Evaluating aspects of speech motor stability in dysarthria

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Introduction

Characterizing speech motor performance in dysarthria important for diagnosis and treatment

- One way to assess motor control over different levels of speech production is to estimate the stability of movement patterns.
- Kinematic measures of speech motor variability (EMA, strain-gauge transducers) indicate changes in dysarthric speakers, but are expensive and invasive.
- Acoustically based measures also promising in signalling presence and severity of dysarthria [1].

Aim of the study

Evaluate speaking conditions and acoustic parameters of variability measures for their suitability to diagnose and classify dysarthria.

Methodology

Speakers

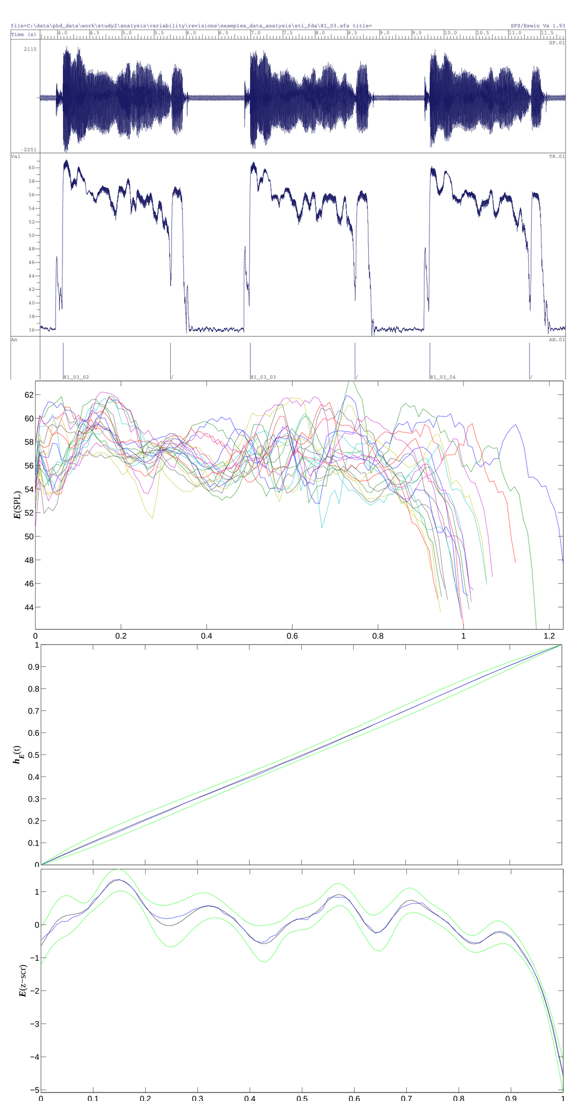
- 23 speakers with Parkinson's disease and mild to moderate **hypokinetic dysarthria** (HD): 18 male, 5 female, age 40-81, M=66.6, SD=10.6.
- 9 speakers with various neurological diseases and mild to severe **ataxic dysarthria** (AD): 6 male, 3 female, age 37-70, M=49.0, SD=11.8.
- 27 age-matched **control speakers** (AMC): 16 male, 11 female, age 35-80, M=57.4, SD=13.9.

Procedure

- Stimuli: Repeat the phrase "*Tony knew you were lying in bed*" 20 times
- Six speaking conditions: **Habitual** rate, **Slow** rate, **Fast** rate, Increased Length (**IL**) "*One two three Tony knew you were lying in bed five six seven*", Increased Complexity (**IC**) "*I heard that Tony knew you were lying in bed this Sunday morning*", and **Dual** task (during spiral drawing).

Data analysis

Experimental setup
Audio data collected with a portable audio-recorder and head-mounted microphone.



Variability analysis

- **Annotation** of phrase repetitions.
- **Extraction** of contours Sound Pressure Level (**SPL**), Fundamental Frequency (**F0**), First Formant (**F1**), and Second Formant (**F2**).
- **Processing** of contours with Functional Data Analysis to obtain spatial variability (**SV**), temporal variability (**TV**), and the spatiotemporal index (**STI**) [2].

