Low tone bias during perception of period doubling 3aSC3

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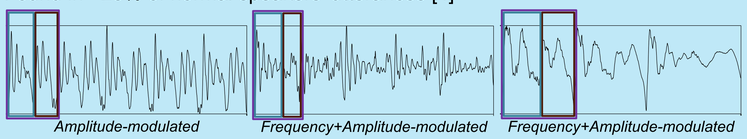
Q: How is period doubling perceived?

Period doubling (PD) is a type of voicing – contains at least 2 simultaneous periodicities, with the following defining characteristics:

- Alternating pulses in **frequency** and/or **amplitude**, and glottal **constriction** measures [2]
- Indeterminate pitch with a **low** and **rough** quality [3, 5, 7]

Also known as a special case of "multiply pulsing", a subtype of creak voice [3]

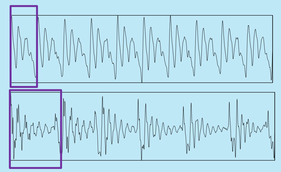
Found in ~25% of normal speakers' utterances [4]



Amplitude-modulated *Frequency+Amplitude-modulated* *Frequency+Amplitude-modulated*

Pitch of PD is perceived *lower* [1, 6]

- as the stimulus f0 *drops*
- as the degree of modulation *increases*
- more quickly in *frequency-modulated* tokens



Modal voice

Vocal fry

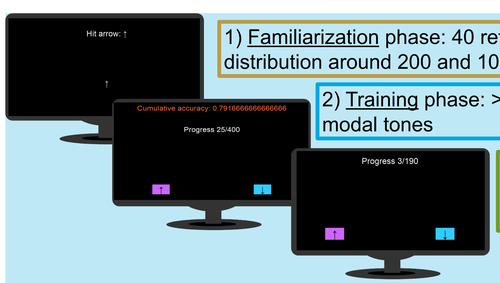
Questions:

- How does period doubling affect **linguistic tone perception**, given its various types and degrees of modulation?
- Do speakers with different language backgrounds perceive PD differently?

Hypotheses:

- Higher modulation degree → more period-doubled tones perceived as low tones
- Most tones perceived low with concurrent frequency and amplitude modulation
- Speakers of tonal language may be more sensitive to pitch changes

2 Artificial language learning experiment



1) Familiarization phase: 40 reference modal tones in a normal distribution around 200 and 100 Hz, or 300 and 150 Hz

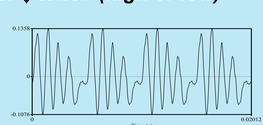
2) Training phase: >=75% accuracy on categorizing modal tones

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

Question: Did you hear a ↑ or ↓ tone? (high or low)

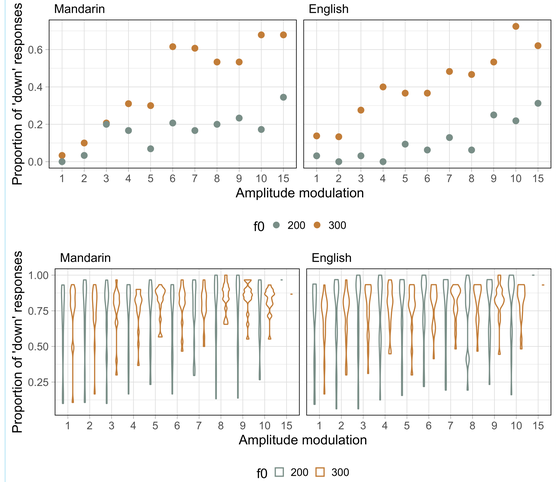
- Participants: 30 native Mandarin (18F; tonal) & 31 English (22F; non-tonal) speakers
- 380 Test tokens: (11 am steps x 17 fm steps + 3 extreme) * 2
- 40 Training modal tones:

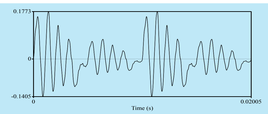
Gauss (200, 20)	Gauss (100, 8)	Gauss (300, 20)	Gauss (150, 15)



3 Results: amplitude modulation

	Range	Step	Median (SD)	Median + 2SD	Total
Amplitude ratio (stronger:weaker)	Range: (1, 3); Extreme: 4	0.2	1.43 (0.73)	2.88	11



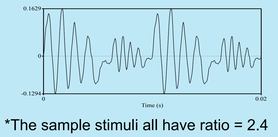


Pure amplitude-modulated tokens

- Higher modulation degree → more 'down' responses
- f0 is *300 Hz* → more low-tone tokens
- No language effect

