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Assessing dysarthria using variability measures from audio recordings

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Introduction

Characterization of motor speech disorders (MSDs):
- Clinical diagnosis primarily based on auditory-perceptual information - subjective and difficult to quantify.
- Possible alternative: analyze variability in speech motor movements based on audio data.

Using variability measures in speech:
- Quantify the variation in temporal and spatial events in speech over a series of repetitions of an identical articulatory movement.
- Spatial-temporal index (STI): a combined index of temporal and spatial variability.
- Functional Data Analysis (FDA): spatial and temporal variability separately quantified.

Research questions:
1. Can FDA detect sub-clinical signs of impaired speech motor control in speakers with Parkinson’s Disease?
2. Is it possible to differentiate speakers with ataxic dysarthria based on severity of the speech disorder?

Methodology

Participants
- Five speakers with Parkinson’s disease and mild hypokinetic dysarthria (PD) (2 male, aged 73-75).
- Five speakers with various neurological diseases and mild ataxic dysarthria (ATD-A) (2 male, aged 44-70).
- Five speakers with various neurological diseases and moderate to severe ataxic dysarthria (ATD-B) (4 male, 1 female, aged 37-58).
- Ten speakers without a speech disorder (CON) (5 male, 5 female, aged 36-80).
- Severity was assessed by a 5-point scale of listener effort (0 = fully understandable, 1 = able to understand nothing, 5 = able to understand around 75%) [4].

Variability analysis:
- Repetition of the phrase: "Tony knows you were dying in bed" around 20 times.
- Speaking conditions: Habitual and Fast.
- Fast rate: twice the normal speech rate as judged by the participant.

Instrumentation and analysis
- Audio data collected with portable wave-recorder and head mounted microphone.
- Analysis and extraction of Amplitude envelopes, PD and FI tracks in audio signal of sentence repetitions.
- Functional Data Analysis:
  - Annotation
  - Contour extraction
  - Normalizing and stretching
  - Temporal variability
  - Phase variability

Results

Identifying (sub-clinical) speech symptoms in PD
- Temporal variability was lower for Amplitude compared to PD and FI across groups and speaking conditions (Parameter F(1,6,21,7) = 44.5 p < .001).
- The PD group showed a trend of lower variability in PD, a trend of increased variability in Amplitude and significantly higher variability in F1 (p=.001) than the control group, across speaking conditions (Group x Parameter: F(1,6,21,7) = 6.28 p < .001).
- Relationship between speaking parameters:
  - CON: Amplitude > PD = FI
  - PD: FI > Amplitude > PD
- There was a trend towards an increase in variability from the habitual to fast condition for Amplitude, and a decrease for PD across groups (Parameter x Group: F(1,6,21,7) = 3.41 p < .07).

Differentiating severity levels in Ataxic Dysarthria
- Temporal variability was lower for PD, compared to Amplitude and FI, across groups and speaking conditions, (Parameter F(1,6,21,7) = 7.27 p < .01).
- The PD group showed a trend of lower variability in PD, a trend of increased variability in Amplitude and significantly higher variability in F1 (p<.005) than the control group, across speaking conditions (Group x Parameter: F(1,6,21,7) = 6.81 p < .001).
- Relationship between speaking parameters:
  - CON: Amplitude > PD = FI
  - PD: FI > Amplitude > PD
- An increase in variability was shown from habitual to fast condition for Amplitude, but a decrease for PD and FI (all trends) (Parameter x Group: F(1,6,21,7) = 4.73 p < .05).

Discussion

In general, the small and heterogeneous nature of the groups account for large within-group variability, obscuring detection of differences between groups and speaking conditions.

Question 1: Can FDA detect sub-clinical impairments of motor control in PD speakers?
- Yes, a significant increase in PD variability and trends towards increased Amplitude variability and decreased F1 variability.
- Also observed in a different relationship of variability among speaking parameters.
- Might reflect emerging signs of hypokinetic dysarthria, i.e. impaired articulation (PD), poor loudness control (Amplitude) and monotropism (F1).

Question 2: Can FDA detect speech motor problems in ataxic dysarthria and reflect differences in severity?
- Detection: Yes, an increase in temporal and spatial variability in Amplitude, F0 and F1 for both mild and moderate speakers with ataxia.
- Differentiation: Yes, an increase in dysarthria severity is related to an increase in temporal variability.
- Reflecting impaired timing of speech motor movements associated with cerebellar dysfunction.

References