



Western

# Acoustic changes along a modified speech rate continuum in Parkinson's disease

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## Background

**Parkinson's disease (PD):** 70-90% of people with PD develop **hypokinetic dysarthria**, characterized by imprecise articulation, speech rate abnormalities, monopitch/monoloudness<sup>1</sup>. For some, speech impairment worsens following deep brain stimulation surgery<sup>2</sup>.

**Speech rate reduction:** Common therapeutic goals to improve speech intelligibility in people with PD & dysarthria<sup>3</sup> and is associated with<sup>4-10</sup>:

- Increased segment durations
- Increased acoustic distinctiveness
- Increased speech intensity

**Puzzle:** Many people with PD and dysarthria do not see improvements in speech intelligibility when they slow their speech rate down<sup>11</sup>. Faster speech is not necessarily associated with "worse" speech for some talkers with PD<sup>12</sup>. Most studies have only elicited one or two speech rates<sup>3</sup>. What other speech changes are occurring when talkers change their rate of speech?

### Purpose

**Explore the acoustic changes (phonatory and articulatory) that occur along a modified speech rate continuum for talkers with and without PD.**

## Methods

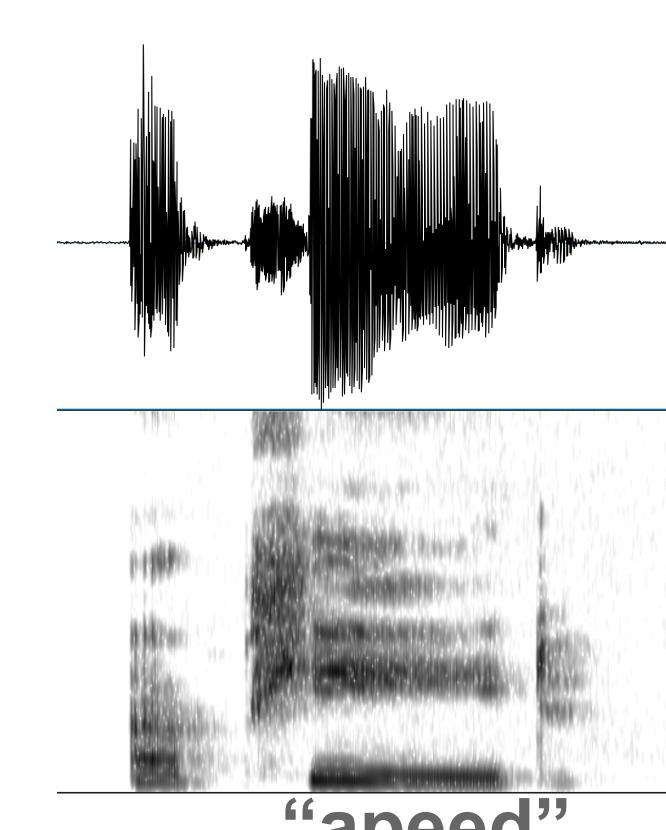
### Participants & Experiment

Participants	3 groups
Older Controls (n = 17)	
PwPD w/out DBS (n = 22)	
PwPD & DBS (n = 17)	

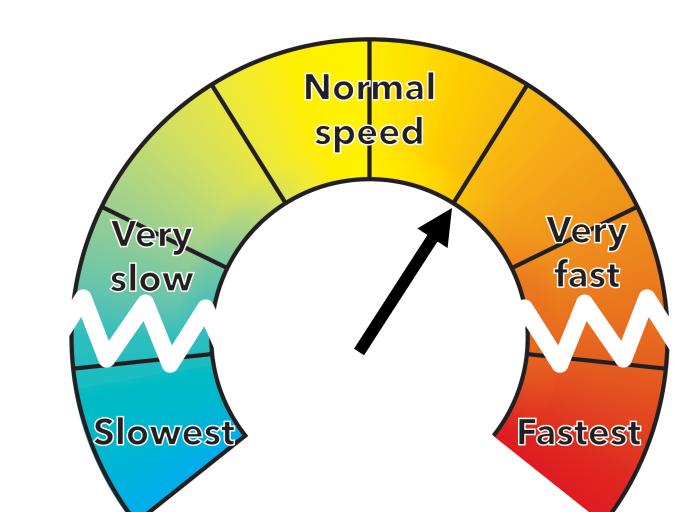
**Speech task:**  
"Please say aCVd again" \*

