Acoustic Markers of Dysarthria in Children with Cerebral Palsy: Comparison of Speech Tasks

Frits van Brenk[1] & Anja Kuschmann[2]

[1]Department of Communicative Disorders and Sciences, University at Buffalo, USA   [2]Department of Speech and Language Therapy, University of Strathclyde, Glasgow, UK

Introduction

- Dysarthria most frequent communication impairment in children with cerebral palsy (CP) (Parkes et al., 2010).
- Speech characteristics include shallow, irregular breathing, harsh and/or breathy voice, hypernasality, and imprecise articulation (e.g., Nordberg et al., 2014).
- Generally assumed that at least one - but often all - speech subsystems (i.e. respiration, phonation, resonance, articulation, and prosody) are affected.
- Acoustic correlates of reduced intelligibility are deviations in articulation rate and F2 range (e.g., Allison & Hustad, 2018), perhaps other candidates.
- Measurements usually obtained from single words or short sentences, but research on adult dysarthria has shown the potential of measuring acoustic features in connected speech (e.g., Rusz et al., 2013; Tjaden et al., 2010).

Purpose

Identify acoustic markers that may aid in the characterization of speech in children with dysarthria due to Cerebral Palsy, and evaluate the suitability of different functional speech tasks by comparing possible group differences side-by-side.

Methods: Participants

Speaker	Gender	Age	CP Type	GMFCS	Dysarthria Type	Severity	Control Speaker	Age
CP01	M	7	Dyskinetic	I	Dyskinetic	Mild	TD01	7
CP02	M	7	Spastic	IV	Spastic	Mild	TD02	8
CP03	M	16	Spastic	III	Spastic	Moderate	TD03	16
CP04	M	18	Ataxic	IV	Ataxic	Moderate	TD04	20
CP05	M	13	Ataxic	III	Ataxic	Severe	TD05	14
CP06	F	8	Dyskinetic	III	Dyskinetic	Moderate	TD06	7
CP07	F	15	Dyskinetic	IV	Dyskinetic	Mild	TD07	16
CP08	M	7	Spastic	IV	Spastic	Severe	TD08	6

- Severity level determined by CSIM scores (Children's Speech Intelligibility Measure, Wilcox & Morris, 1999 (mild: ≥80%, moderate: 50–80%, severe:<50%))
- GMFCS : Gross Motor Function Classification System

Methods: Speech Tasks

1. Series of words from Children's Speech Intelligibility Measure (CSIM)
2. 5-word sentences varying in sentence stress placement (Kuschmann & Lowit, 2018)
3. Retelling of Renfrew Bus Story
4. Monologue: talking about past birthday

Methods: Acoustic Measures

- Across the speech tasks, suitable voiced fragments for acoustic analyses were identified, labeled, extracted, and concatenated, using Praat (Boersma & Weenink, 2018).
- Acoustic measures were quasi-automatically obtained by means of custom Praat scripts.
- Measures reflect aspects of voice quality, vocal intensity, intonation, and articulatory working space:
  - Sound Pressure Level (Mean)
  - Sound Pressure Level (SD)
  - Sound Pressure Level range (90th-10th percentile)
  - Fundamental Frequency (Mean)
  - Fundamental Frequency (SD)
  - Fundamental Frequency (90th-10th percentile)
  - Second Formant Interquartile Range (F2IQR; 3rd quartile – 1st quartile)
  - Cepstral Peak Prominence (CPP)
  - Smoothed Cepstral Peak Prominence (CPPS)

Methods: Statistical Analyses

- One-way ANOVAs performed to compare Groups, Tasks, Measures:
  - Groups compared by pooling different Speech Tasks for each Acoustic Measure.
 - Group differences evaluated separately for each Task and Acoustic Measure.

