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Bidirectional Consonantal Effects on Vowel F0 Production in Modern Burmese

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GOAL OF PRESENT STUDY

- To investigate how consonant voicing (voiced vs. voiceless) influences the F0 of preceding and following vowels in Burmese.
- To analyze the phonetic realization of Fundamental Frequency (F0) in minor syllables of modern Burmese.
- To evaluate whether these acoustic cues can be perceptually used as reliable indicators of consonant voicing.

RESEARCH QUESTIONS

- How does consonant voicing (voiced vs. voiceless) influence the F0 of preceding (minor) and following (major) syllables in Burmese?
- How is F0 realized in minor syllable in Burmese?
- Can we tell the following voicing based on the F0 realization in the preceding minor syllable in Burmese?

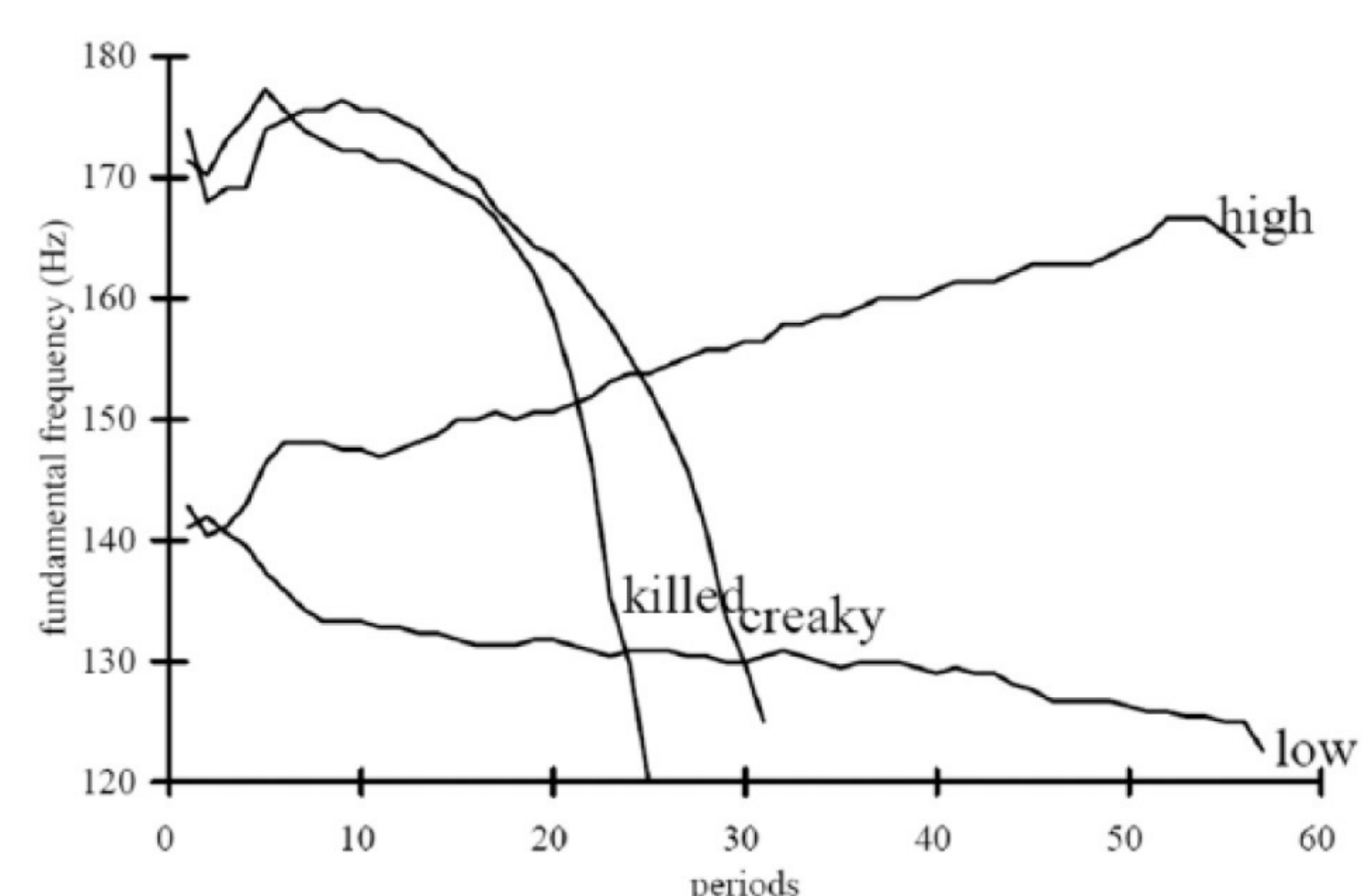
BACKGROUND

MODERN BURMESE LEXICAL TONE

- Syllable types:** major syllables (fully realized heavy syllables) and minor syllables (reduced or light syllables)

	Major syllables	Minor syllables
Quantity	Bimoraic	Monomoraic