- 24 nonce words
- C: /p, t, k, b, d, g/
- V: /i, u, ae, a/

\* Part of a larger battery of speech tasks



- **Blocked magnitude production:** 7 rate conditions (habitual, 3 fast, 3 slow) elicited via magnitude production: "Please speak at a rate that feels 2x/3x/4x faster/slower"
- **Order:** Habitual rate always elicited first. Modified rates were elicited in a graded order within a block (2x, 3x, 4x), and order of block (fast vs. slow) counter balanced.
- **Practice & facilitation:** Participants underwent a brief practice period at the start of each condition. A practice utterance was recorded and played back every ~10 trials as an anchor to facilitate target rate production.
- **Proportional rate:** Actual speech rate was binned into 5 categories based on individuals' proportional rates.



Slowest | Slower | Habitual | Faster | Fastest

### Analysis

#### Acoustic analysis

- Words per minute (WPM) of the carrier phrase
- Vowel intensity
- Vowel harmonics-to-noise
- 4-Vowel articulation index (QVAI)<sup>13</sup>
- Voice onset time (VOT)

#### Statistical analysis

- Linear mixed regression models for acoustic variables of interest:  
 $DV \sim Group * Rate + \dots + (\dots / Participant) + (1 / Item)$
- **Base model fixed effects** included Group + Rate + Group x Rate. Additional variables were iteratively added as appropriate (e.g., consonant voicing), and kept if model fit improved (e.g., consonant voicing).
  - **Group:** Helmert contrasts: OC vs. PD/DBS, PD vs. DBS
  - **Rate:** Treatment contrasts: each proportional rate compared to habitual speech
- Speech rate differences compared using Welch 2-sample t-tests

