Relationship Between Acoustic Measures and Judgements of Intelligibility in Parkinson's Disease: A Within-Speaker Approach

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Hypokinetic Dysarthria

https://www.youtube.com/watch?v=X39j42u33wQ

Purpose and Objectives

- An individual with dysarthria often has reduced intelligibility.

- Identify acoustic variables that contribute to intelligibility.
  - Current understanding is incomplete with mixed results.
  - Previous research has utilized a different study design.

Main Question

Is **GREATER** modulation in **fundamental frequency** (F0) and **sound pressure level** (SPL), as well as relatively greater **F2 interquartile range** (F2 IQR), associated with **GREATER** scaled sentence **intelligibility** for the individual's with Parkinson's disease?

Previous Research: Intelligibility

- **Speech Rate**
  - The number of output units per unit time, including pauses.
    - Previous research has yielded inconsistent results.
- **Fundamental Frequency (F0)**
  - Sentence-level measures of F0 have been found to be related to intelligibility.
    - Dysarthric speakers: If F0 is reduced at the sentence-level, intelligibility is reduced.
    - Healthy speakers: speakers that were rated as more intelligible had greater sentence-level F0 ranges.
    - Adjacent Syllable Boundaries
    - Reduced F0 has been associated with reduced intelligibility.
      - Hinders a listener's ability to identify lexical boundaries within an utterance.

Previous Research: Intelligibility

- **Sound Pressure Level (SPL)**
  - Increase in SPL is associated with an increase in intelligibility.
    - Supported by studies assessing efficacy of LSVT™ intervention.
    - Suggested that increased vocal intensity could be related to an increase in F0/F0 range, expanded vowel space, or spectral differences.
    - May be related to an improved signal-to-noise ratio.
      - Further research is needed to fully understand this relationship.
  - Reduced SPL modulation tended to be associated with reduced speech intelligibility for individuals with ALS.
    - Other studies have found no relationship.
    - Mixed results, requiring further research.

Previous Research: Intelligibility

- **Vocal Segmental Integrity**
  - Shallower F2 slopes, associated with slower tongue movement speeds, resulted in ratings of poorer speech intelligibility**.**

- **Group vs. Within-Speaker Design**
  - Group designs typically include individuals with a large span in severity of the disease; a third mediating variable may be influencing the results.
  - Within-speaker design studies have found that F2 IQR may partially explain within-speaker variation in intelligibility for individuals with Parkinson's disease.

Methods

- **Participants**
  - 12 speakers with idiopathic Parkinson's disease
  - 12 age-matched healthy speakers
    - Native speakers of English
    - Achieved at least a high school diploma
    - Did not use a hearing aid
      - Thresholds of at least 40 dB HL in one ear at 1000 and 2000 Hz
    - Scored 26 or greater on the MMSE

- **Intelligibility Ratings**
  - Grandfather Passage
    - Scaled Speech Severity
    - Sentence Intelligibility Test

Methods

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  Speech Task
  Stimuli:
  - 10 sentences from the IEEE Harvard Psychoacoustic Sentences
    - Declarative and imperative sentences
    - 7 to 9 words in length
  - Setting:
    - Sound-treated room
  - Equipment:
    - AKG C410 head mounted microphone, 10 cm from the lips
    - TF32.
  - Conditions:
    - Habitual
    - Clear
    - Loud
    - Fast
    - Slow

Methods

- **Listeners**
  - 50 inexperienced listeners
    - Native speakers of English
    - Between 18 and 30 years of age
    - No history of speech, language or hearing problems
    - Passed a hearing screen at 20 dB HL bilaterally

Methods

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  Perceptual Task
  Listeners judged the intelligibility for the sentences using a 150mm computerized Visual Analog Scale

Understand Everything

Cannot Understand Anything

- Stimuli were presented over headphones (Sony MDRV300) at 75 Db HL for peak vowel amplitude of key words in sentences
- Listeners were blinded to participants' neurological status.
- Five listeners judged each set of sentences
  - Each set contained one sentence from each participant

Methods

- **Statistical Analysis**
  - Levene's test for homogeneity of variance
    - Assumption was not met
  - Non-parametric Mann-Whitney *U* tests
    - Compare acoustic measures for the two groups.
  - Spearman rank order correlations
    - Evaluate the strength of association between the acoustic variables and scaled sentence intelligibility within each speaker.
      - Moderate correlations ±0.30 are considered meaningful.

Results

- **Scaled Sentence Intelligibility and Acoustic Measures**
  - PD: 0.47 (SD = 0.14)
  - Controls: 0.28 (SD = 0.10)
    - Significant difference for intelligibility was found across the two different groups of speakers.
  - *Descriptive Statistics*:
    - PD, on average, demonstrated:
      - Slightly faster articulatory rates
        - Consistent with diagnosis of dysarthria in PD.
      - Reduced F2 IQR
      - Greater across-speaker F2 IQR variability
      - Greater F0 range
      - Greater F0 SD
      - Reduction in mean SPL
      - Reduced SPL SD

Results

- **Correlations between Acoustic Measures and Intelligibility (PD)**

Table 3. Spearman rank order correlation results are reported.

