

# PERCEPTION AND IMITATION OF PERIOD DOUBLING

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## I. OVERVIEW

**Period doubling (PD)** is a type of voice quality – carries at least 2 simultaneous periodicities

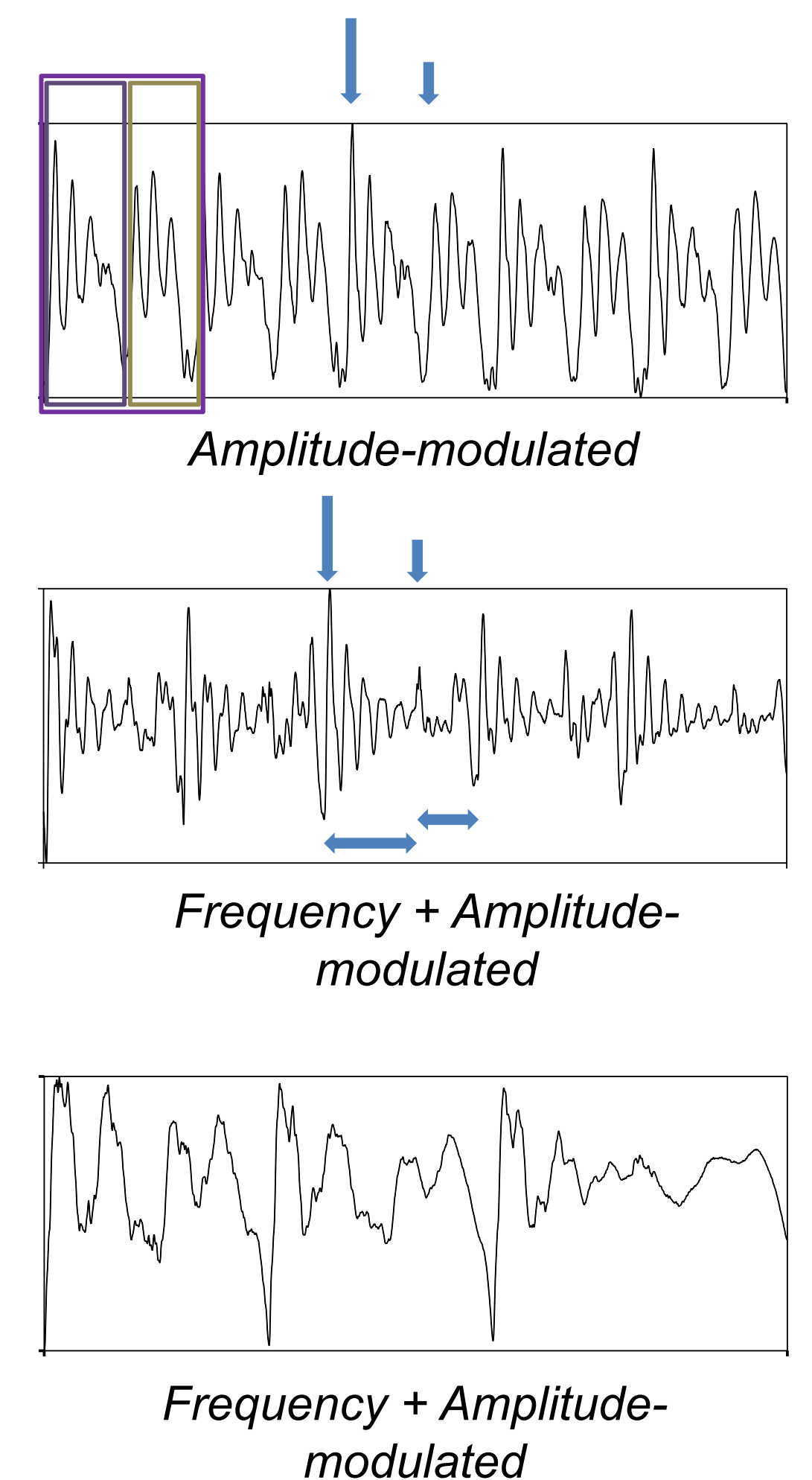
- Alternating pulses in **frequency** and/or **amplitude**, and glottal **constriction** degrees (Titze 1994, Huang 2022)
- **Rough** sounding with an **indeterminate** pitch (Schreibweiss-Merin et al. 1986, Yu 2010, Keating et al. 2015)
- A subtype of **creaky** voice that often occurs in **tone** languages (Mandarin, Vietnamese, etc.)
- Found in ~25% of normal speakers' utterances (Klatt & Klatt, 1990)