Statistical analyses

- 72 variables obtained [4 speech parameters X 6 speaking conditions X 3 variability measures].
- Data reduction with **Principal Component Analysis**; extraction of oblique rotated factors [3].
- **Logistic Regression** to analyse the relationship between the extracted factors and outcome (dysarthria / unaffected; dysarthria type) [4].

Results

	Hypokinetic vs Controls	Ataxic vs Controls	Dysarthria vs Controls	Hypokinetic vs Ataxic
	Principal Component Analysis			
Number of Factors	16	15	16	16
% variance explained	86.6%	89.7%	85.9%	91.6%
	Logistic Regression			
Block 0 Constant	B S.E. Sig. Exp(B) -.160 .284 .572 .852	B S.E. Sig. Exp(B) 1.099 .385 .004 3.000	B S.E. Sig. Exp(B) .170 .261 .216 1.185	B S.E. Sig. Exp(B) .938 .393 .017 2.556
Block 1 Model fit	- 2LL: 40.11 (from 68.99) Nagelkerke R^2 = .586	- 2LL: 22.99 (from 40.49) Nagelkerke R^2 = .570	- 2LL: 38.48 (from 81.37) Nagelkerke R^2 = .690	- 2LL: 30.732 (from 38.02) Nagelkerke R^2 = .293
Block 1 Constant	B S.E. Sig. Exp(B) .125 .444 .778 1.134	B S.E. Sig. Exp(B) 1.631 .593 .006 5.109	B S.E. Sig. Exp(B) 1.283 .633 .043 3.606	B S.E. Sig. Exp(B) 1.096 .458 .017 2.993
Classification Table	HD AMC % correct HD 18 5 78.3 AMC 23 4 85.2	AD AMC % correct AD 6 3 66.7 AMC 27 0 100	DYS AMC % correct DYS 28 4 85.2 AMC 4 23 87.5	HD AD % correct HD 21 2 91.3 AD 6 3 33.3
Overall % correct	**82.0**	**91.7**	**86.4**	**75.0**
Contributing Factors / Variables	1 / 5	2 / 16	6 / 31	1 / 5
Prominent Variables	{STI,SV,TV}_SPL_IC TV_F1_{Slow,IC}	{STI,SV,TV}_SPL_Slow SV_SPL_{Hab,IL,IC} {STI,SV}_F0_{Hab,Slow,IC} TV_F1_{Slow,IC}	Trends: {STI,SV}_SPL {STI,SV,TV}_F0 F1_{Hab,Slow} F2_{IL,Dual}	SV_SPL_{Hab, Slow,Fast,IL,Dual}

Discussion

Principal Component Analysis

- Grouping 72 variables into relatively high number of factors (15-16).
- First 2 factors explain only 36 - 41% of total variance.

Logistic Regression

- Using PCA rotated factors as predictors resulted in improved logistic models.
- Each model contained at least 1 significant factor that improved the models.

Classification

- Classifications HD vs AMC and DYS vs AMC reasonably successful.
- AD vs AMC: 1 in 3 are classified as false negatives.
- HD vs AD: many AD speakers classified as HD.
- Possibly due to low sample size and varying speaker profiles in the AD group.

Parameter Selection

- HD vs AMC: SPL variability higher in HD group during repetition of phrase in IC speaking condition.
- AD vs AMC: increased SPL and F0 variability in Hab, Slow, and IC conditions.
- DYS vs AMC: difficult to select small number of diagnostic parameters; increased variability across all acoustic parameters and most speaking conditions.
- HD vs AD: increased spatial variability of SPL in AD group.

Conclusions

- Acoustic measures of variability may be used to **signal dysarthria**: HD (SPL, F1) and AD (SPL, F0, F1).
- ...and to **distinguish dysarthria types** (SV of SPL).
- Most robust overall: **Spatial Variability** of **Sound Pressure Level** in **Slow** and **Increased Complexity** conditions.
- Demonstrates added value of Functional Data analysis to STI.

Limitations

- Low sample sizes (AD group) and missing data (F2 contours).
- Different underlying etiologies in speakers with ataxic dysarthria.
- HD and AD group not comparable in severity (based on intelligibility).

References

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