Acoustic and Perceptual Consequences of Clear and Loud Speech

Kris Tjaden, PhD
Department of Communicative Disorders and Sciences, University at Buffalo
122 Cary Hall, 3435 Main Street
Buffalo, NY 14214 (USA)
E-Mail Tjaden@buffalo.edu

© 2014 S. Karger AG, Basel
Published online: February 5, 2014
DOI: 10.1159/000355867

Key Words
F2 slope · Clear speech · Loud speech · Intelligibility

Introduction

The slope of the second formant (F2) frequency is an acoustic measure reflecting rate of vocal tract shape change [1]. Shallower slopes also are associated with slower lingual movement speeds [2]. Compared to healthy talkers, reduced F2 slopes have been reported for a variety of dysarthrias and neurological diagnoses, including Parkinson’s disease (PD) – the clinical population of interest to the current study [see reviews in 1–5]. Research further suggests that F2 slope measures do not differ for dysarthrias of different etiologies or types [4, 5]. Finally, F2 slope is sensitive to dysarthria severity such that speakers with more severe dysarthria or relatively poorer intelligibility have shallower F2 slopes compared to speakers with less severe dysarthria or relatively better intelligibility [2, 4, 5].

Although F2 slope in dysarthria has been studied a fair amount, several issues deserve additional attention. One of these issues is the utility of average F2 slope metrics, as reported in the studies reviewed in the preceding paragraph, versus extreme F2 slope metrics for characterizing articulatory behavior in dysarthria. By way of background, F2 slope is typically quantified as transition extent divided by transition duration, with transition onset...
and offset identified using the 20 Hz/20 ms rule [6]. The traditional slope measure thus reflects overall or average rate of spectral change during the operationally defined transition interval. F2 slope also may be computed on a point-by-point basis from a linear predictive coding (LPC)-generated F2 trajectory to yield a time history of instantaneous slope values. The transition interval is still identified using the 20 Hz/20 ms rule and instantaneous slope values are averaged over the transition interval to provide an overall or average F2 slope metric which correlates strongly with the traditional transition extent/transition duration measure [2, 7]. This approach also allows extreme instantaneous slope values, such as maxima, to be identified. A recent study of multiple sclerosis further concluded that extreme F2 slope measures were more sensitive to mild dysarthria than average slope measures [8]. Only one dysarthria study has reported extreme F2 slope metrics, however, and additional studies obviously are needed before drawing strong conclusions regarding the utility of extreme F2 slope metrics in mild dysarthria. Indeed, there is likely some redundancy between average and extreme slope measures owing to their part-whole relationship, although the relationship has not been empirically evaluated.

F2 slope also shows strong potential as an objective measure of treatment-related changes in the articulatory mechanism for individuals with PD [1], yet few treatment-related studies of PD have reported F2 slope measures. Moreover, results of these studies which have employed formal training programs such as the Lee Silverman Voice Treatment® (LSVT) as well as stimulation are equivocal [9, 10]. An increased vocal intensity is probably the most widely used treatment technique for PD, but clear speech is another global therapy technique that shows promise for addressing the speech impairment in PD as well as for enhancing intelligibility [11]. Global techniques span the time domain of an utterance and have the potential to simultaneously impact multiple speech subsystems [11]. In this manner, although an increased vocal intensity focuses on modifying respiratory-phonatory behavior, adjustments in segmental articulatory behavior may occur. Similarly, clear speech focuses on exaggerated articulation, but respiratory-phonatory adjustments may also accompany clear speech. Comparative studies are critical for determining the relative advantages of therapeutic techniques, but studies comparing an increased intensity and clear speech in PD are lacking.

