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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.
- Spatiotemporal 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)**: five male, aged 73-76.
- Five speakers with various neurological diseases and **mild ataxic dysarthria (ATD-A)**: 2 male, 3 female, 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**: 8 male, 2 female, aged 36-80.
- Severity was assessed by a 9-point scale of listener effort (9 = fully understandable, no effort; 1 = able to understand nothing; 5 = able to understand around 75%) [4].

⇒ Severity range: PD 7-9 | ATD-A 8-9 | ATD-B 2-5.

Task

Variability analysis:

- Repetition of the phrase "*Tony knew you were lying in bed*" around 20 times.

Speaking conditions:

- Habitual speech rate.
- 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.
- Annotation and extraction of Amplitude envelopes, F0 and F1 tracks in audio signal of sentence repetitions.
- Functional Data Analysis:

Annotation | Contour extraction | Normalizing and stretching | Temporal variability | Phase variability
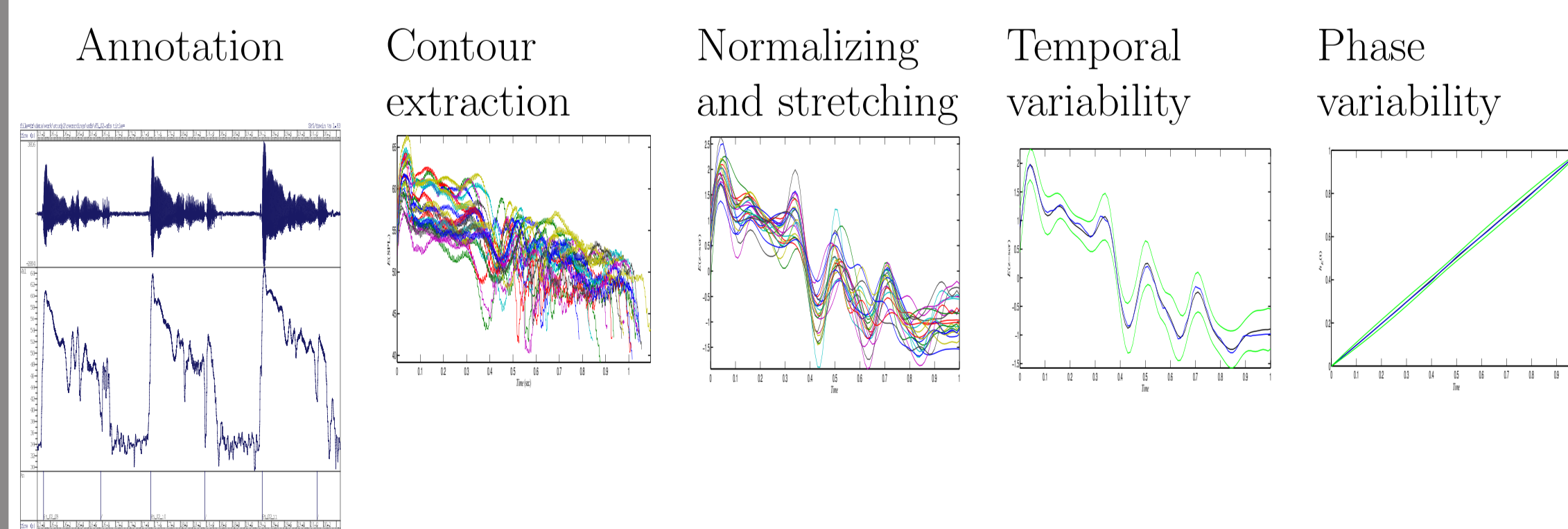
Results

