Comparing variability in speech motor control in dysarthria with perceptual and acoustic assessments

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Introduction

Clinical diagnosis and characterization of motor speech disorders

- Perceptual ⇒ subjective and difficult to quantify.
- Acoustic ⇒ non-invasive and cheap, however time consuming and elaborate.
- Variability ⇒ promising for sub-clinical impairment detection, differentiating dysarthria type.

Research question:

- How well does variability of speech motor control correlate with perceptual assessments of intelligibility and acoustic assessments of DDK tasks in speech of people with dysarthria?

Methodology

Participants

- 23 speakers with Parkinsons Disease and mild to moderate hypokinetic dysarthria (HYPO): 18 male, 5 female, aged 40-81.
- 8 speakers with various neurological diseases and mild to severe ataxic dysarthria (ATAX): 5 male, 3 female, aged 37-58.

Experimental tasks

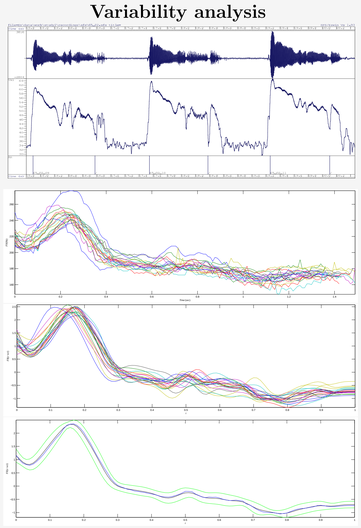
All participants performed the following speaking tasks:

- **For perceptual analysis:**
  - 30 seconds monologue about past holiday experiences
  - Reading a set of 10 unpredictable sentences [1]
- **For acoustical analysis:**
  - Diadochokinesis tasks /pʌ/, /tʌ/, /kʌ/ and /pʌtʌkʌ/
- **For variability analysis:**
  - Repeat the phrase "*Tony knew you were lying in bed*" around 20 times during Habitual speech rate

Instrumentation and analysis

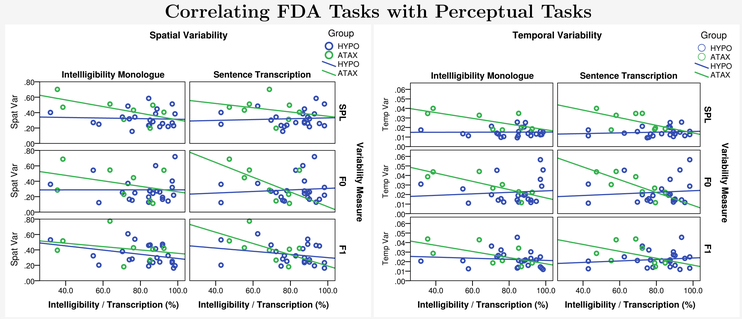
- Audio data was collected with a portable wave-recorder and head–mounted microphone.
- **Acoustic analysis:** calculated Coefficient of Variation (CoV) of mean syllable repetition rates of diadochokinetic tasks.
- **Perceptual analysis:** 15 SLT students participated in a listening experiment:
  - Rate intelligibility and listening effort of a monologue on a 9-point scale (9 = perfect intelligible; 1 = not intelligible) [2].
  - Transcribe unpredictable sentences. The number of correctly transcribed words per sentence were calculated.
  - All results were converted to a % scale.
- **Variability analysis:** calculated Spatial and Temporal Variability of Amplitude (SPL), Pitch (F0), and First Formant (F1) envelopes of sentence repetitions [3,4].
- Correlations were estimated by linear regression analysis.

Variability analysis



Results

Correlating FDA Tasks with Perceptual Tasks



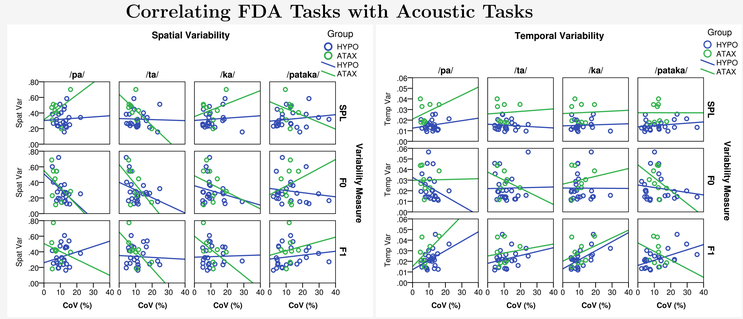
The graphs show the correlation between spatial and temporal variability and intelligibility and transcription results. The correlation coefficients (r) are summarized below:

	HYPO				ATAX			
	Spatial		Temporal		Spatial		Temporal	
	Mono	Sent	Mono	Sent	Mono	Sent	Mono	Sent
SPL	.057	.077	.013	.123	.629	.248	.687	.563
F0	.001	.099	.101	.101	.364	.605	.811	.776
F1	.341	.244	.110	.143	.269	.555	.612	.423

Results:

- In general, the correlation direction suggest that an increase in monologue and sentence intelligibility was associated with a decrease in variability.
- Correlations were weak in the HYPO group.
- For the ATAX group, the following significant correlations were present ($p < .05$; orange colour):
  - Increase in monologue intelligibility correlated with decrease in temporal var of F0 ($p = .014$)
  - Increase in sentence intelligibility correlated with decrease in temporal var of F0 ($p = .024$)
- For the ATAX group, the following trends were present ($.1 < p > .05$; yellow colour):
  - Increase in monologue intelligibility correlated with decrease in spatial var of SPL ($p = .095$)
  - Increase in monologue intelligibility correlated with decrease in temporal var of SPL ($p = .060$)

Correlating FDA Tasks with Acoustic Tasks



The graphs show the correlation between variability and Coefficient of Variation of syllable repetition rates in DDK tasks. The correlation coefficients (r) are displayed below:

	HYPO				HYPO			
	Spatial				Temporal			
	/pa/	/ta/	/ka/	/pataka/	/pa/	/ta/	/ka/	/pataka/
SPL	.052	.034	.082	.175	.188	.106	.063	.226
F0	.464	.356	.237	.158	.261	.017	.004	.169
F1	.199	.052	.032	.175	.400	.249	.611	.541
	ATAX				ATAX			
SPL	.405	.618	.261	.183	.302	.058	.038	.001
F0	.400	.559	.234	.166	.013	.302	.148	.327
F1	.219	.609	.449	.103	.530	.113	.299	.221

Results:

- Direction of correlations between variability and CoV not always clear cut; in general increase in CoV associated with increase in SPL and F1 variability and with decrease in F0 variability.
- Correlations were weak in the ATAX group.
- For the HYPO group, the following significant correlations were present ($p < .05$; orange colour):
  - Increase in CoV of /pa/ correlated with decrease in spatial variability of F0 ($p = .026$)
  - Increase in CoV of /ka/ correlated with increase in temporal variability of F1 ($p = .002$)
  - Increase in CoV of /pataka/ correlated with increase in temporal variability of F1 ($p = .008$)
- For the ATAX group, the following trends were present ($.1 < p > .05$; yellow colour):
  - Increase in CoV of /ta/ correlated with decrease in spatial variability of F0 ($p = .095$)
  - Increase in CoV of /pa/ correlated with increase in temporal variability of F1 ($p = .008$)

Discussion

Correlating variability and perceptual measures:

- The results for the ATAX group suggest a positive relationship between speech motor control stability and intelligibility.
- ATAX group: the results on temporal variability suggest an impaired timing of speech motor movements associated with cerebellar dysfunction.

Correlating variability and acoustic measures:

- HYPO group: the significant results of CoV and temporal variability of F1 suggest a relationship between variation in jaw opening during sentence repetition and variation in syllable duration during a DDK task. Possible common factor: decreased articulation accuracy.
- HYPO group: decrease of F0 spatial variability associated with higher DDK variability. Possible common factor: decrease in respiratory support.

Conclusions

- Variability (especially temporally) of loudness, pitch and articulation during a sentence repetition task might be associated with intelligibility in dysarthria.
- Using FDA besides applying DDK tasks might give a more complete picture of speech problems in hypokinetic dysarthria, as FDA is able to differentiate between loudness, pitch and articulation characteristics.

References

[1] McHenry, M.A., Parle, A.M. "Construction of a Set of Unpredictable Sentences for Intelligibility Testing". *Journal of Medical Speech - Language Pathology*, 14(4):269-271, 2006.

[2] Dobinson, C., "An investigation into the use of computers for conducting home practice of speech exercises for people with dysarthria", *Unpublished PhD Thesis*. University of Newcastle, 2009.

[3] Ramsay, J. O., Munhall, K. G., Gracco, V. L., Ostry, D. J. "Functional data analyses of lip motion." *Journal of the Acoustical Society of America*, 99(6):3718 - 3727, 1996.

[4] Anderson, A., Lowit, A., Howell, P., "Temporal and spatial variability in speakers with Parkinson's Disease and Friedreich's Ataxia", *Journal of Medical Speech - Language Pathology*, 16(4):173 - 180, 2009.