Previous findings on pitch and tone perception that involved PD:

- Pitch of PD was perceived **lower** with lower stimulus  $f_0$ , higher degrees of modulation, and more quickly in frequency-modulated tokens (Bergan & Titze 2001, Sun & Xu 2002)
- Resynthesized tones with PD **hindered** Mandarin tone identification under noise (Huang 2020)

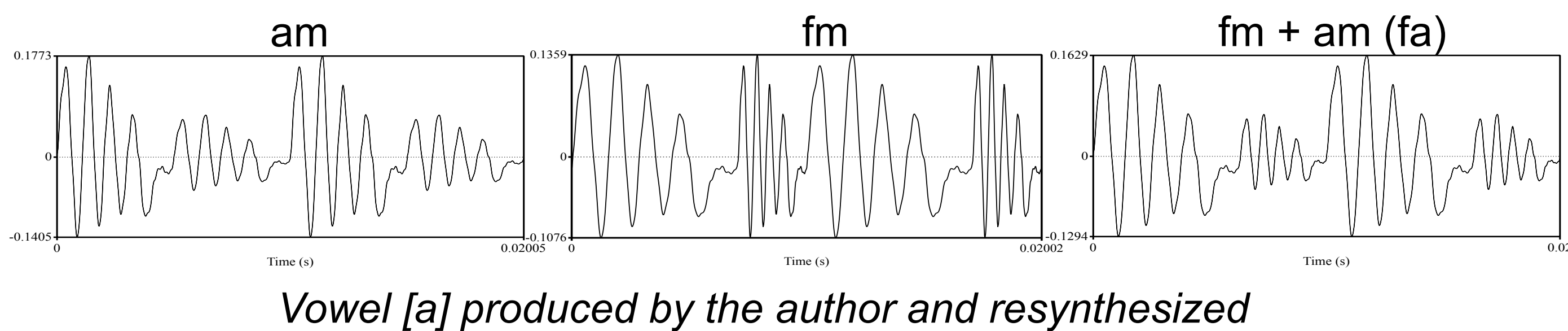
**Question: How is period doubling perceived and imitated as linguistic tones?**

- Higher modulation degrees, frequency modulation → listeners hear a **low** tone more frequently
- Higher stimulus  $f_0$  (300 Hz) → listeners hear a **low** tone more frequently in **amplitude-modulated** tokens
- PD is imitated with **lowered**  $f_0$  and **creaky** quality
- Mandarin (tonal) and English (non-tonal) listeners behave similarly



## II. METHODS

- Participants: 30 native Mandarin (18F) & 31 English (22F) speakers
- 380 Test PD tokens: (11 am steps x 17 fm steps + 3 extreme) \* 2



- 40 Training modal tones sampled from normal distributions of  $f_0$ s of 200 and 100 Hz, or 300 and 150 Hz