## Results & Discussion

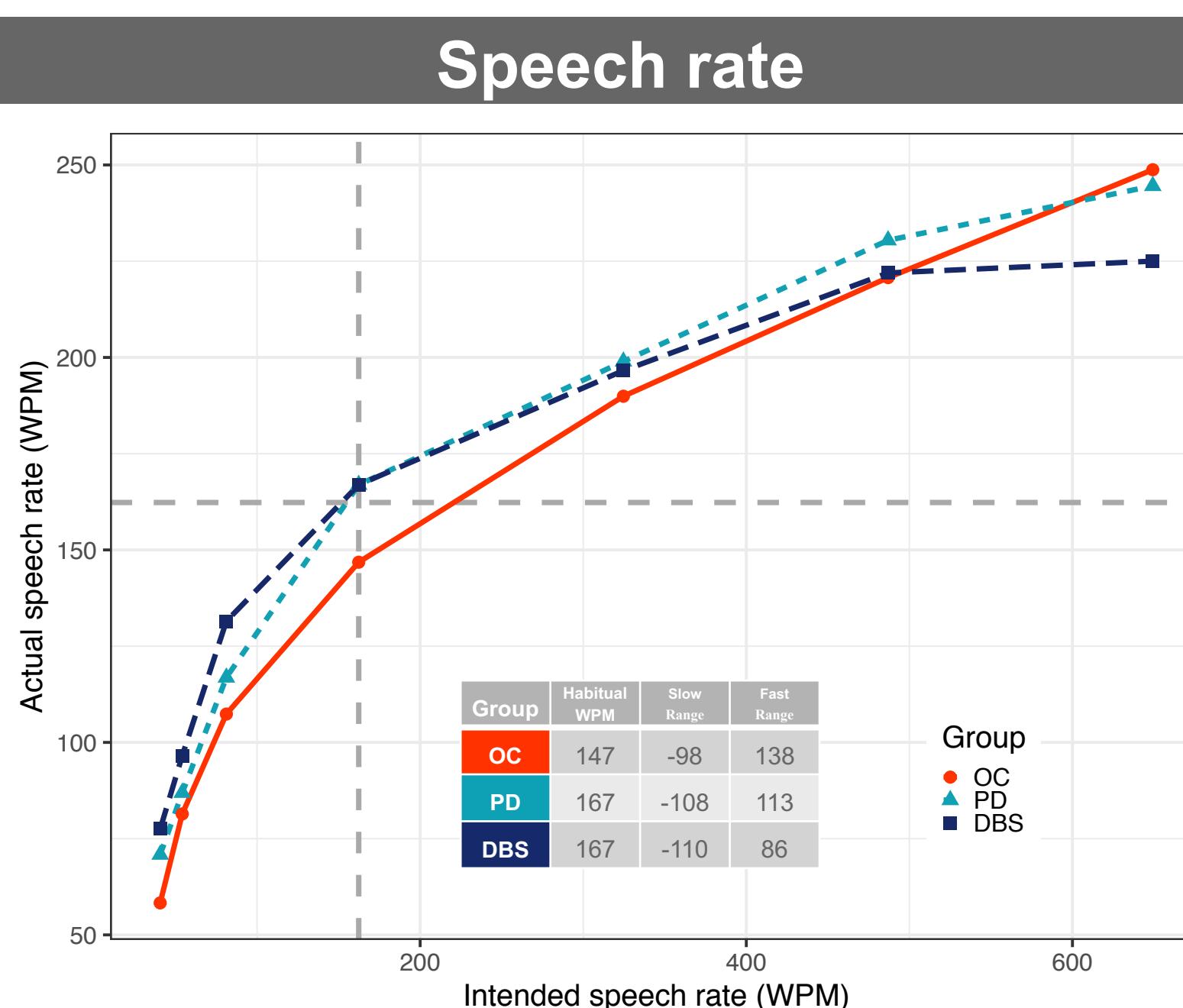


Figure 1: Actual speech rate (WPM; y-axis) vs intended speech rate (WPM; x-axis). Grey dotted lines represent grand means.

