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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 (EMG, 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 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

<table>
<thead>
<tr>
<th>Number of Factors</th>
<th>Hypokinetic vs Controls</th>
<th>Ataxic vs Controls</th>
<th>Dysarthria vs Controls</th>
<th>Hypokinetic vs Ataxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>% variation explained</td>
<td>26.6%</td>
<td>16.6%</td>
<td>16.6%</td>
<td>26.6%</td>
</tr>
<tr>
<td>Block 0 Constant</td>
<td>B S.E. Sig. Exp(B)</td>
<td>B S.E. Sig. Exp(B)</td>
<td>B S.E. Sig. Exp(B)</td>
<td>B S.E. Sig. Exp(B)</td>
</tr>
<tr>
<td>Block 1 Model fit</td>
<td>-2LL: 38.48 (from 81.37)</td>
<td>-2LL: 38.48 (from 81.37)</td>
<td>-2LL: 38.48 (from 81.37)</td>
<td>-2LL: 38.48 (from 81.37)</td>
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<tr>
<td>Block 1 Constant</td>
<td>B S.E. Sig. Exp(B)</td>
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<td>B S.E. Sig. Exp(B)</td>
<td>B S.E. Sig. Exp(B)</td>
</tr>
<tr>
<td>Classification Table</td>
<td>HD AMC % correct</td>
<td>HD AMC % correct</td>
<td>HD AMC % correct</td>
<td>HD AMC % correct</td>
</tr>
<tr>
<td>Overall % correct</td>
<td>82.0</td>
<td>82.0</td>
<td>82.0</td>
<td>82.0</td>
</tr>
<tr>
<td>Contributing Factors / Variables</td>
<td>STI,SV,TV,SPL,IC</td>
<td>STI,SV,TV,SPL,IC</td>
<td>STI,SV,TV,SPL,IC</td>
<td>STI,SV,TV,SPL,IC</td>
</tr>
<tr>
<td>Prominent Variables</td>
<td>F0 (IL, Dual)</td>
<td>F0 (IL, Dual)</td>
<td>F0 (IL, Dual)</td>
<td>F0 (IL, Dual)</td>
</tr>
<tr>
<td>Principal Component Analysis</td>
<td>1/3</td>
<td>1/3</td>
<td>1/3</td>
<td>1/3</td>
</tr>
</tbody>
</table>

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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