SPECTRAL ANALYSIS OF VOWELS AND FRICATIVES AT VARIED LEVELS OF DYSARTHRIA SEVERITY FOR AMYOTROPHIC LATERAL SCLEROSIS

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Dysarthria in ALS

- **Dysarthria** due to **Amyotrophic Lateral Sclerosis (ALS)** progressively affects several aspects of **speech production** including **articulation**, **phonation**, **respiration**, **resonance** and **prosody**.
- Such impairments lead to a range of **acoustic abnormalities in different speech sounds**, like vowels, fricatives, stop consonants etc.
- With **increasing severity**, the nature and degree of the abnormalities change, leading to significant distortion, or even, **collapse of the acoustic space** of these patients.

Objective

To characterize spectral changes in the vowel and fricative spaces of the ALS patients as compared to healthy controls

- **Key questions to be answered:**
  1. How do the frequency band specific and full band spectral properties of different sustained vowels and fricatives change with increasing severity of ALS-induced dysarthria?
  2. How do these changes affect the discriminability of different vowels and different fricatives at each severity level?
- We consider
  - **4 sustained vowels** - /a/, /i/, /o/, and /u/
  - **3 sustained fricatives** - /s/, /sh/, and /f/

Dataset

- **Place of data collection:** National Institute of Mental Health and Neurosciences, Bengaluru, India
- **Dysarthria severity rating for ALS patients:**
  - Three speech-language pathologists rated as per the **ALSFRS-R scale**.

Condition	Score
Normal speech processes	4
Detectable speech disturbance	3
Intelligible with repeating	2
Speech needs to be combined with nonvocal communication	1
Loss of useful speech	0

  - Mode of the three ratings was considered as the final severity score.
- **Subject demographics:**

Group	Description	ALSFRS-R	#Subjects	#M:#F	Age range (years)
SV	**Severe dysarthria**	0,1	39	22:17	23-81
ML	**Mild dysarthria**	2,3	40	26:14	
ND	**ALS without dysarthria**	4	40	25:15	
HC	**Healthy**	-	40	20:20	22-55

- **Speech task:**
  - Sustained utterances of /a/, /i/, /o/, /u/, /s/, /sh/ and /f/
  - 1-3 utterances per phoneme per subject
  - **Vowel utterance count:** 409 (SV), 466 (ML), 453 (ND), 445 (HC)
  - **Fricative utterance count:** 223 (SV), 345 (ML), 342 (ND), 334 (HC)

Method

- **Frequency band specific** and **full band spectral analyses** are performed.
- **Spectral features:**
  - Spectral energy (E)
  - Spectral moments - Mean (M), Variance (V), Skewness (S), and Kurtosis (K)

  All features are computed from the middle $1/3^{rd}$ portion of the utterances to avoid the transient changes in the beginning and end portions.
- **Statistical test:** Multiple Comparison test with critical value type being Tukey's Honestly Significant Difference Procedure at 1% significance level

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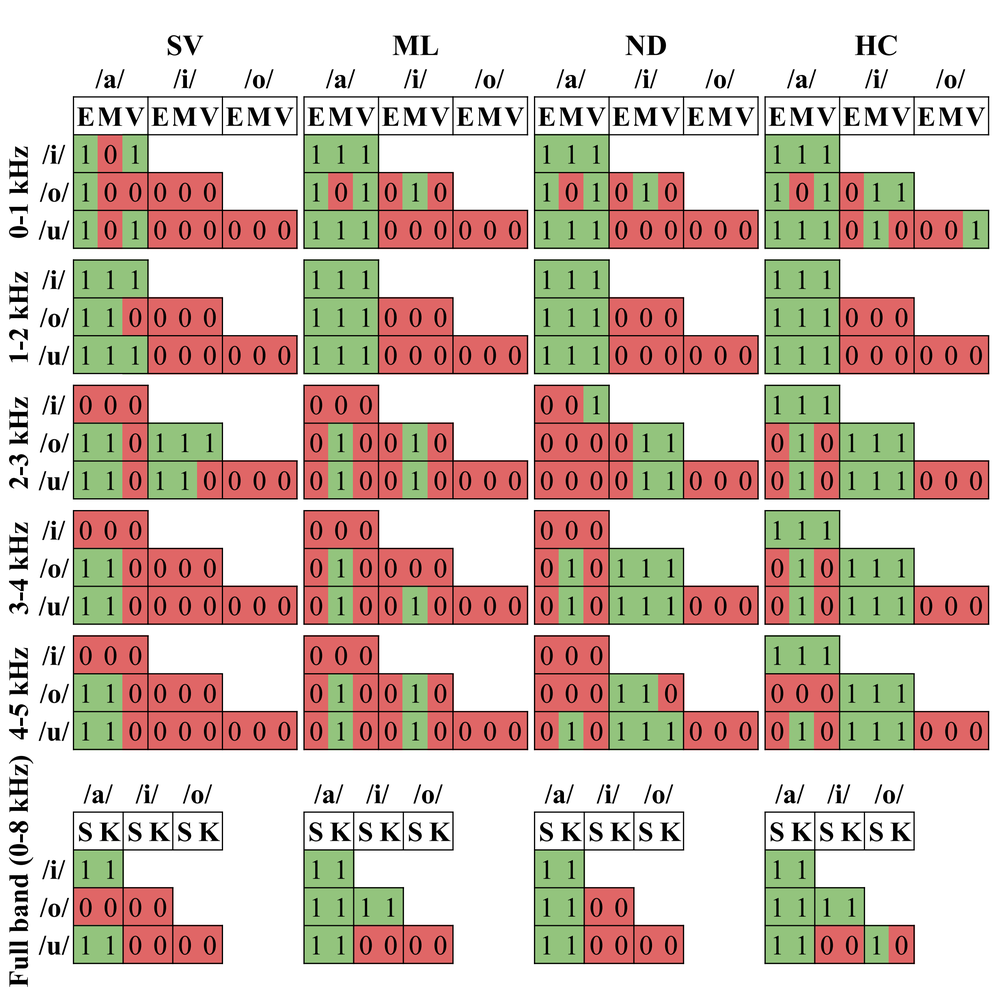
Analysis of Vowels