### Identifying (sub-clinical) speech symptoms in PD

- Mean temporal and spatial variability were separately compared by Repeated Measures ANOVA:
- Speaker groups: PD and CON | Speaking conditions: Habitual and Fast | Speech parameters: Amplitude, F0 and F1
- Significant interaction effects were further explored by Univariate ANOVA
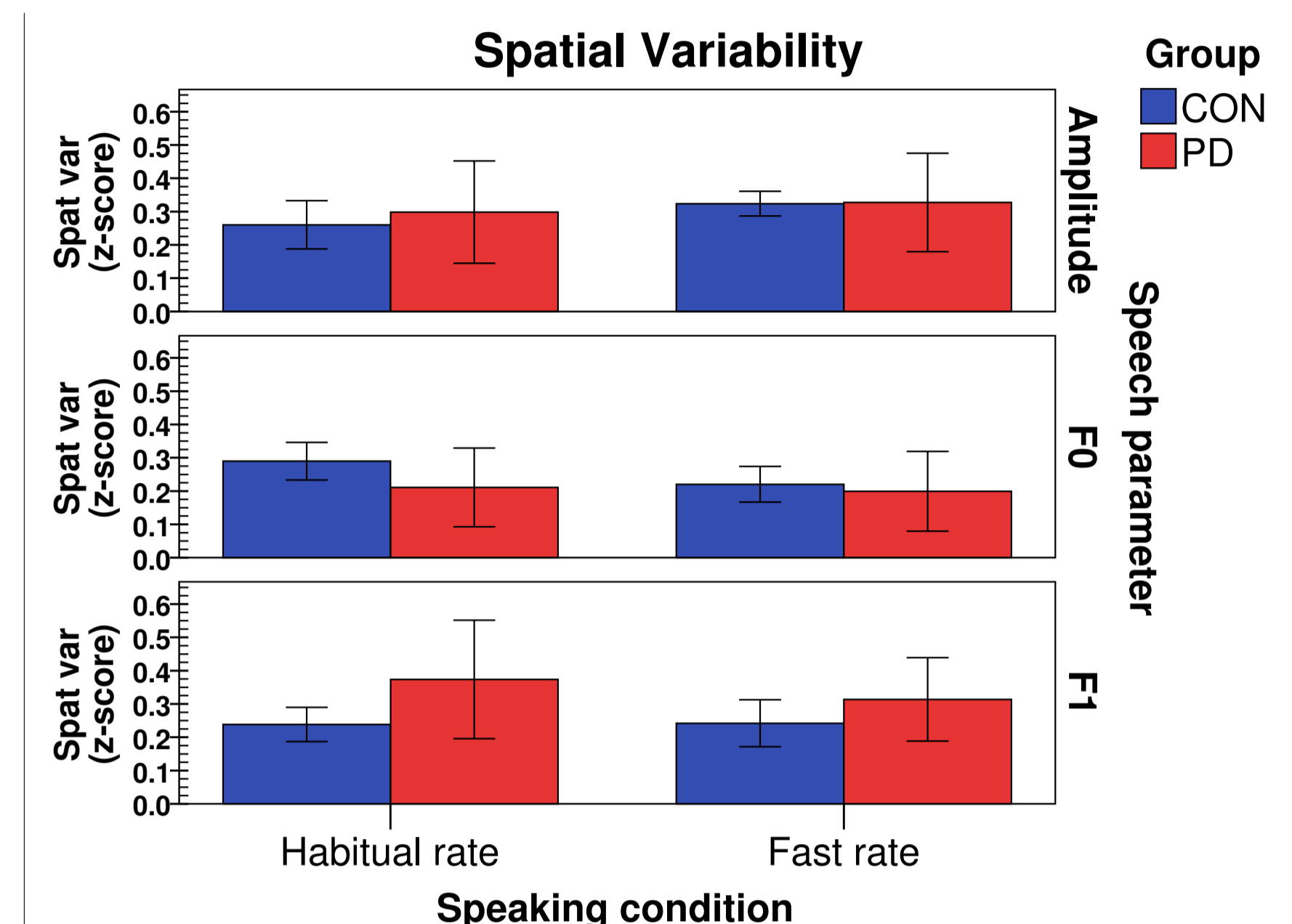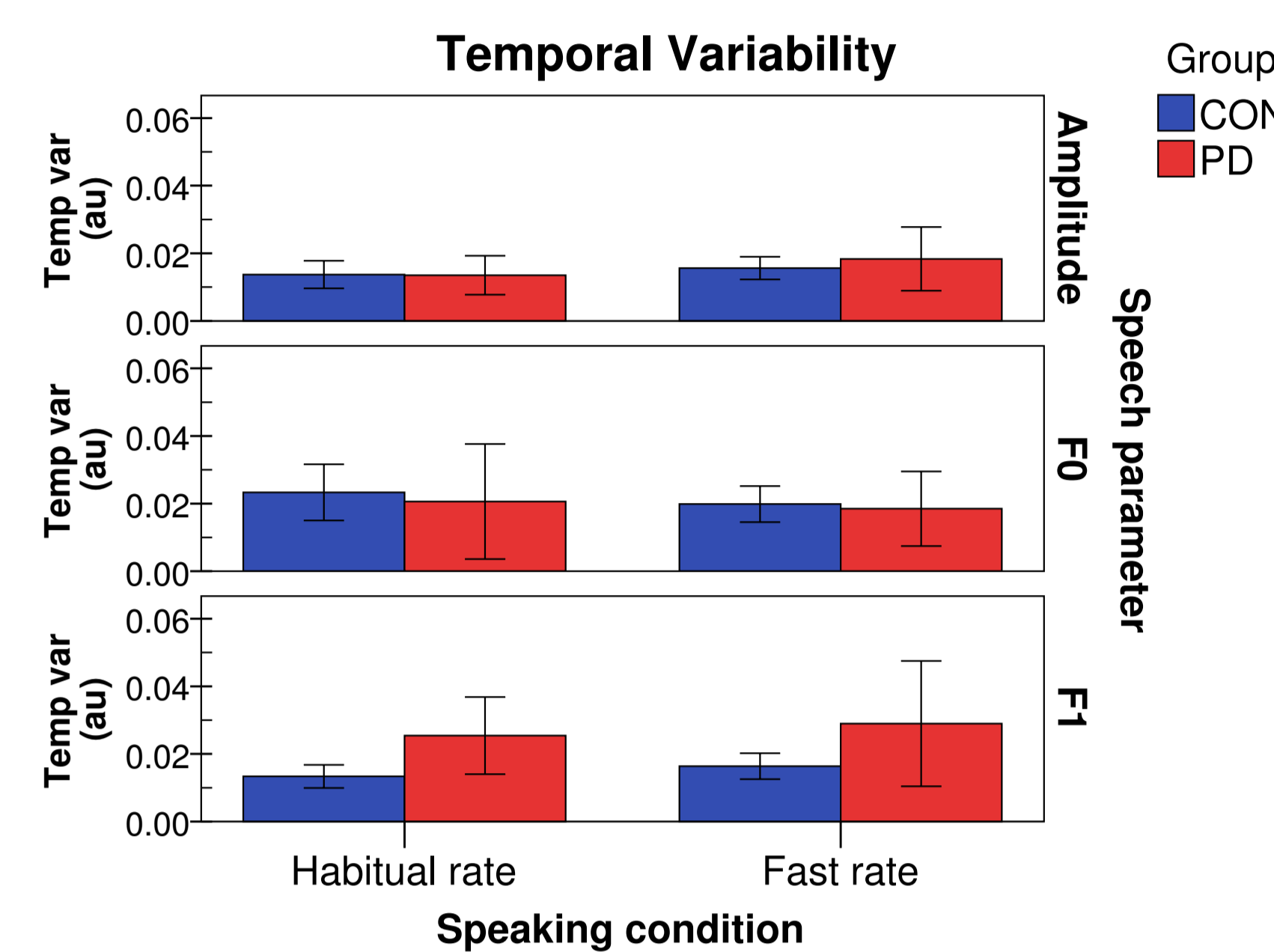
- Temporal variability was lower for Amplitude compared to F0 and F1 across groups and speaking conditions (Parameter [F(1.65,21.5)=4,61 p=.027]).
- The PD group showed a trend of lower variability in F0, a trend of increased variability in Amplitude and **significantly higher variability in F1 (p<.001)** than the control group, across speaking conditions (Group*Parameter [F(1.65,21.5)=6,38 p=.009]).
- Relationship between speech parameters:
  - CON: F0 > Amplitude = F1
  - PD: F1 > Amplitude = F0
- There was a trend towards an increase in variability from the habitual to fast condition for Amplitude and F1, and a decrease for F0 across groups (Parameter*Condition [F(2,26)=3,46 p=.047]).