Results: Group comparisons pooled over Tasks

Group Comparisons of Acoustic Measures by Parameter
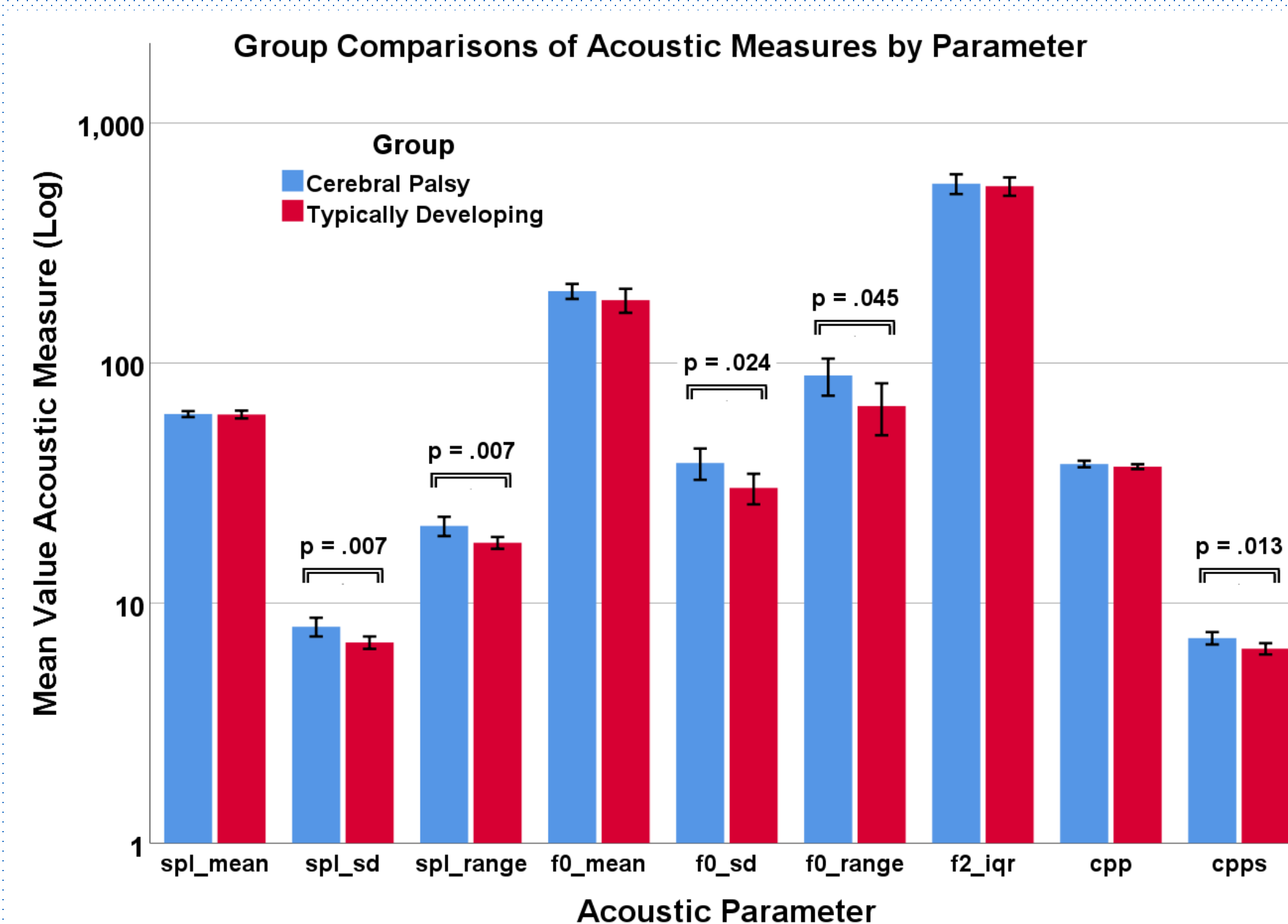
Notable results:

- **SPL Range:** F (1,63) = 8.52, p = .005: higher SPL range for CP group
- **SPL SD:** F (1,63) = 7.75, p = .007: higher SPL variation for CP group
- **F0 Range:** F (1,63) = 4.20, p = .045: higher F0 range for CP group
- **F0 SD:** F (1,63) = 5.34, p = .024: higher F0 variation for CP group
- **CPPS:** F (1,63) = 5.34, p = .024: higher mean CPPS for CP group

Results: Group comparisons separately by Task

Group Comparisons of Acoustic Measures by Task by Parameter
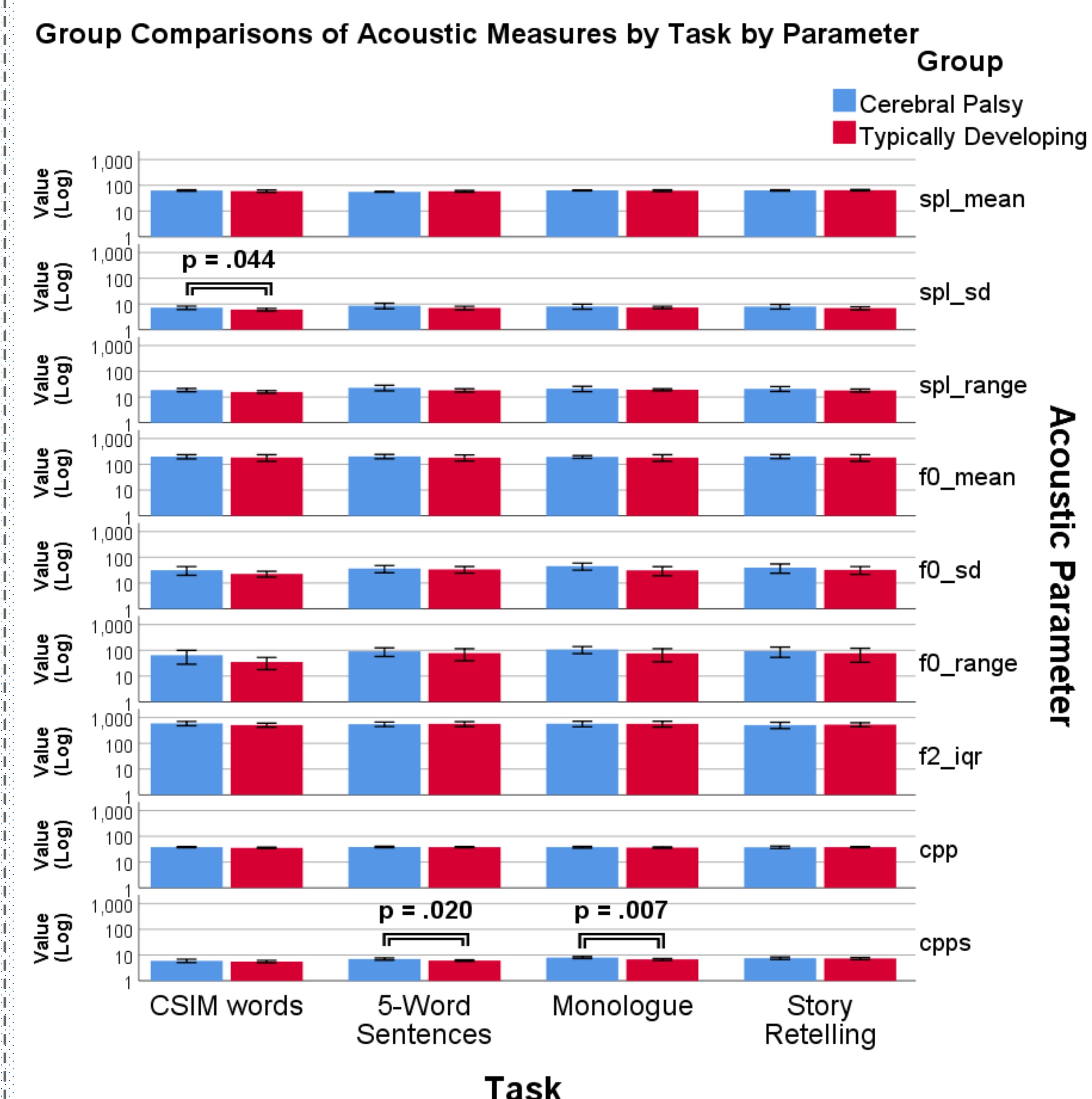
Notable results:

- **Overall:** very few differences between CP and TD groups when split out by speech task
- **CSIM:** SPL range higher in CP group
- **Sentences:** CPPS higher in CP group
- **Monologue:** CPPS higher in CP group
- **Story Retelling:** No group differences

Lack of group differences partly due to large within-group variation for the CP speakers; possibly due to underlying differences in dysarthria type.

Results: Subgroup Analysis

Ratios of outcome measures of CP speakers and their controls, summed by dysarthria type, pooled over speech tasks.

Ratio CP / TD Outcome Measure by Dysarthria Type
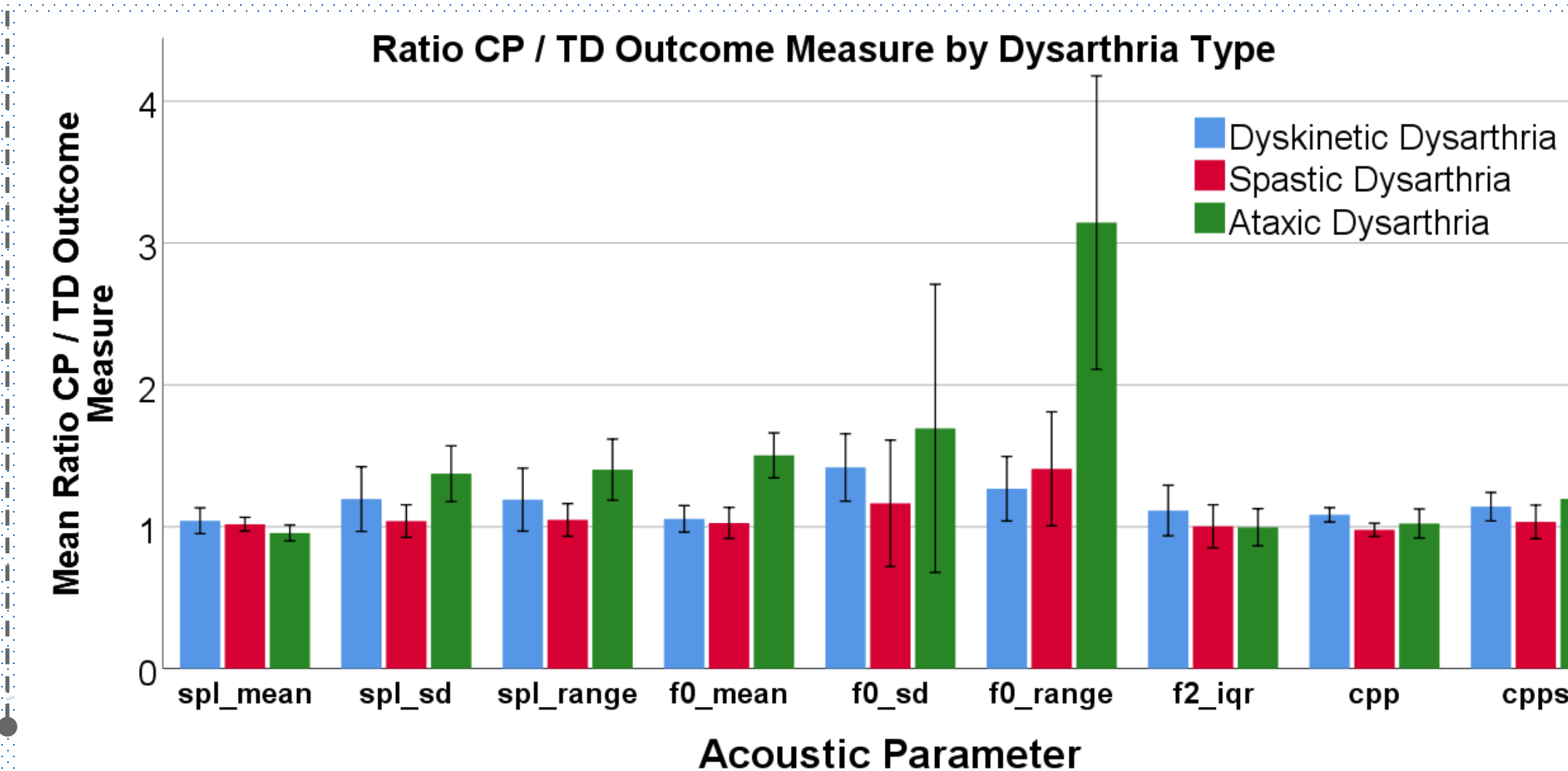
Notable results of qualitative approach:

- **Overall:** ratios of outcome measures mostly deviating in *Ataxic Dysarthria* followed by *Dyskinetic Dysarthria*.
- Range and SD of SPL and F0 most prominent markers.
- CPP and CPPS values higher in speakers with dyskinetic and ataxic dysarthria: indicative of voice problems for these dysarthria types.

Summary & Conclusion

- CPP and CPPS possible marker of breathiness and strained voice problems in speakers with CP.
- Higher SPL and F0 range and SD indicative of excessive and variable stress patterns, and reflect reduced velopharyngeal control.
- Current selection of quasi-automatically obtained acoustic measures might not capture differences in speech characteristics between CP and TD children / adolescents, regardless of speech task.
- Underlying variation in etiology and its manifesting dysarthria, as well as developmental differences may contribute to current results.

- Overall results point at need for an individualized assessment of acoustic characteristics in the speech of children with Cerebral Palsy.

Future directions:

- Identify relationships between acoustic measures and intelligibility measures.
- Fine-grained acoustic analysis on vowel level.

References

1. Allison, K. M. & Hustad, K. C. (2018). Acoustic Predictors of Pediatric Dysarthria in Cerebral Palsy. *Journal of Speech, Language, and Hearing Research, 61*, 462–478.
2. Kuschmann, A. & Lowit, A. (2018). Sentence stress in children with dysarthria and cerebral palsy, *International Journal of Speech-Language Pathology.* DOI: 10.1080/17549507.2018.1444093
3. Lee, J., Hustad, K. C., Weismer, G. 2014. Predicting Speech Intelligibility with a Multiple Speech Subsystems Approach in Children With Cerebral Palsy. *Journal of Speech, Language, and Hearing Research. 57*, 1666-1678.
4. Nordberg, A., Miniscalco, C., & Lohmander, A. (2014). Consonant production and overall speech characteristics in school-aged children with cerebral palsy and speech impairment., 386–395. *International Journal of Speech-Language Pathology, 16*
5. Parkes, J., Hill, N., Platt, M.J., & Donnelly, C. (2010). Oromotor dysfunction and communication impairments in children with cerebral palsy: A register study. *Developmental Medicine & Child Neurology, 52*, 1113–1119.
6. Rusz, J., Cmejla, R., Tykalova, T., Ruzickova, H., Klempir, J., Majerova, V., ... Ruzicka, E. (2013). Imprecise vowel articulation as a potential early marker of Parkinson's disease: Effect of speaking task. *The Journal of the Acoustical Society of America, 134*, 2171-2181.
7. Tjaden, K., Sussman, J., & Liu, G. (2010). Long-term average spectral measures (LTAS) of dysarthria and their relationship to perceived severity. *Journal of Medical Speech - Language Pathology, 18*(4), 125–132.
8. Boersma, Paul & Weenink, David (2018). *Praat: doing phonetics by computer* [Computer program]. Version 6.0.43, retrieved 8 September 2018 from http://www.praat.org/