Concurrent frequency + amplitude:

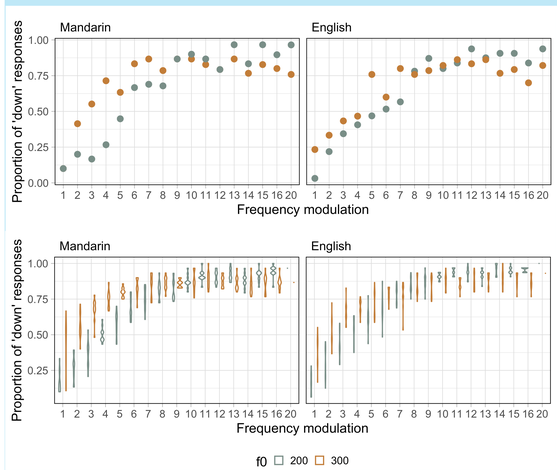
- No clear pattern of degree of amplitude modulation (am)

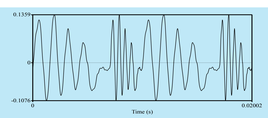


*The sample stimuli all have ratio = 2.4

4 Results: frequency modulation

	Range	Step	Median (SD)	Median + 2SD	Total
Frequency ratio (longer:shorter)	Range: (1, 2.6); Extreme: 3	0.1	1.38 (0.56)	2.50	17





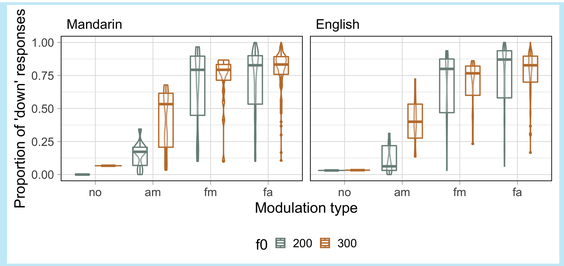
Pure frequency-modulated tokens

- Higher modulation degree → more 'down' responses
- No language effect

Concurrent frequency + amplitude:

- *Driving* pattern by degree of frequency modulation (fm)

5 Results: type, ambiguity



- Frequency + amplitude > frequency > amplitude modulation
- English & Mandarin speakers perceive PD similarly
- More *am* tokens of 300 Hz are perceived as lower

Stimulus f0 (Hz)	Fm step	Am step	Mean response	SD response	
200	0	0	0.016	0.127	Least ambiguous
200	0	1	0.016	0.127	• fm = extreme
200	0	2	0.016	0.127	
200	11	8	0.984	0.127	
200	20	15	0.984	0.127	
300	1	9	0.500	0.505	Most ambiguous
300	3	1	0.509	0.505	• fm, am = smaller
200	3	4	0.500	0.504	
300	2	4	0.491	0.504	
200	4	8	0.500	0.504	

A: PD is perceived as *low* tone

- Higher modulation degree → larger proportion of low tones heard
- **Frequency modulation** drives the trend of perceiving more low-tone responses, not amplitude modulation
- Pitch perception during PD is *not* language-specific, at least for Mandarin versus English speakers

→ PD is predicted to signal **low tones** in languages, even when the f0 is high

→ Presence of PD (found to be more frequent at utterance edges; Huang, dissertation) is predicted to **interfere with high-tone perception**, at least with moderate-high modulation

References

[1] Bergan, C. C., & Titze, I. R. (2001). Perception of pitch and roughness in vocal signals with subharmonics. *Journal of Voice, 15*(2), 165-175. [2] Huang, Y. (2022). Articulatory properties of period-doubled voice in Mandarin. *Proc. Speech Prosody 2022*, 545-549. [3] Keating, P. A., Garellek, M., & Kreiman, J. (2015). *Acoustic properties of different kinds of creaky voice*. In *ICPhS 2015*, No. 1, pp. 2-7). [4] Klatt, D. H., & Klatt, L. C. (1990). Analysis, synthesis, and perception of voice quality variations among female and male talkers. *The Journal of the Acoustical Society of America, 87*(2), 820-857. [5] Schreibweiss-Merin, D., & Terrio, L. M. (1986). Acoustic analysis of diplophonia: A case study. *Perceptual and motor skills, 63*(2), 755-765. [6] Sun, X., & Xu, Y. (2002). Perceived pitch of synthesized voice with alternate cycles. *Journal of Voice, 16*(4), 443-459. [7] Yu, K. M. (2010). Laryngealization and features for Chinese tonal recognition. In *Eleventh Annual Conference of the International Speech Communication Association*.