Vowel-wise comparison:

- Spectral **energy**, **mean** and **variance** in the **6-8 kHz band of /a/** and **1-2 kHz band of /i/** differ significantly between **SV and other groups**.
- For /**o**/ and /**u**/, the major severity-wise differences are w.r.t. **spectral mean**.
- **No significant spectral difference** exists between **ML-ND** and **ND-HC** pairs for any vowel.
- **No inter-severity difference** of spectral **skewness** or **kurtosis** is observed for any vowel.

Group-wise comparison:

- The significant differences between /**a**/ **and the other 3 vowels** in the **0-2 kHz band** as well as between /**a**/ **and /o/, /u/ in higher bands** are mostly **preserved** at all severity levels.
- Though /**i**/ differs significantly from others in **2-5 kHz band** for **HC group**, these differences gradually become **insignificant** with increasing dysarthria severity level.
- /**a**/ differs from /**i**/, /**o**/, and /**u**/ w.r.t. both full band spectral **skewness** and **kurtosis** for **ML**, **ND** and **HC** groups. In case of **SV**, the difference between /**a**/ and /**o**/ becomes **insignificant**.



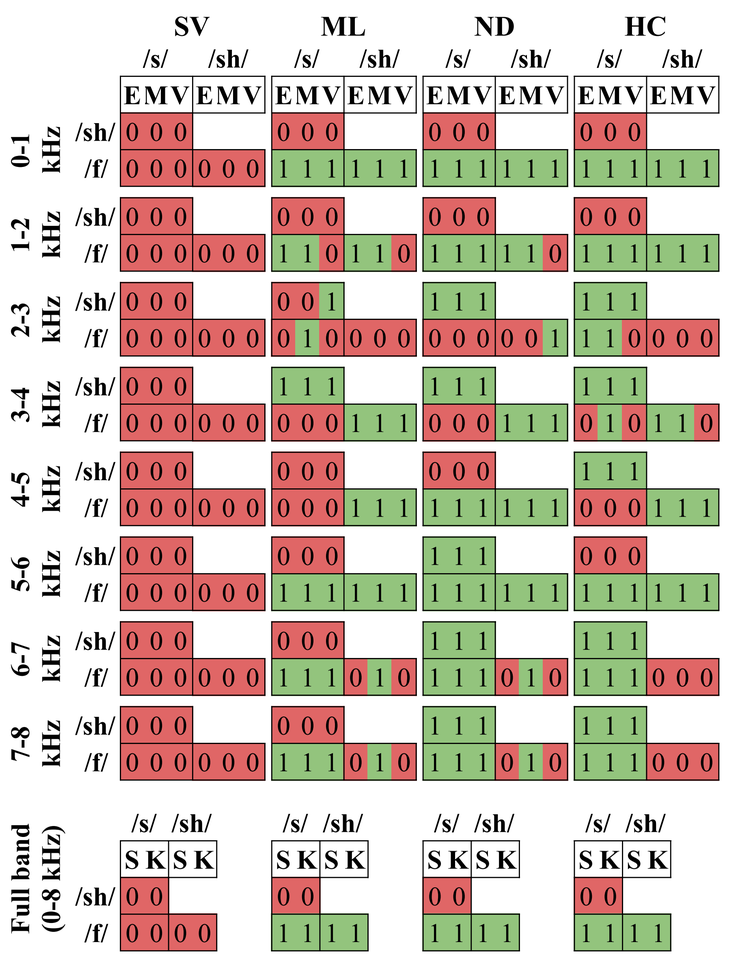
Analysis of Fricatives

Fricative-wise comparison:

- **/f/ preserves its spectral properties** irrespective of the severity level, whereas, /**s**/ **and /sh/** significantly **change**.
- The **only differences observed between ND and HC** are w.r.t. the spectral **energy**, **mean** and **variance** of the **3-5 kHz band of /s/**.
- **SV** differs from the **other severity groups** w.r.t. full band spectral **skewness** and **kurtosis** of /**s**/ and /**sh**/.

Group-wise comparison:

- /**f**/ differs significantly from /**s**/ **and /sh/** w.r.t. most of the spectral features in majority of the bands for **HC**, **ND** and **ML** groups.
- The **differences between /s/ and /sh/** are observed primarily in the cases of **HC** and **ND** groups in the **2-8 kHz band**.
- **/s/ and /sh/** undergo significant spectral changes with increase in dysarthria severity level and **collapse towards /f/** at the highest severity level.



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