Voice Quality Analysis Of Children With Cerebral Palsy During Sustained Phonation And Story Retell

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INTRODUCTION

Children with Cerebral Palsy Have Voice Quality Changes

- Cerebral Palsy (CP) is a group of disorders caused by perinatal damage to the central nervous system resulting in movement, sensory, communication, and cognitive impairments (Rosenbaum et al., 2007)
- Over 50% of children with CP have communication disorders, including dysarthria (Cockerill et al., 2014; Himmelman & Uvebrant, 2011; Hustad et al., 2010; Nordberg et al., 2013; Parkes et al., 2010) and associated voice quality changes (e.g., Ansel & Kent, 1991; Miller et al., 2013; Nip, 2017).

Quantifying Voice Quality

- Voice quality differences are typically captured via rating scales; e.g., CAPE-V (Kempster et al., 2009)
- Voice ratings are mildly correlated with intelligibility in children with CP; however more fine-grained measures of voice quality may provide a better basis for documenting therapeutic changes (Miller et al., 2013)
- Psychoacoustic measures of the voice source are associated with changes in voice quality perception and articulatory origins (Kreiman et al., 2014)
- H1*-A2* is a spectral tilt measure relating the amplitude of the harmonic F2 to the amplitude of the first harmonic, corrected for vowel formants (allowing for cross-vowel comparisons)
- Cepstral peak prominence (CPP), which measures the relative ratio of harmonic and inharmonic acoustic energy, has a strong relationship with breathiness (Hillenbrand et al., 1994)
- Speaking task differences do not impact psychoacoustic measures of the voice source in healthy talkers (Gerratt et al., 2016)
- It is unclear if psychoacoustic measures of voice are affected by speaking tasks in children with CP though acoustic measures of speech production in children with CP (e.g., intensity, F0) are (Pennington et al., in press)
- Characterizing the voice quality difference between children with CP and their health peers using fine-grained acoustic measures are needed to understand the laryngeal impairments causing the voice quality changes

Research Questions

- How do acoustic measures in voice quality differs between children with CP and their typically-developing age- and sex-matched peers in both isolated vowels and in a story re-tell task?

METHOD

Participants

- 8 children with CP (2F, 7M) and 8 age- and sex-matched typically developing peers (TD; 2F, 7M), aged 4 to 15 years
- All participants passed a hearing screening (ASHA, 1997) at .5, 1, 2, and 4 kHz in at least one ear
- Intelligibility measured with the Test of Children's Speech + (Hodge & Daniels, 2007)

Speaking Tasks

- 10 repetitions of the vowels /i, ɑ, u/ in isolation
- /i, ɑ, u/ in connected speech through a story re-tell task (Bats, Beets, Boots; Green et al., 2010)

Data Collection

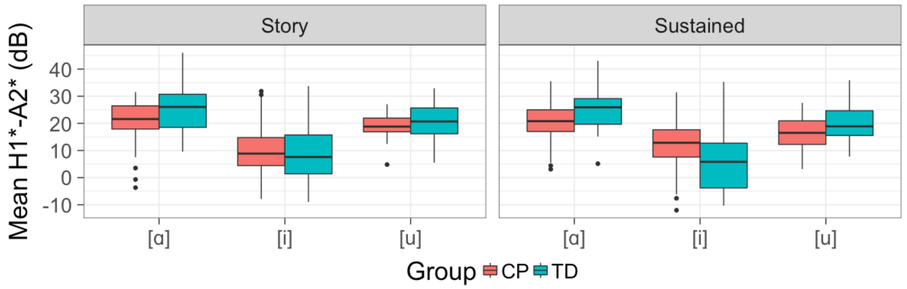
- Audio recording (16-bit, 44.1 KHz) using a head-mounted microphone