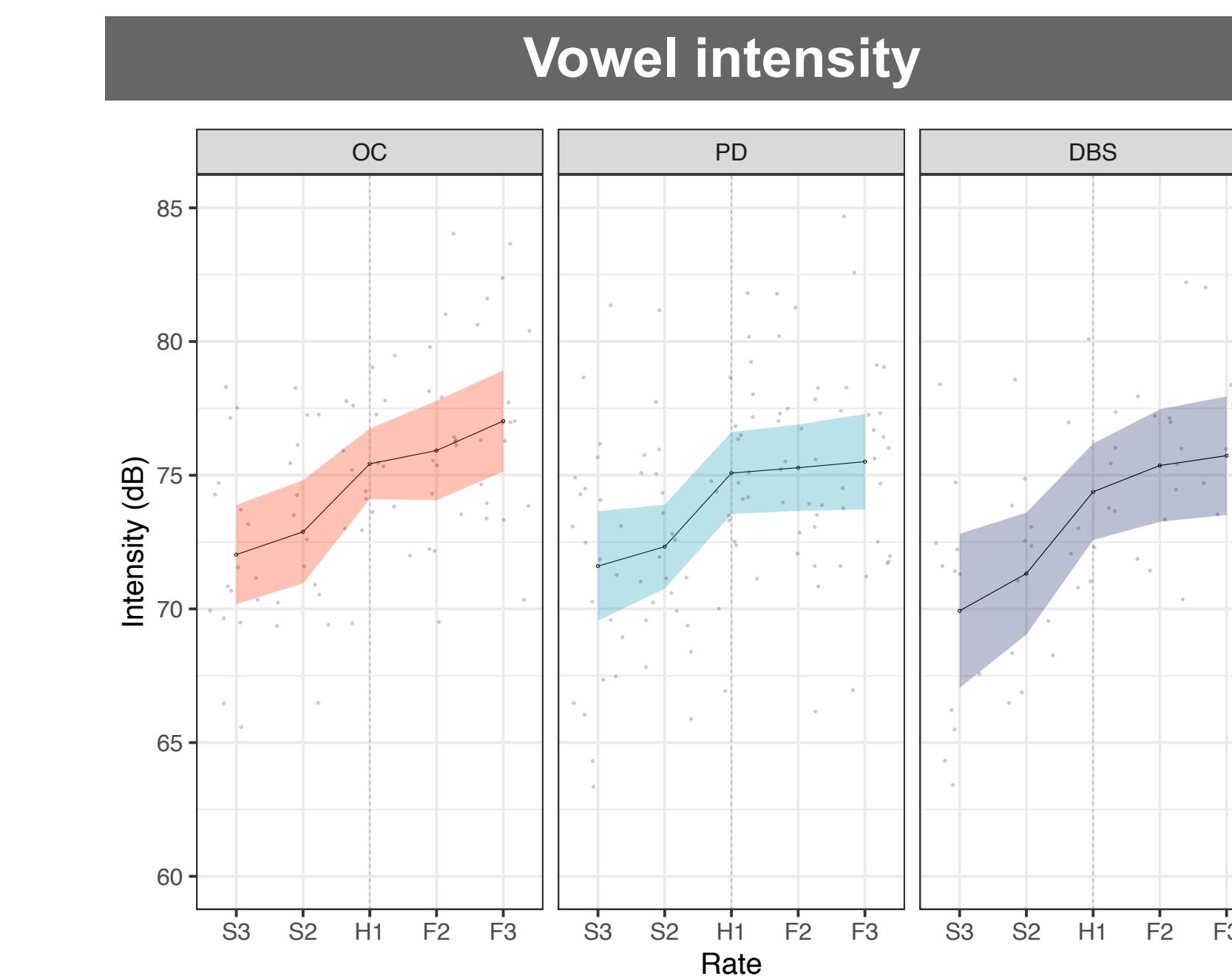


Figure 2: Vowel intensity (dB) by speaker group and speech rate, averaged over participants. Shaded band represents the 95% confidence interval.