- Spatial variability was **lowest for F0**, compared to Amplitude and F1, across groups and speaking conditions, (Parameter [F(2,26)=7,07 p=.004]).
- The PD group showed a trend of lower variability in F0, a trend of increased variability in Amplitude and **significantly higher variability in F1 (p=.005)** than the control group, across speaking conditions, (Group*Parameter [F(2,26)=6,81 p=.004]).
- Relationship between speech parameters:
  - CON: Amplitude = F0 = F1
  - PD: F0 < Amplitude = F1
- An increase in variability was shown from habitual to fast condition for Amplitude, but a decrease for F0 and F1 (all trends) (Parameter*Condition [F(2,26)=4,35 p=.023]).

Differentiating severity levels in Ataxic Dysarthria

- Mean temporal and spatial variability were separately compared by Repeated Measures ANOVA:
- Speaker groups: ATD-A, ATD-B and CON | Speaking conditions: Habitual and Fast | Speech parameters: Amplitude, F0 and F1
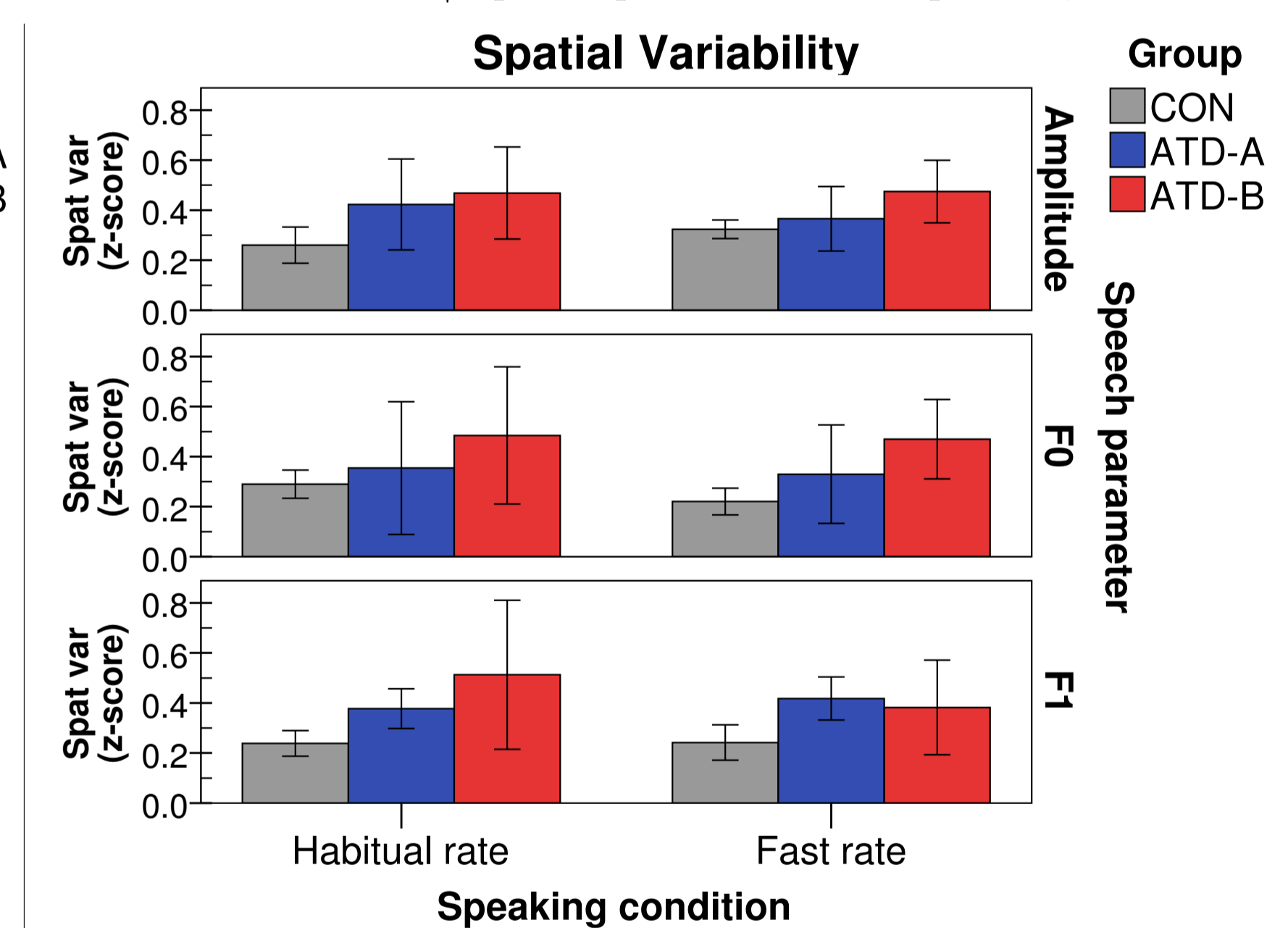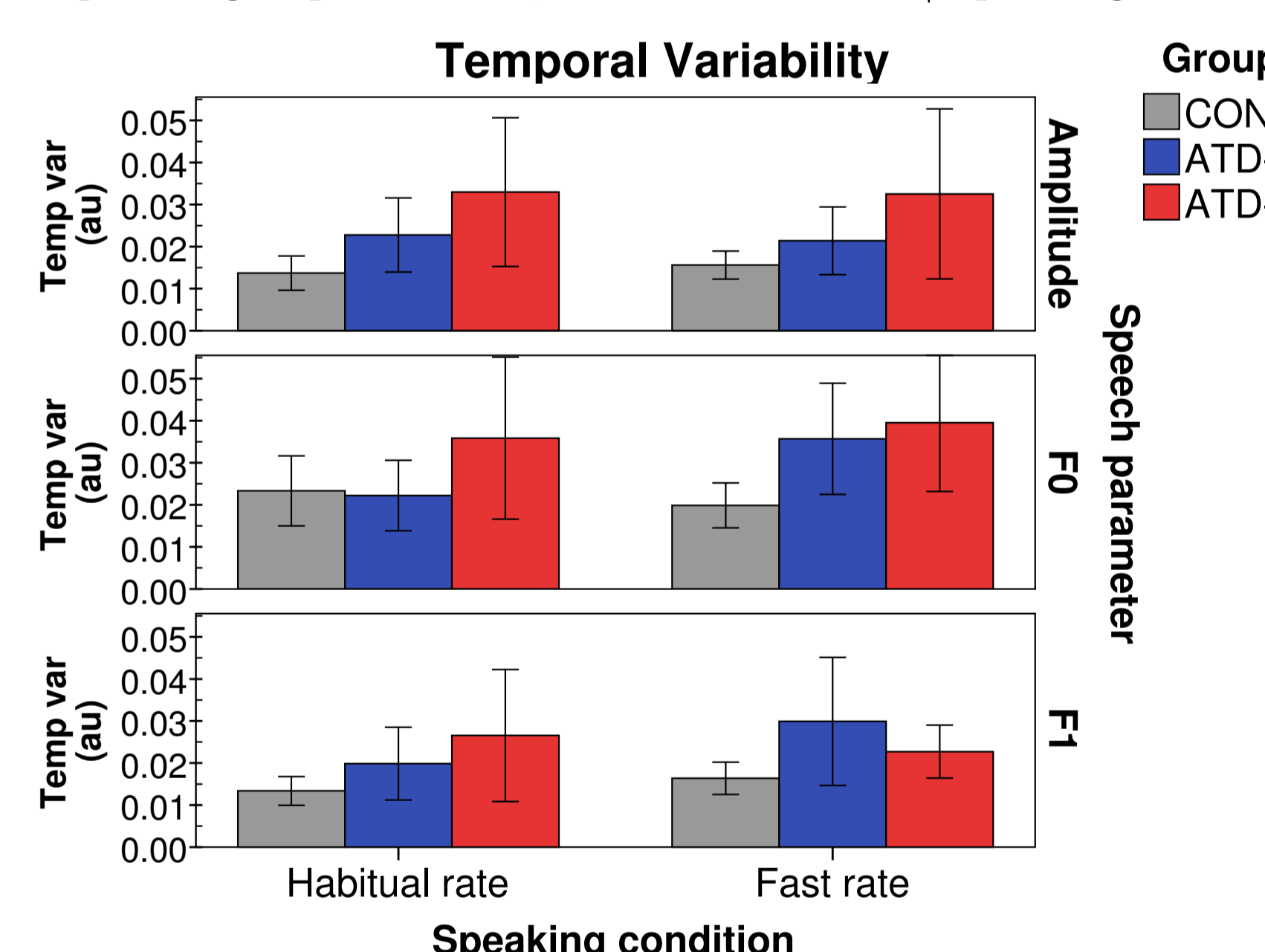
- A main **effect of Group** was present across speech parameters and speaking conditions F(2,17)=100,6 p<.001.
- Post-Hoc analysis (LSD) showed:
  - Variability is higher in ATD-A versus CON: p<.001
  - Variability is higher in ATD-B versus CON: p<.001
  - Variability is higher in ATD-B versus ATD-A: p<.001
  - ⇒ **ATD-B > ATD-A > CON**

- A main **effect of Group** was present across speech parameters and speaking conditions F(2,17)=10,05 p=.001.
- Post-Hoc analysis (LSD) showed:
  - Variability is higher in ATD-A versus CON: p=.024
  - Variability is higher in ATD-B versus CON: p=.001
  - No difference between ATD-B and ATD-A: p=.123
  - ⇒ **ATD-B = ATD-A > CON**

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 F1 variability and trends towards increased Amplitude variability and decreased F0 variability.
  - Also expressed in a different relationship of variability amongst speech parameters.
  - ⇒ might reflect emerging signs of hypokinetic dysarthria, i.e. imprecise articulation (F1), poor loudness control (Amplitude) and monopitch (F0).
- 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

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