In conclusion, the present study sought to address several issues concerning F2 slope in dysarthria. First, the utility of an extreme or maximum F2 slope measure for characterizing articulatory behavior in dysarthria above and beyond the traditional, average or overall F2 slope measure is not well understood. The sensitivity of F2 slope to articulatory changes elicited by different global dysarthria therapy techniques also is not well established. The current study sought to advance understanding of these issues by comparing the impact of clear speech and an increased vocal intensity on average and maximum F2 slope metrics for diphthongs produced by speakers with mild dysarthria secondary to PD as well as healthy controls. The strength of the relationship between average and maximum F2 slope metrics was quantified as was the relationship between F2 slope and vocal intensity. Our interest in the relationship between F2 slope and vocal intensity was motivated by statements in the dysarthria literature concerning the potential ‘spreading effect’ of an increased vocal effort to the articulatory mechanism [12, 13], although studies of neurologically normal speech have demonstrated the reverse—that articulatory adjustments impact phonatory behavior [e.g., 14, 15]. Given the potential for clear speech and an increased intensity to enhance intelligibility as well as long-standing interest in the relationship between F2 slope and intelligibility in dysarthria, we also investigated the predictive relationship of F2 slope to intelligibility for the PD group. Magnitude production was used to elicit an increased vocal intensity and clear speech. Although results are not directly comparable to studies employing training, studies investigating experimental manipulation of speech suggest the potential of intervention techniques [11, 16]. Finally, although speakers with PD in the current study had mild dysarthria, even persons with mild dysarthria may benefit from treatment focused on an increased vocal intensity or clear speech [11, 16].

**Method**

**Speakers**
Thirteen speakers with idiopathic PD and 15 healthy controls who are part of a larger project were included for study [17]. The PD group was comprised of 7 men and 6 women 48–78 years of age (mean = 68; SD = 10), and the control group was comprised of 8 men and 7 women 46–75 years of age (mean = 61; SD = 10). Participants were native speakers of American English, spoke with the Inland North dialect of western New York State and scored at least 26/30 on the Standardized Mini-Mental State [18]. No speaker used a hearing aid or had undergone neurosurgery. Two females with PD had completed LSVT more than 2 years prior to the study and one of these speakers was enrolled in a group, bimonthly LSVT...
refractory course. Speakers with PD were recorded 1 h prior to taking medication. All speakers were paid USD 10 per hour.

Table 1 describes the PD group. Sentence intelligibility scores for 10 student listeners as well as 3 speech-language pathologists’ mean judgment of speech severity for the ‘Grandfather Passage’ were previously reported [17]. The operationally defined perceptual construct of speech severity aims to tap into prosodic adequacy and naturalness with values closer to 1.0 indicating more impairment and values closer to 0 indicating less impairment. Sentence intelligibility test scores [19] in table 1 for the PD group (mean = 89; SD = 3) coupled with mid-range judgments of speech severity (mean = 0.54; SD = 0.21) are consistent with clinical descriptions of mild dysarthria [16]. For comparison, the mean sentence intelligibility test score for the control group was 93 (SD = 2), and mean speech severity was 0.26 (SD = 0.14). The slightly reduced intelligibility and elevated speech severity scores for controls likely reflect the fact that speech samples were pooled across normal and disordered speakers for these analyses [17]. Speakers with PD were further noted to have reduced segmental precision and a breathy, monotonous voice.

Experimental Speech Stimuli and Procedures
Speakers were audio recorded in a sound-treated room reading 25 Harvard Psychoacoustic Sentences [20] in a variety of conditions. The Habitual, Clear and Loud conditions were of interest to the current study. Across 12 sentences, there were 10 occurrences of /ɔɪ/ and 4 occurrences of /œɪ/ in stressed syllables of content words varying in sentence position and phonetic context. The acoustic signal was transduced using an AKG C410 head-mounted microphone positioned 10 cm and 45–50° from the left oral angle. The signal was preamplified, low pass-filtered at 9.8 kHz and digitized to computer hard disk at a sampling rate of 22 kHz using TF32 [21]. A calibration tone also was recorded to allow for offline measurement of vocal intensity from the acoustic signal. For the Loud condition, participants were instructed to use a vocal intensity twice as loud as their typical speech. For the Clear condition, participants were instructed to say each sentence twice as clearly as their typical speech. Speakers were told to exaggerate the movements of their mouth and were instructed that this is how they might speak to someone in a noisy environment or to someone with a hearing loss. Speakers also were told that their speech might be slower and louder than usual. Instructions were modeled after those used in other clear speech studies [22]. For each speaker and condition, a unique ordering of sentences was recorded. Sentences were read first in the Habitual condition with the order of the remaining conditions randomized across speakers.