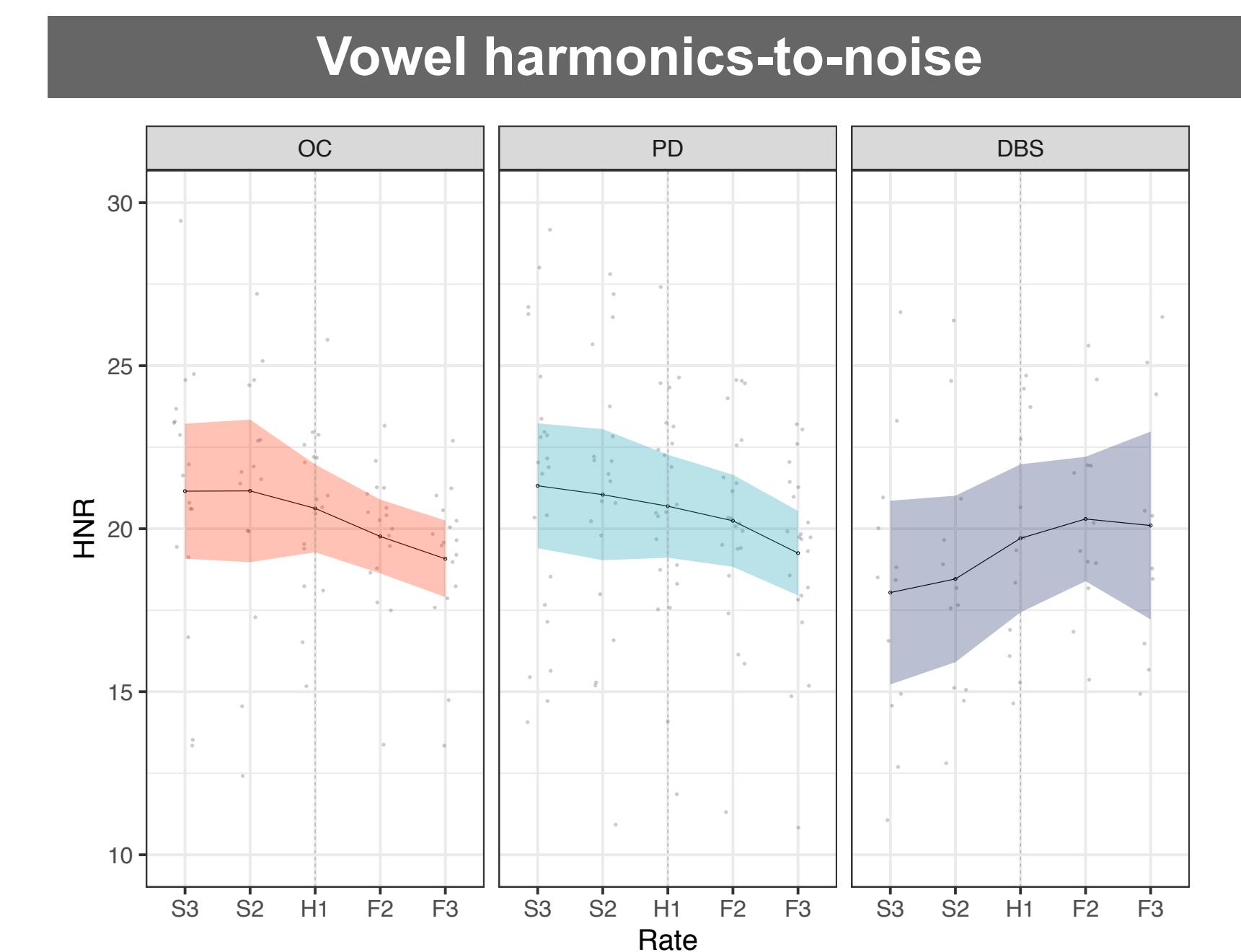


Figure 3: Vowel harmonics-to-noise ratio by speaker group and speech rate, averaged across participants. Shaded band represents the 95% confidence interval.

### Summary

#### Across a rate continuum, PwPD:

- Made *similar* proportional adjustments to their rate of speech from very slow to very fast when compared to older controls.
- Made *smaller* adjustments in consonant voicing distinctiveness at both slower and faster ends of the continuum.

#### At slower rates:

- Quieter, poorer quality speech for all talkers (and especially those with DBS).

#### At faster rates:

- Phonatory and vowel space changes did not significantly differ compared to habitual speech.
- Some talkers with DBS actually became louder and had better voice quality.