Vowel Type	Any but schwa	Only schwa
Lexical Tone	Any	No
Coda	Yes	No
Position	Any position	Prefix or initially

- Lexical tone types:** four types of lexical tones are studied:



Low	[mà:]	'hard'
High	[má:]	'high'
Creaky	[mǎ]	'female'
Killed	[maʔ]	'March'

ONSET VOICING EFFECT ON F0 REALIZATION

- Typically, vowels following **voiceless consonants have a higher onset F0**, while vowels following **voiced consonants have lower onset F0** (House & Fairbanks 1953; Hombert et al. 1979).
- Such observations are documented in both **tonal** languages, such as Cantonese (Zee 1980) and Yoruba, and **non-tonal** languages, such as English and French (Kirby and Ladd 2016).
- Some **language-specific differences** exist: Mandarin and Hindi show lowered F0 after heavily aspirated consonants due to timing and vocal fold adjustments (Xu & Xu 2004; Kagaya & Hirose 1975).

F0 REALIZATION ON TONELESS SYLLABLES

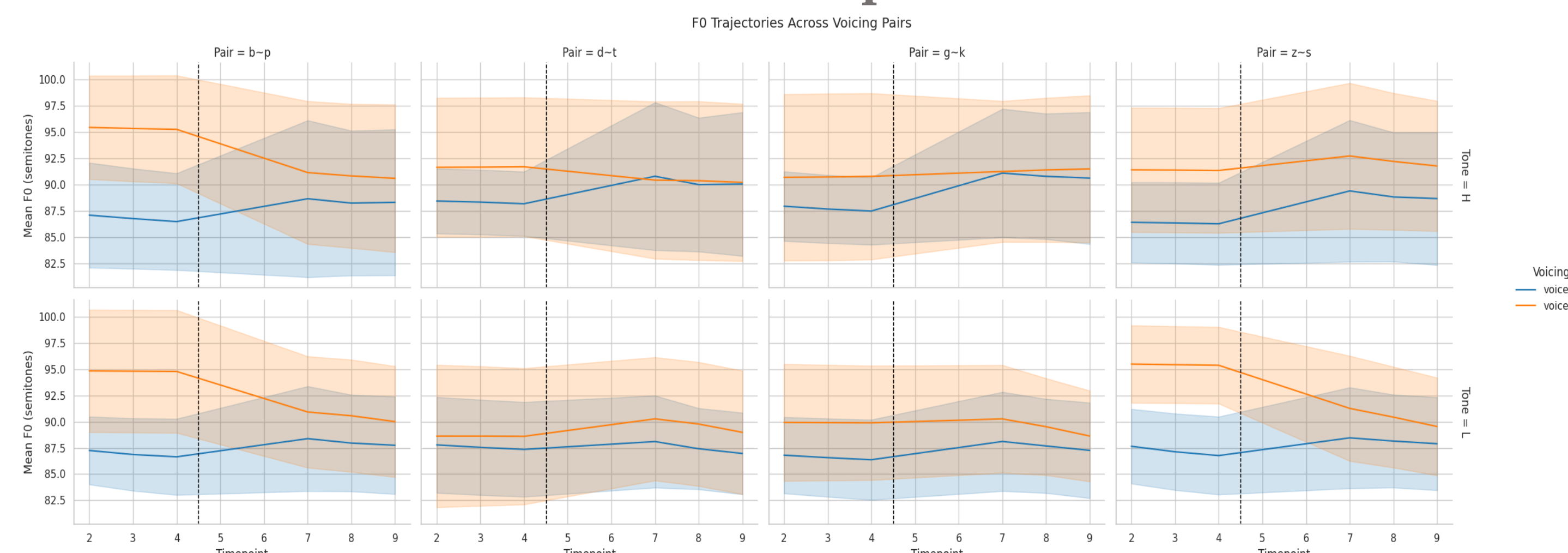
- In tonal languages, **interpolation** (Xu & Xu 2004), **default tone insertion** (Chen & Xu 2006), and **tone spreading** (Chen & Xu 2006; Zhu 2022) are found.