Speaker	Articulatory Rate (syll/sec)	Mean F0 (Semitone)	F0 SD (Semitone)	F0 Range (Semitone)	Mean SPL (dB)	SPL SD (dB)	F2 IQR (Hz)
PDM07	**0.370**	0.055	−0.139	−0.127	0.261	−0.115	−0.091
PDF01	−0.152	0.103	0.091	0.055	0.164	**0.370**	0.067
PDM01	0.018	**−0.503**	**0.479**	**0.527**	−0.030	0.292	0.139
PDM06	**−0.794***	**0.806***	**0.491**	**0.442**	0.188	0.134	**0.673***
PDM08	**−0.576**	0.176	**−0.515**	−0.176	0.018	0.127	**0.503**
PDF05	−0.115	**−0.442**	**0.418**	**0.503**	−0.238	0.042	**−0.321**
PDF04	**0.430**	**−0.333**	0.127	0.103	**0.559**	−0.243	0.236
PDF06	−0.212	−0.030	0.127	**0.321**	0.012	−0.043	−0.006
PDM04	0.195	**−0.517**	0.109	**0.334**	0.128	**−0.571**	−0.195
PDM03	**0.333**	**0.636***	0.188	0.224	0.285	−0.115	**0.709***
PDM02	0.115	−0.285	**0.321**	0.115	0.006	**0.366**	**0.358**
PDF08	0.091	0.139	0.188	−0.152	0.188	0.049	0.091

F0 Range = 90th percentile minus 10th percentile. Alpha level 0.05.

Results summarize the association between acoustic variables and scaled sentence intelligibility within speakers. The sign of the correlation indicates the direction of the association. Bold text indicates correlations of 0.30 or greater and an asterisk indicates significant correlations ($\rho < 0.05$). Speakers are listed from least intelligible (PMD07) to most intelligible (PDF08).

Results

- **Articulatory Rate**
  - Moderately correlated with scaled sentence intelligibility for 5 of the 12 speakers.
    - Direction of the effect varied across speakers.
  - ***Relevance:***
    - Direction of the effect was related to the individual's typical articulation rate:
      - Slower typical rate, intelligibility improved with a faster rate of speech.
      - Faster typical rate, intelligibility improved with slowing down rate of speech.

Results

- **Fundamental Frequency**
  - Mean F0 was moderately correlated with scaled sentence intelligibility for 6 of the 12 speakers.
    - Direction of the effect varied across speakers.
  - F0 SD was moderately correlated with scaled sentence intelligibility for 5 of the 12 speakers.
    - For all but one speaker, lower values for F0 SD were associated with better intelligibility.
  - F0 range was moderately correlated with scaled sentence intelligibility for 5 of the 12 speakers.
    - Reduced F0 ranges were associated with better intelligibility.
  - ***Relevance:***
    - Reduced F0 modulation may be associated with better intelligibility due to low frequency vocal instability, ex. glottal fry.
      - However, may have different effects in women and men.

Results

- **Sound Pressure Level**
  - Mean SPL was at least moderately correlated with scaled sentence intelligibility for one speaker.
    - Lower mean SPL was associated with better intelligibility.
  - SPL SD was moderately correlated with scaled sentence intelligibility for 3 of 12 speakers.
    - Direction of the effect varied across speakers.
  - ***Relevance:***
    - Complex phenomenon that needs to be further explored.
    - Similar results for studies with healthy older adults; may relate to the relatively preserved sentence-level intelligibility for the PD speakers; more severe dysarthric speakers may demonstrate a different pattern of effect.

Results

- **F2 Inter Quartile Range**
  - Moderately correlated with sentence intelligibility for 5 of the 12 speakers.
    - Direction of the effect varied across speakers; 4 speakers presented with better intelligibility with a reduced F2 IQR, and 1 speaker demonstrated better intelligibility with a higher F2 IQR.
  - ***Relevance:***
    - Presumed to reflect diminished vocalic segmental integrity.
      - Listeners may have rated slow speakers as less intelligible.
    - Limited variation in F2 IQR may not have had sufficient magnitude to establish a relationship to intelligibility.

Results

- **Linguistic Variables**
  - Certain sentences were found to be more or less intelligible than others based on word frequency data.
    - Removed the 2 most intelligible and least intelligible sentences and repeated the analyses.
      - Results were similar to the original analysis.
        - Strengthened the associations for mean SPL and SPL SD.
  - ***Relevance:***
    - Listeners may have not been able to use semantic knowledge to recover the intended message for these sentences.
      - This may explain why intelligibility varies for an individual with mild dysarthria.
      - As well, word frequency may influence and mask the effect of other acoustic variables on intelligibility.

Conclusion

- The results support a within-speaker analysis for identifying acoustic variables that likely contribute to variations in sentence intelligibility for individuals with mild PD.
  - Variation in pattern for acoustic variables for the different participants emphasizes the heterogeneity of this population.
  - Results from other studies should be interpreted with caution as some variables may mask the strong relationship between an acoustic measure and intelligibility.
- ***Clinical Application:*** Identifying these influential acoustic variables may make it possible to target treatment for individuals with dysarthria.

Future Directions

- Investigate the relationship of other acoustic measures to within speaker variation in intelligibility.
  - Ex. Spectral measures of consonants
- Investigate the relationship between acoustic variables and intelligibility for individuals varying in severity of dysarthria.
- Further explore this relationship in both quiet settings and background noise.
- Investigate this relationship using more naturalistic conversational tasks.