#### Voice onset time

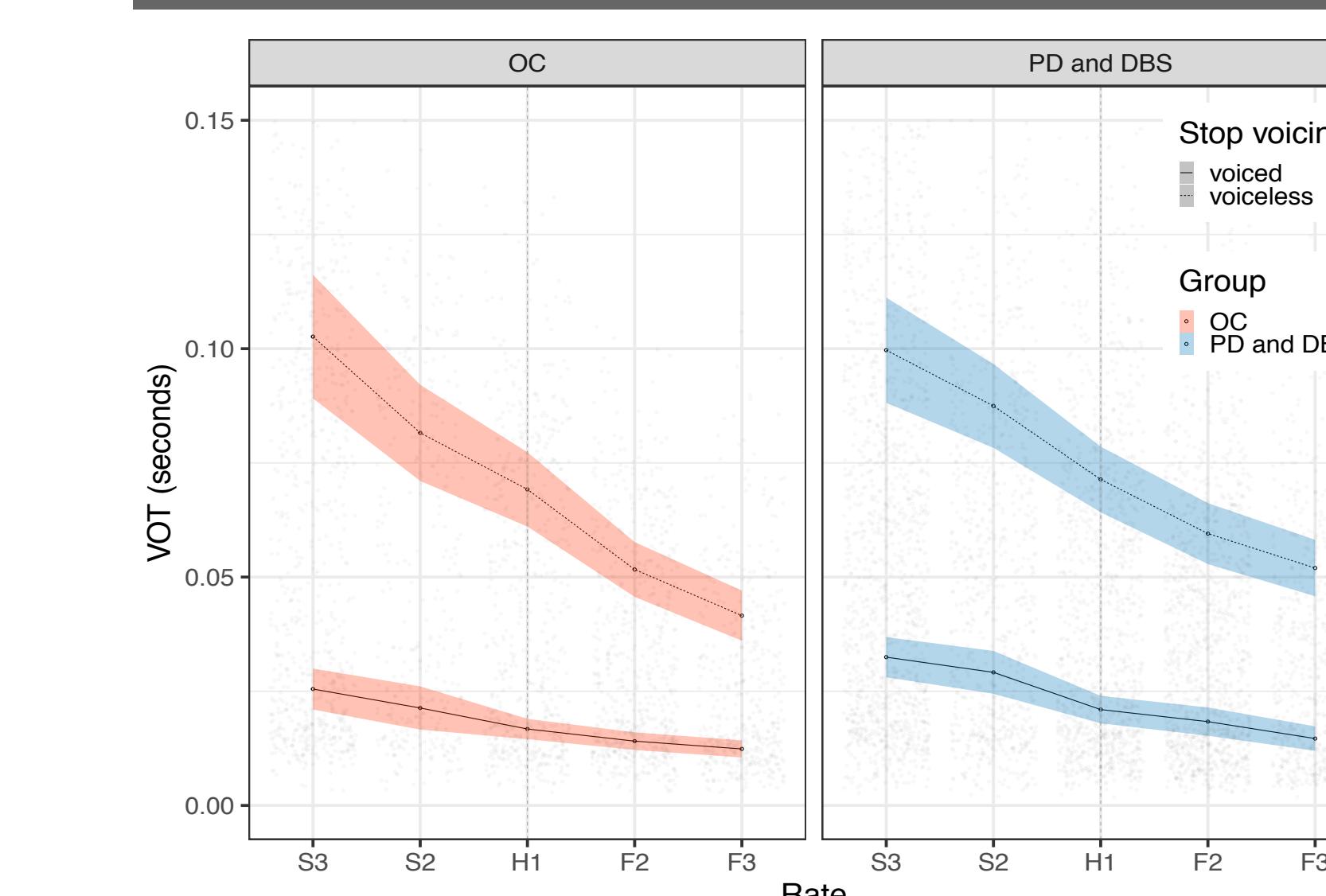


Figure 4: VOT by group, rate, and stop voicing, averaged across participants. Shaded band represents the 95% confidence interval.