Acoustic Analysis
Acoustic measures were obtained using TF32. Measures of sentence-level sound pressure level (SPL) and articulatory rate served to document that the magnitude production paradigm elicited production differences among conditions. Diphthong durations, described in the following paragraph, further documented segment-level duration differences among conditions. Sentences first were segmented into runs using the combined waveform and wideband (300–400 Hz) spectrographic displays. A run was operationally defined as a stretch of speech bounded by silent periods between words of at least 200 ms. Run onsets and offsets were identified using conventional acoustic criteria. Articulatory rate, in syllables per second, was determined by tallying the number of syllables per run and dividing by run duration. Mean SPL for each run was obtained by using the root-mean-squared intensity trace of TF32. For each speaker and condition, SPL and rate measures were averaged across runs.

Diphthong onsets and offsets were identified and labeled from the combined waveform and wideband (300–400 Hz) spectrographic displays. Pitch-synchronous LPC tracks on a wideband (300–400 Hz bandwidth; 26 coefficients) spectrogram were generated and computer-generated tracking errors were manually corrected. Diphthong duration was calculated as the time between diphthong onset and offset. Instantaneous slope was computed for each point of the LPC F2 formant time history as the change in frequency (Hz) divided by the change in time (ms). Instantaneous slope values were subsequently used to identify the onset and offset of each major, rising F2 transition using operational criteria approximating the 20 Hz/20 ms rule [6]. Maximum F2 slope was identified as the maximum instantaneous slope value of the F2 transition. Average F2 slope was obtained by averaging all instantaneous slope values during the operationally defined transition. For each speaker, condition and diphthong, segment durations and F2 slope measures were averaged across tokens.

Perceptual Task
Fifty listeners aged 18–30 years judged sentence intelligibility. Listeners were native speakers of standard American English, had at least a high school diploma, reported no history of speech, language, or hearing problems, passed a hearing screening at 20 dB HL for octave frequencies from 250 to 8,000 Hz bilaterally and were unfamiliar with speech disorders. Listeners were paid USD 10 per hour.

For each speaker, a random selection of the same 10 Harvard Sentences produced in all conditions was studied to allow the perceptual task to be completed in a single session. To prevent ceiling effects, sentences were presented in multitalker babble, as is commonly done in the clear speech literature [20]. Sentences first were normalized for

<table>
<thead>
<tr>
<th>Table 1. Characteristics for participants with PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject code</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>PD 01</td>
</tr>
<tr>
<td>PD 02</td>
</tr>
<tr>
<td>PD 04</td>
</tr>
<tr>
<td>PD 05</td>
</tr>
<tr>
<td>PD 06</td>
</tr>
<tr>
<td>PD 08</td>
</tr>
<tr>
<td>PD 01</td>
</tr>
<tr>
<td>PD 02</td>
</tr>
<tr>
<td>PD 03</td>
</tr>
<tr>
<td>PD 04</td>
</tr>
<tr>
<td>PD 06</td>
</tr>
<tr>
<td>PD 07</td>
</tr>
<tr>
<td>PD 08</td>
</tr>
</tbody>
</table>

Mean ± SD 68±9 9±8 89±3 0.54±0.21
peak amplitude using Goldwave version 5 [23], and then mixed with 20-person babble [24, 25] in Goldwave. A signal-to-noise ratio of ~3 dB was applied to each sentence, as pilot testing indicated that this signal-to-noise ratio minimized both floor and ceiling effects. This signal-to-noise ratio also has been used in other studies [26, 27]. Stimuli were presented to listeners at 75 dB SPL via headphones (Sony, MDR V300) in a double-walled audiometric booth.