METHODOLOGY

- Speakers:** 4 modern Burmese speakers originally from Yangon, currently residing in the U.S. for about 1–2 years.
 - All speakers are Burmese-English bilinguals pursuing higher education degrees.
 - 2 male and 2 female speakers, aged between 30–40 years.
- Lexical items:** disyllabic Burmese words, composed of a minor syllable (first syllable) and a major syllable (second syllable).
 - Major syllable carries either a High-level or Low-level lexical tone.
 - Onset consonants of major syllables are restricted to voiced and voiceless stops (/p, b, t, d, k, g/) and fricatives (/s, z/), differing only in voicing;
 - All combinations of minor + major syllables are confirmed as possible words in modern Burmese by Speaker 1 (a Burmese language instructor in the U.S.).
 - Speakers produced these lexical items inserted in the non-final position of a carrier sentence: *mín* ___ *sá-dè* ("You eat ___.");
 - Each lexical item was produced three times by each speaker.
 - All the vowels in major syllables are controlled to be the low vowel /a/;
 - Possible words: /ʔə-pá:/ vs. /ʔə-pà:/; /ʔə-bá:/ vs. /ʔə-bà:/;

RESULTS

EXPERIMENT I -- Acoustic Description



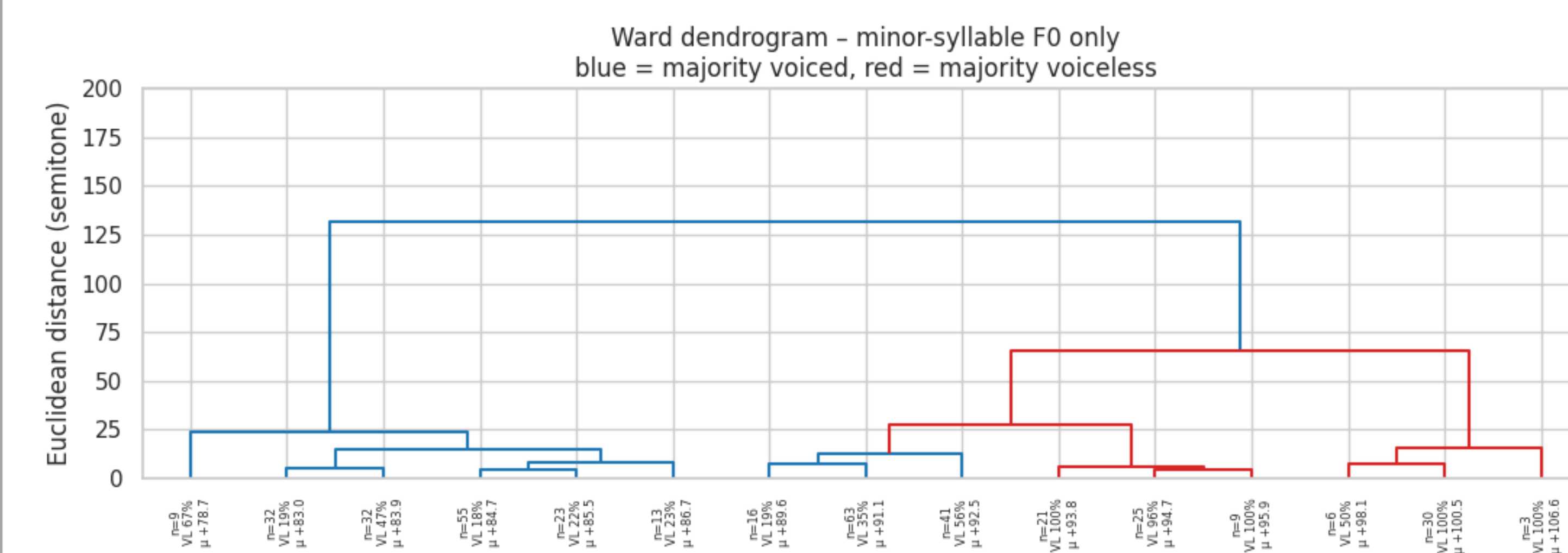
- A Linear Mixed model is conducted:
Semitone ~ Voicing × SyllablePosition × Tone + Gender + (1 | Speaker).
- Three points from minor syllable offset and 5 points from major syllable onset are extracted via ProsodyPro (Xu 2013).
- Consonant voicing significantly affects F0 in Burmese.
 - Voiceless consonants consistently raise pitch compared to voiced consonants ($\beta = 1.609, SE = 0.628, z = 2.563, p = 0.010$).
 - /k, p, s/ are significantly elevating F0 ($p = 0.011, 0.036, 0.001$).
- Stronger anticipatory effect (minor syllable offset) than carry-over

effect (major syllable onset): ($\beta = 3.604, SE = 0.828, z = 4.351, p < 0.001$);