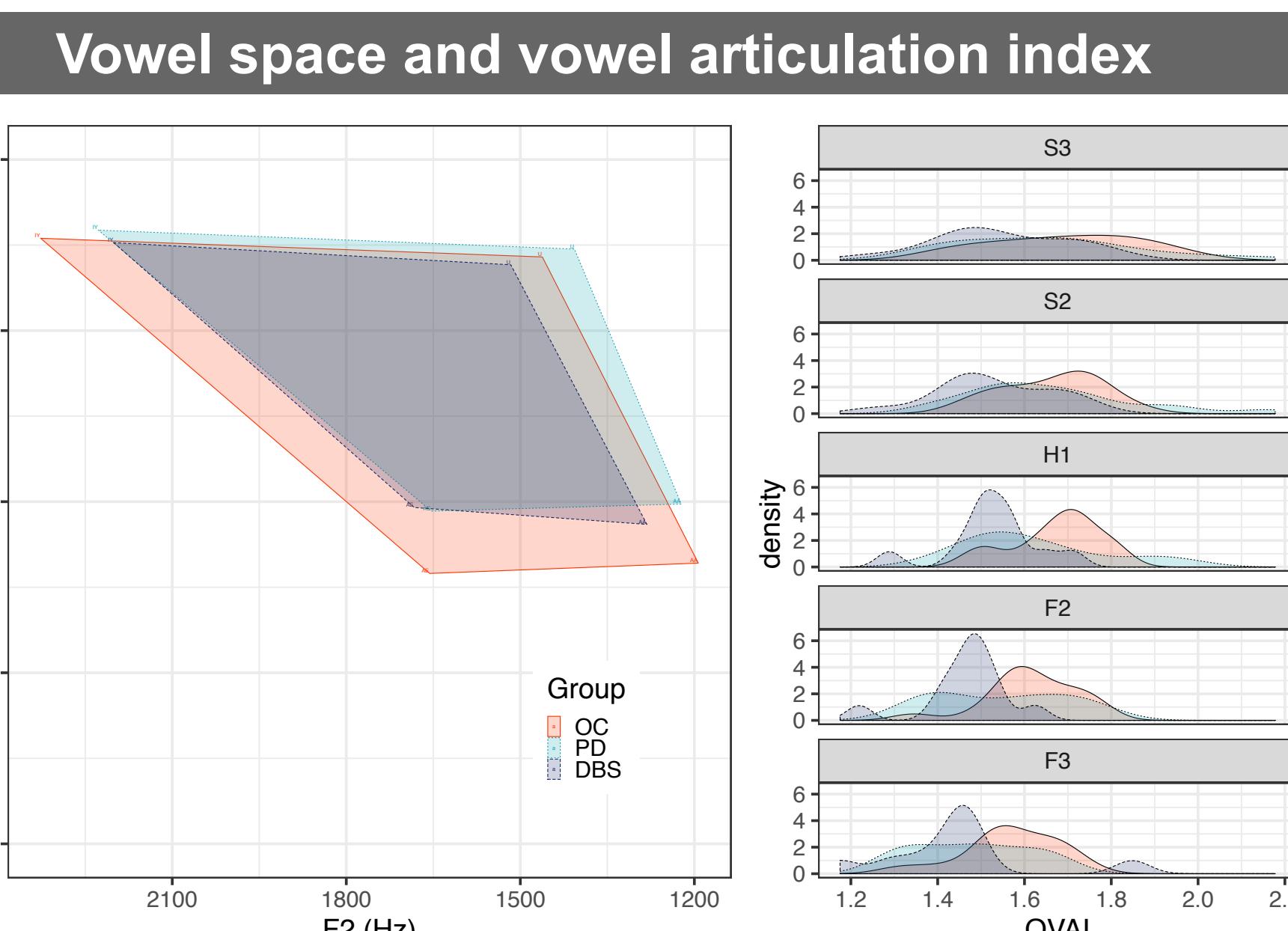


Figure 5: Left: Vowel polygons produced in the first and second formant space by each speaker group. Right: density plots showing the distribution of QVAI for each group at each rate (ordered top to bottom from slow to fast).

- **Rate effect:** Overall, longer VOT in slower speech & shorter VOT in faster speech ( $p < 0.001$ ).
- **Group effect:** OC > PD > DBS ( $p = 0.02 - 0.06$ )
- **Group x rate:** No significant interaction.
- **Group x rate x voicing:** OC showed greater voicing contrast at their slowest rates ( $p < 0.05$ ), and smaller voicing contrast at all faster rates. PD & DBS did not differ from one another. Pairwise comparisons showed group differences were usually greatest for voiced stops.
- **Rate effect:** Smaller QVAI in fast speech ( $p < 0.001$ ), trend for larger QVAI in slow speech ( $p = 0.04 - 0.12$ ).
- **Group effect:** OC > PD > DBS ( $p < 0.05$ ).
- **Group x rate:** No significant interactions.
- More variability of QVAI at slower rates (flatter distribution in Panel B).

References available upon request



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