Listeners judged intelligibility using a computerized, continuous 150-mm visual analog scale [17]. Each sentence was judged without knowledge of the speaker’s neurological diagnosis or identity. Written and verbal instructions directed listeners to judge how well sentences could be understood, with endpoints of the continuous scale labeled as ‘Understand everything’ to ‘Cannot understand anything’. Sentences for all speakers from the larger database and all conditions were pooled and divided into 10 sets. Sets were constructed to ensure each set was comprised of one sentence produced by each talker in each condition and that all 25 Harvard Sentences were represented in similar proportions. Five listeners judged each set. To determine intrajudge reliability, 10% of the sentences were presented twice. Pearson product correlations for intrajudge reliability ranged from 0.60 to 0.88 (mean = 0.72; SD = 0.07) for the 50 listeners. Interjudge reliability was assessed using the intraclass correlation coefficient. Mean intraclass correlation coefficients ranged from 0.85 to 0.91 (mean = 0.85; SD = 0.02) across the 10 sets and were significant (p < 0.001). Listener reliability is considered further in the ‘Discussion’.

Data Analyses

Descriptive and parametric statistics were employed. The variables of articulatory rate, SPL, average F2 slope, maximum F2 slope, and intelligibility were fit with a mixed linear model in this repeated measures design. The within-subjects factor was Condition (Habitual, Clear, Loud) and the between-subjects factor was Group (PD, Control). Covariates included age and speaker sex. F2 slope analyses also included diphthong segment duration as a covariate, given studies reporting a relationship between speech duration and F2 slope [2]. Post hoc comparisons were made using a Bonferroni correction. Relationships among variables were examined using correlation and regression analyses.

### Results

#### Speech Durations and Vocal Intensity

Table 2 reports descriptive statistics for SPL and duration. The Condition effect was significant for articulation rate \( F(2, 52) = 70.88, p < 0.0001 \) and SPL \( F(2, 52) = 157.36, p < 0.0001 \). Post hoc testing within groups confirmed differences for all pairs of conditions (\( p < 0.003 \)), with the exception of the PD group’s Habitual-Loud contrast for articulation rate. The Group effect also was significant for articulation rate \( F(1, 24) = 9.39, p = 0.005 \) and mean SPL \( F(1, 24) = 10.76, p = 0.003 \). The interaction of Group and Condition also was significant for SPL \( F(2, 52) = 6.49, p = 0.003 \). Post hoc testing indicated that the interaction was due to the PD group having a reduced SPL compared to controls in both the Clear and Loud conditions, but not Habitual (\( p < 0.004 \)). Segment duration results were identical to those for articulation rate. To summarize, both groups increased vocal intensity in the Clear and Loud conditions relative to Habitual, with the magnitude of the increase being greatest for the Loud condition. SPL for the PD group also was reduced compared to controls in both the Clear and Loud conditions, but not Habitual. Segment duration results were identical to those for articulation rate. To summarize, both groups increased vocal intensity in the Clear and Loud conditions relative to Habitual, with the magnitude of the increase being greatest for the Loud condition. SPL for the PD group also was reduced compared to controls in both the Clear and Loud conditions.

Both groups also typically lengthened speech durations for the Clear and Loud conditions, although speech durations for the PD group tended to be accelerated compared to controls.

#### F2 Slope

Table 3 reports descriptive statistics for slope. Within groups and conditions, average and maximum slope metrics were significantly correlated for both diphthongs, with Pearson r coefficients ranging from 0.76 to 0.92.