Data Analysis

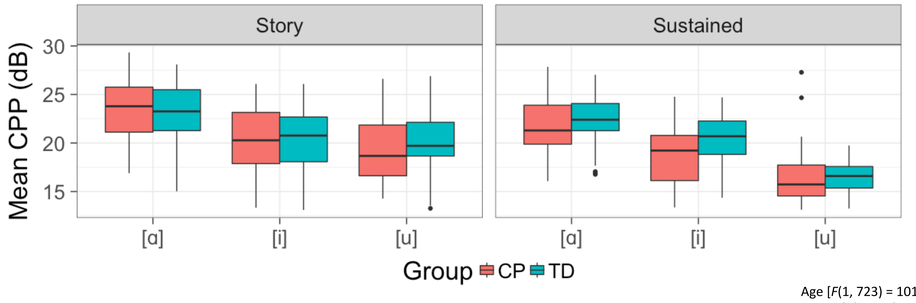
- Vowels were identified and marked in Praat (Boersma & Weenink, 2016)
- Vowel recordings were analyzed with VoiceSauce (Shue et al., 2011) to obtain cepstral peak prominence (CPP) and H1*-A2*, the difference in amplitude between the first harmonic and the harmonic closest to F2
- By-speaker outliers > 2.5 SDs for f0, F1, F2 were excluded.
- Two 2x2x3 multilevel models were run for each dependent variable (H1*-A2*, CPP) with Group (CP, TD), Task (Vowel, Story), and Vowel ([i], [ɑ], [u]) as the independent variables with participants as the repeated factor. Age was used as a covariate for both models.

Speaker	Age	Sex	CP Type	GMFCS	Dysarthria / Speech	Voice Quality	Word Intelligibility	Sentence Intelligibility	CELF-4 Std Score	Age of TD Peer
1	4;8	F	Spastic Quadriplegia	V	Spastic	Strain-Strangled	23%	16%	106	4;7
2	6;6	M	Spastic Diplegia	III	Spastic	Mild Strain	72%	83%	106	6;2
3	7;5	F	Spastic Hemiplegia	III	Mild	Mild Strain / Fry	68%	65%	102	7;4
4	9;2	M	Spastic Diplegia	II	Mild	Mild Strain	80%	72%	98	8;4
5	9;9	M	Spastic Hemiplegia	III	Mild	Mild Strain	81%	66%	67	9;4
6	10;7	M	Spastic Quadriplegia	IV	/r/ error	Mild Strain	85%	96%	127	10;11
7	12;4	M	Spastic Diplegia	II	None	WNL	91%	95%	112	13;2
8	15;0	F	Spastic Diplegia	II	None	Occasional Fry	82%	93%	129	15;7

RESULTS



Age [$F(1, 736) = 70.56$, $p < .001$]
Vowel [$F(2, 725) = 214.74$, $p < .001$], ɑ > i > u
Group x Vowel [$F(2, 725) = 20.60$, $p < .001$], TD > CP for ɑ, i



Age [$F(1, 723) = 101.95$, $p < .001$]
Group [$F(1, 709) = 5.29$, $p < .05$], TD > CP
Task [$F(1, 709) = 65.92$, $p < .001$], Story > Sustained
Vowel [$F(2, 714) = 134.57$, $p < .001$], ɑ > i > u
Task x Vowel [$F(2, 714) = 10.43$, $p < .001$], Story ɑ > i > u
Sustained ɑ > i, u

DISCUSSION

Children with CP have Lower Spectral Tilt and Lower CPP Values than their TD Peers

- H1*-A2* values were significantly lower, indicating a more constricted voice quality for children with CP than TD peers for [ɑ, i]
- Smaller CPP values for the CP group indicate greater noise (e.g., breathiness, roughness, or voicing irregularity) at the laryngeal level
- The combination of lower H1*-A2* and CPP suggest that children with CP have creakier, more irregular phonation

Vowels Differed in Spectral Tilt and CPP Values for Both Groups

- For both H1*-A2* and CPP, [ɑ] had the highest values whereas [u] had the lowest
- Results hold for children with CP and their TD peers
- [ɑ] is the least constricted and least irregular of the vowels, suggesting that normal (modal) voicing is easiest to sustain with a low-jaw, low-tongue position

Task Differences between Isolated Vowels and Story Retell

- Unlike previous findings in adults (e.g., Gerratt et al., 2016), both groups demonstrated task differences between isolated vowels and vowels produced during story retell
- More noisy vocal fold vibration for isolated vowels than in stories suggests more difficulty producing modal phonation in sustained vowels, which are longer and louder
- Evaluating psychoacoustic measures of voice quality in children should include sampling the voice source in isolated vowels and connected speech

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