35) | (110.96) | (53.86) | (161.98) | (50.18) | (68.53) | (134.00) | (51.16) | (70.37) | (107.20) | (57.83) | (41.28) |
| | PD | 359.22 | 60.95 | 93.36 | 546.69 | 65.43 | 92.51 | 564.71 | 53.02 | 64.93 | 317.12 | 50.08 | 67.65 | 345.67 | 49.36 | 130.79 | 385.98 | 49.78 | 126.25 |
| | | (437.62) | (87.17) | (132.92) | (500.46) | (78.17) | (91.83) | (640.42) | (74.41) | (69.23) | (375.80) | (80.34) | (88.31) | (388.98) | (55.33) | (164.11) | (423.29) | (56.60) | (161.11) |