---

Table 2. Means and SDs for speech durations, vocal intensity and scaled sentence intelligibility

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>Habitual</th>
<th>Clear</th>
<th>Loud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulatory rate, syllables/s</td>
<td>control</td>
<td>3.7±0.5</td>
<td>2.4±0.4</td>
<td>3.3±0.6</td>
</tr>
<tr>
<td></td>
<td>PD</td>
<td>4.0±0.6</td>
<td>3.1±0.7</td>
<td>3.9±0.7</td>
</tr>
<tr>
<td>SPL, dB</td>
<td>control</td>
<td>74±2.8</td>
<td>79±4.4</td>
<td>85±4.2</td>
</tr>
<tr>
<td></td>
<td>PD</td>
<td>72±2.4</td>
<td>75±3.6</td>
<td>79±3.0</td>
</tr>
<tr>
<td>Diphthong duration /ɑɪ/, ms</td>
<td>control</td>
<td>178±69</td>
<td>273±119</td>
<td>231±92</td>
</tr>
<tr>
<td></td>
<td>PD</td>
<td>165±51</td>
<td>224±99</td>
<td>188±69</td>
</tr>
<tr>
<td>Diphthong duration /ɔɪ/, ms</td>
<td>control</td>
<td>190±43</td>
<td>304±80</td>
<td>253±65</td>
</tr>
<tr>
<td></td>
<td>PD</td>
<td>178±53</td>
<td>249±101</td>
<td>206±52</td>
</tr>
<tr>
<td>Intelligibility</td>
<td>control</td>
<td>0.32±0.07</td>
<td>0.23±0.06</td>
<td>0.22±0.09</td>
</tr>
<tr>
<td></td>
<td>PD</td>
<td>0.50±0.13</td>
<td>0.38±0.15</td>
<td>0.35±0.12</td>
</tr>
</tbody>
</table>

Smaller numerical values for intelligibility (i.e., values closer to 0) indicate relatively better intelligibility.
for SPL. Only the Control group’s Clear regression for speaker sex was not significant in the statistical analysis and females was pooled as the variable representing conditions for each group and diphthong. Data for males were further characterized by lengthened durations, increased intensity and improved intelligibility versus Habitual and Loud conditions. Clear and Loud speech for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.

The relationship of average F2 slope to intelligibility for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.

The relationship of average F2 slope to intelligibility for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.

The relationship of average F2 slope to intelligibility for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.

The relationship of average F2 slope to intelligibility for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.

The relationship of average F2 slope to intelligibility for the PD group was examined using hierarchical regression analysis. Additional predictor variables included articulation rate and vocal intensity. Speaker sex was not significant in the intelligibility analysis previously summarized. Thus, as in other studies, data for men and women were pooled [2]. F2 slope values were averaged across diphthongs thus yielding a composite F2 slope metric similar to composite metrics for articulation rate, SPL and intelligibility. The model including only F2 slope accounted for 14% of the variance in intelligibility [F (1, 24) = 13.84, p < 0.001]. The Condition effect also was significant [F (2, 52) = 26.85, p < 0.0001]. Post hoc tests further indicated better intelligibility in the Clear and Loud conditions for both groups versus Habitual (p < 0.003), but no difference for Clear and Loud.
bital. F2 slope and intensity were unrelated but F2 slope was a significant predictor of intelligibility. The remainder of the ‘Discussion’ considers these findings and their implications in more detail.

In addition to eliciting adjustments in segmental articulation, as inferred from F2 slope, it is worth reiterating at the outset that the magnitude production paradigm was successful in eliciting variations in vocal intensity, speech duration and intelligibility. The nature of changes in vocal intensity and speech duration were similar for the Clear and Loud conditions relative to Habitual, although the magnitude of the adjustments differed. The finding of similar magnitudes of improvement in intelligibility for the Clear and Loud conditions versus Habitual further suggests the feasibility of using either a clear speech style or an increased vocal intensity therapeutically to enhance intelligibility for speakers with mild dysarthria secondary to PD. Comparative studies employing training paradigms are needed to build upon these results to determine whether the short-term effects for experimental speech stimuli demonstrated here can be maintained in the long term for functional speech tasks.