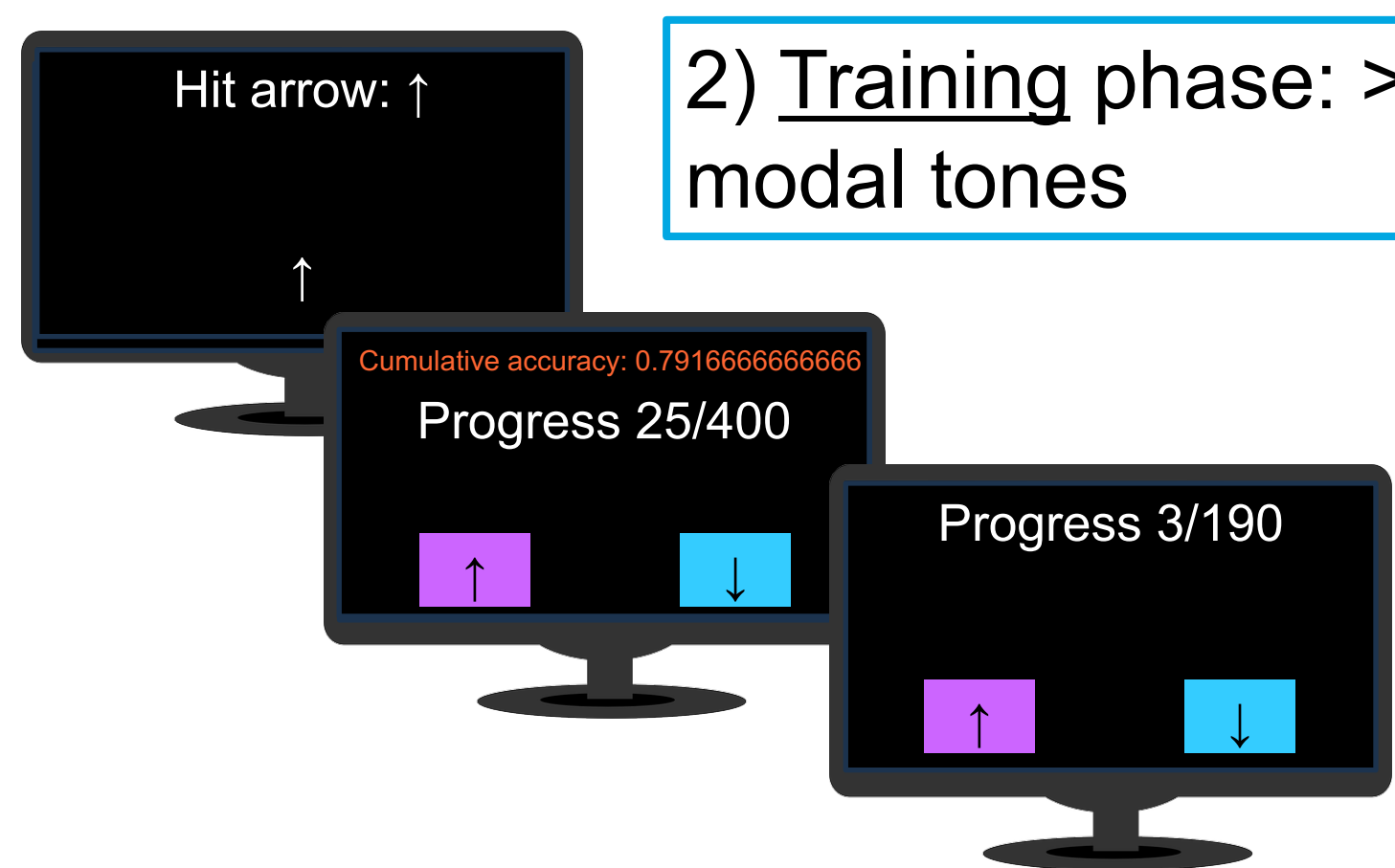
**Categorization task: Did you hear a ↑ or ↓ tone? (high or low)**

1) **Familiarization** phase: 40 modal tones ~200/100, ~300/150 Hz

2) **Training** phase:  $\geq 75\%$  accuracy on categorizing modal tones

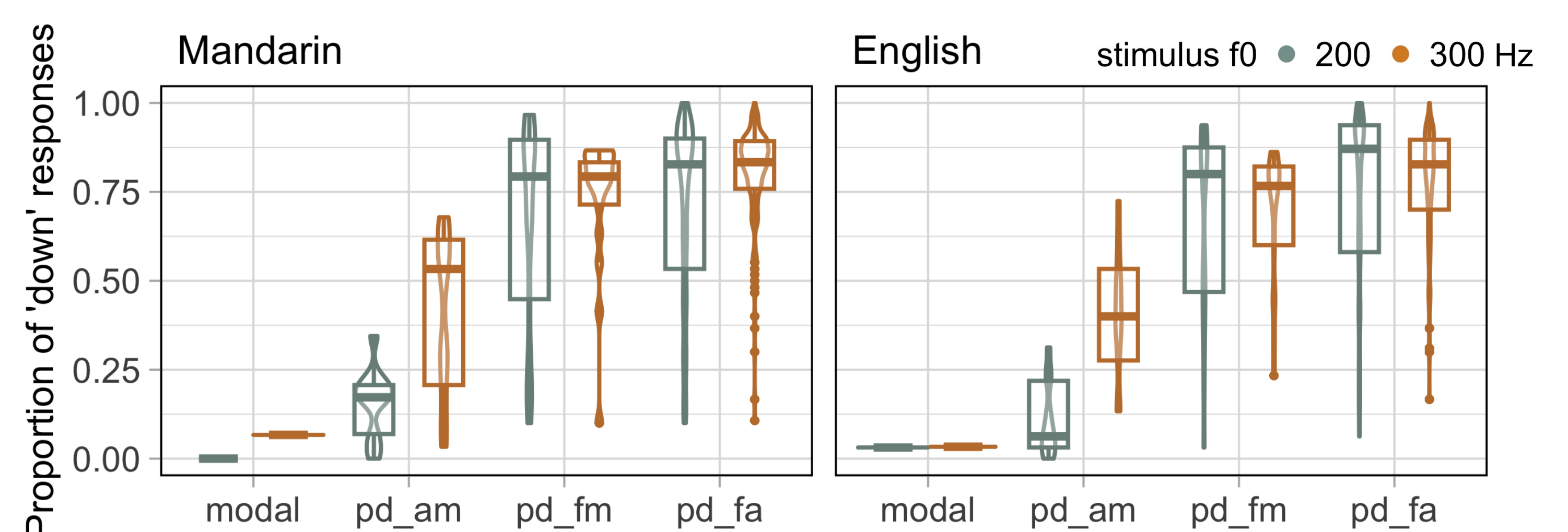
3) **Testing** phase x 2: resynthesized stimuli of PD with varying degrees resulting in an octave difference