- Voicing effect is stable across tonal contexts: ($\beta = 0.468, SE = 0.825, z = 0.567, p = 0.571$);
- No significant gender effect on F0 observed.

EXPERIMENT II – Simulation of Perceptual Cue Usability

- A **random-forest classifier** to test whether this F0 cue predicts: **Consonant voicing** (voiced vs. voiceless) and **Lexical tone** (High vs. Low) of the following major syllable.
- Used leave-one-speaker-out cross-validation to evaluate generalizability across speakers.
 - Voicing prediction:** accuracy = 65% (chance = 50%), suggests minor-syllable pitch robustly signals voicing across speakers.
 - Tone prediction:** accuracy = 43% (\approx chance), indicating minor-syllable pitch does not encode upcoming lexical tone.



- Ward hierarchical clustering** on mean F0 of minor (toneless) syllables was performed.
 - Left branch (blue): predominantly voiced tokens and right branch (red): predominantly voiceless tokens;
 - Voicing effects are phonetically real, but merely categorically separated—supporting the 65% accuracy observed in supervised classification.

DISCUSSION

- This study provides another case of F0 realization in toneless syllable in a tonal language: the phonetic realization is adjusted based on the voicing feature of the following consonant.
- Minor-syllable anticipatory pitch effects provide a clear phonetic precursor to potential lexical tone development, supporting models of consonant-induced tonogenesis (cf. Kirby et al. 2024).
- Across all consonant pairs (except /t, d/ pair), voiceless consonants consistently yield higher F0 compared to voiced consonants, particularly visible at the offset of minor syllables (anticipatory effect).
- Salient anticipatory adjustments observed at minor syllable offsets reinforce the hypothesis that anticipatory laryngeal adjustments could initiate phonologization processes.