The sensitivity of F2 slope to articulatory changes elicited by different global dysarthria therapy techniques was one topic of interest. With the exception of maximum F2 slope for /ɒɪ/, the Clear condition generally yielded F2 slopes for the PD group that not only were significantly different from Habitual, but also more closely approximated Habitual slopes for neurologically normal talkers. Thus, results support the suggestion that F2 slope might serve as an objective metric of treatment-related changes in the articulatory mechanism in PD [1], at least for behavioral techniques such as clear speech which focus on articulatory behavior. The finding that F2 slope metrics in the Loud condition did not differ from Habitual is not entirely unexpected given other studies [9, 10]. However, it is important to note that an increased vocal intensity has been shown to be associated with other types of segmental articulatory adjustments. For example, an expanded vowel space area and enhanced spectral distinctiveness for stops as well as increased movement velocities and displacements may accompany an increased vocal intensity [e.g., 9, 10, 13, 26]. Thus, F2 slope may simply not be sensitive to intensity-related adjustments in articulatory behavior. The lack of a robust relationship between F2 slope and SPL supports this suggestion.

The nature of the relationship between maximum and average F2 slope metrics also was of interest as well as the ability of both metrics to distinguish speakers with mild dysarthria from healthy controls. Average but not maximum F2 slope metrics were significantly reduced for the PD group versus controls. Thus, results do not support the suggestion that measures of extreme F2 slope are more sensitive to mild dysarthria than average slope measures [8]. The correlation analysis further indicated a great deal of redundancy or overlap for the two slope measures. Given that extreme F2 slope metrics were not consistently sensitive to condition-related adjustments in segmental articulation, the strong correlation between the two slope metrics, and the fact that only average F2 slope distinguished the PD and control groups, the value of obtaining maximum F2 slope metrics in dysarthria seems questionable. Before drawing strong conclusions, however, studies with greater speaker numbers and more varied phonetic contexts are needed.

Finally, an ongoing goal of dysarthria research is to identify aspects of speech potentially related to intelligibility. In the present study, a composite metric of average F2 slope was a significant predictor of intelligibility for the PD group when data were pooled across conditions, with articulation rate and vocal intensity explaining an additional small amount of the variance in intelligibility. Thus, as suggested in other studies, F2 slope is linked to intelligibility even in mild dysarthria and holds promise as an index of functional communication skill [2, 5]. The final regression model indicated that steeper F2 slopes, slower articulation rates, and higher vocal intensities were associated with better intelligibility. A clinical implication is that therapeutic techniques that elicit an increase in F2 slope, reduced articulation rate and increased vocal intensity would likely also maximize intelligibility.

Caveats

Several factors should be kept in mind when interpreting results. The importance of studying intelligibility in dysarthria in adverse listening conditions has been noted, and multitalker babble is arguably an ecologically valid perceptual environment [11]. However, results may differ for speech in quiet. Listener reliability metrics further suggest the challenging nature of the intelligibility task. Although some reliability metrics may appear modest, our metrics compare well to other studies using scaling tasks to measure intelligibility in dysarthria [e.g., 28–30]. Moreover, when the intelligibility data were reanalyzed using only listeners with intra-judge reliability of $r = 0.7$ or better, results were identical to those for the larger pool of 50 listeners. Finally, although unlikely, it is possible that LSVT history for 2 of

Consequences of Clear and Loud Speech

Folia Phoniatri Logop 2013;65:214–220
DOI: 10.1159/000355867

Downloaded by: 54.191.40.80 - 4/18/2017 9:57:10 PM
the PD speakers had some bearing on the results. The direction of the effect would be to magnify differences between the Loud condition and other conditions, however. Thus, if anything, acoustic and intelligibility changes associated with the Loud condition are overestimated in the current study.

Conclusions

In conclusion, average diphthong F2 slope was more sensitive than maximum F2 slope for capturing articulatory involvement in mild dysarthria in PD. Future studies are needed to determine whether F2 slope metrics might be sensitive to disease presence in the articulatory mechanism in PD prior to any observable reduction in intelligibility. F2 slope also holds promise as an objective measure of treatment-related changes in the articulatory mechanism for therapeutic techniques that focus on eliciting changes in articulation. Studies employing kinematic, acoustic, and perceptual methods, such as that of Yunusova et al. [2], would aid in further understanding the nature of the speech movements responsible for changes in F2 slope and the impact on intelligibility.

Acknowledgments

Research was supported by R01DC004689.

References