4) **Imitation** phase: repeat 190 period-doubled stimuli

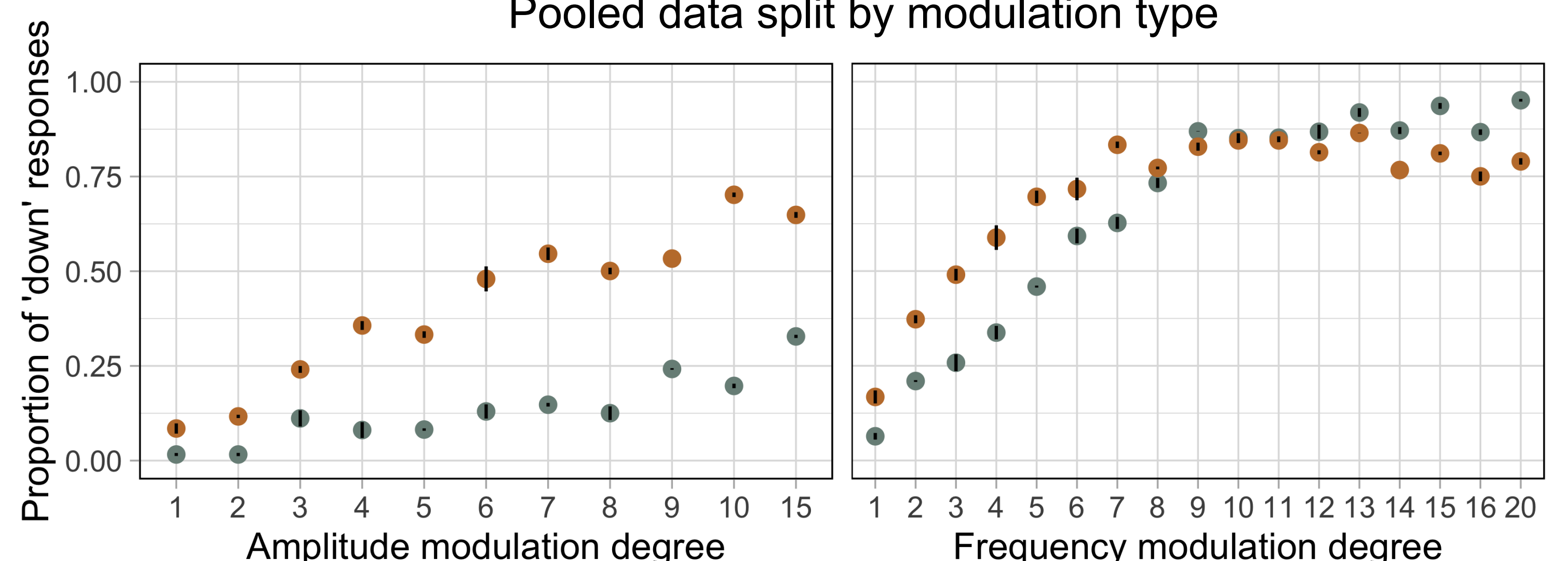


## III. RESULTS: PERCEPTION

Low-tone responses by voicing types by language

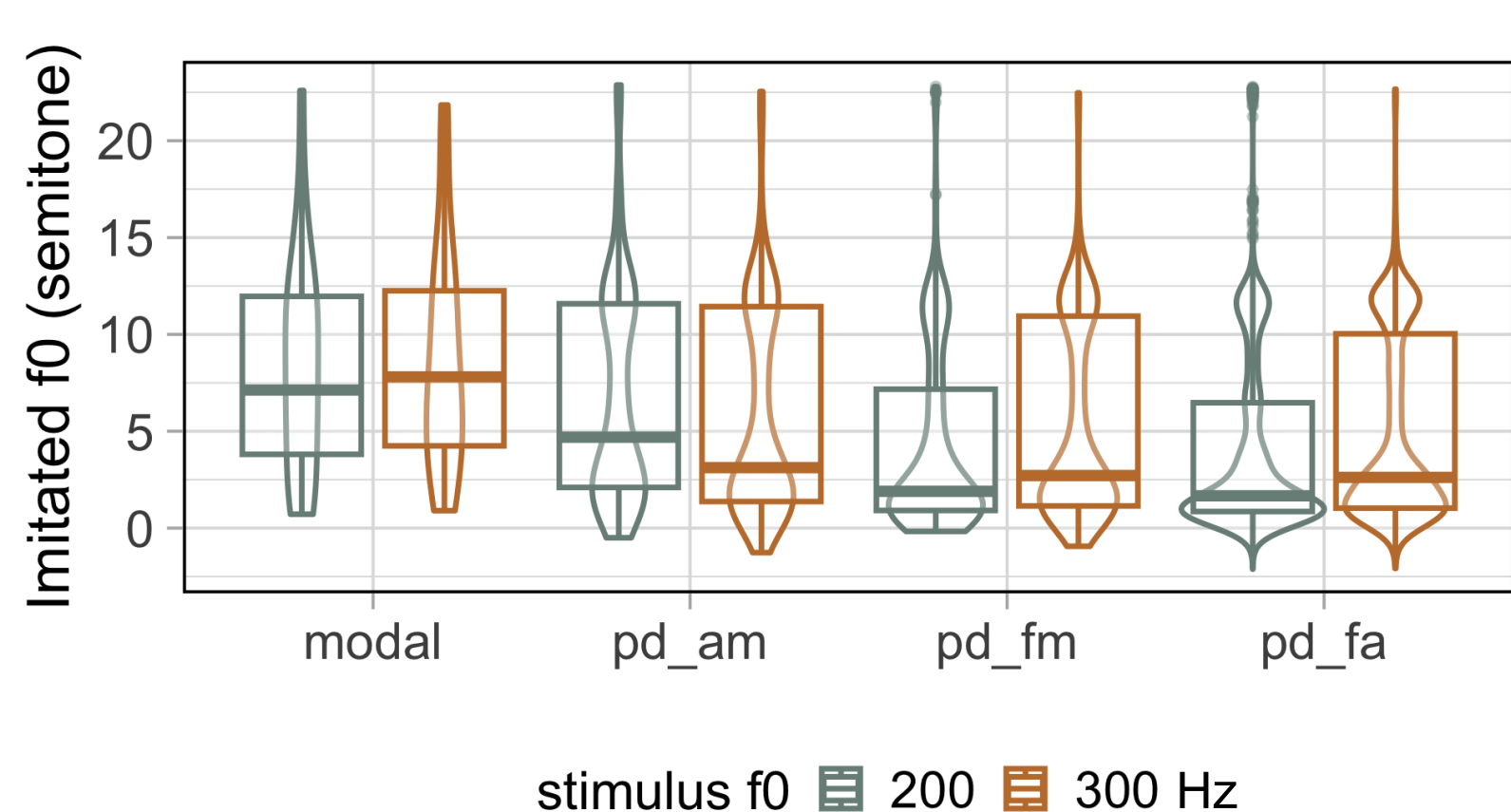


Pooled data split by modulation type

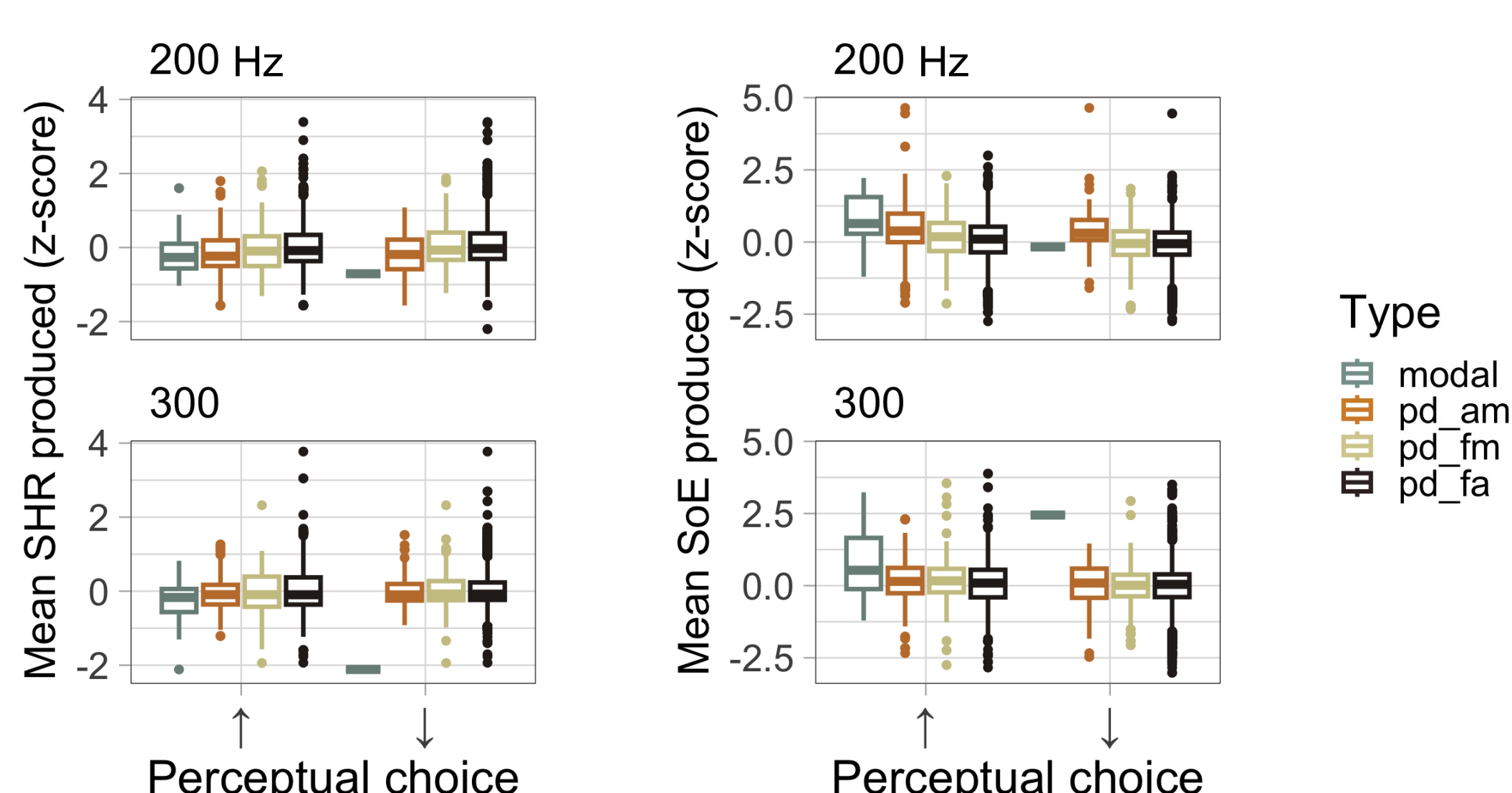


## IV. RESULTS: IMITATION

Imitated mean  $f_0$  by voicing types: lowered when imitating PD



Imitated creakier voice quality predicted by perception: higher subharmonics, lower energy measures when imitating PD



## V. DISCUSSION & CONCLUSIONS

- A general trend that the perceived pitch and imitated  $f_0$  are lower with period doubling, esp. when the modulation is stronger
- Listeners identify a lower pitch during PD, esp. with frequency modulation; with amplitude modulation, 70% perceived as low at the extreme. **Low pitch may be one shared property of creaky voice, even if it is not inherent to PD**
- Amplitude modulation can still signal a 'high' tone, especially when the original  $f_0$  is lower (200 Hz)
  - Maybe the pitch lowering is not salient enough given a low  $f_0$  baseline
- Listeners are more sensitive to changes in **period** than amplitude of glottal pulses when extracting pitch
  - Temporal noise measures (jitter & shimmer) are not perceptually relevant independently of spectral harmonics-to-noise ratio (Kreiman & Gerratt 2005, Garellek 2019)
- Speakers imitate low  $f_0$  and creaky voice, which matches with perception
  - Could use PD to realize **roughness**
- Pitch perception during PD is *not* language-specific; may not be influenced by tonal knowledge