Perceptual equivalence between co-articulated cues during a sound change in progress

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Cue shifting and sound change

- Phonological contrasts involve multiple cues
- Sound change happens when a secondary cue becomes primary, while maintaining the original lexical contrasts (c.f. tonogenesis)
- Listeners are often in the lead [8, 3, 5]
- **Perceptual equivalence as a crucial step:** Cue shifting in perception is possible when co-articulated cues become equally informative [1]
- **Question:** What is the relationship between source cues and co-articulated cues during a sound change in progress?

Sound change in Southern Yi

- Tibeto-Burman language
- 3 tonal contrasts and 2 register contrasts (Table 1)

Tone	Low		Mid		High
Reg.	Lax	Tense	Lax	Tense	Lax
/e/	/be21/	/be̲21/	/be33/	/be̲33/	/be55/
	“to drop"	“to entangle"	“to fight"	“to shoot"	“kettle"
/u/	/bu21/	/bu̲21/	/bu33/	/bu̲33/	/bu55/
	“to carry"	“moldy"	“worm"	“full"	“to weep"

Table. 1: Minimal sets of tonal and register contrasts in Southern Yi.

- **Primary cue** for the register contrast is distinct phonation [6]
- **Co-articulated cues**: tense vowels are lower and backer
- **Sound change in progress** [5]
  - Co-articulated F1 cues are overtaking phonation as the primary cue for the register contrast
  - Cue shifting takes place in perception first
  - Cue shifting in low vowels (e.g., /e/) is more advanced than that in high vowels (e.g., /u/).

Methods

Participants

- 56 native Southern Yi speakers; 32 female (age range 19-81; mean 48.22) and 24 male (age range 30-76; mean 51.08).

Stimuli

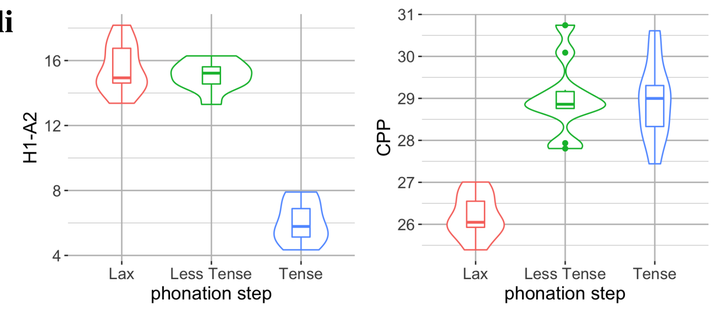

Fig. 1: Illustration of the phonation manipulations on the stimuli.

- 3 phonation steps x 5 f0 steps x 2 vowels = 30 stimuli
- Created from naturally produced minimal pairs /be33, be̲33/ and /bu33, bu̲33/ from a male speaker in his 40s
- The vowel quality of each pair was neutralized
- Step 1 = natural lax; step 3 = natural tense
- Step 2 (Less tense): increasing the steepness of the tense stimuli to match the spectral tilt of step 1 (i.e., natural lax), using TANDEM-STRAIGHT [4].

Procedures

- **Exp 1**: baseline production
- **Exp 2**: shadowing; repeat each word quickly and closely imitate the model speaker (3 repetitions)
- Acoustic measurements were taken using VoiceSauce [9]

Acknowledgments

This work is supported by an URF award from the University of Pennsylvania to Jianjing Kuang and an NSF EAPSI fellowship to Aletheia Cui. We thank the Yi speakers who kindly participated in our study.

Specific questions

- **Are speakers sensitive to the phonetic details of the phonation steps? Do they shadow them faithfully?**
- **Do speakers enhance vowel quality cues (i.e., greater F1) when shadowing tenser phonation?**
- **If co-varying cues can be enhanced, are all co-varying cues (e.g., f0) equally enhanced?**

Results: Phonation step effects

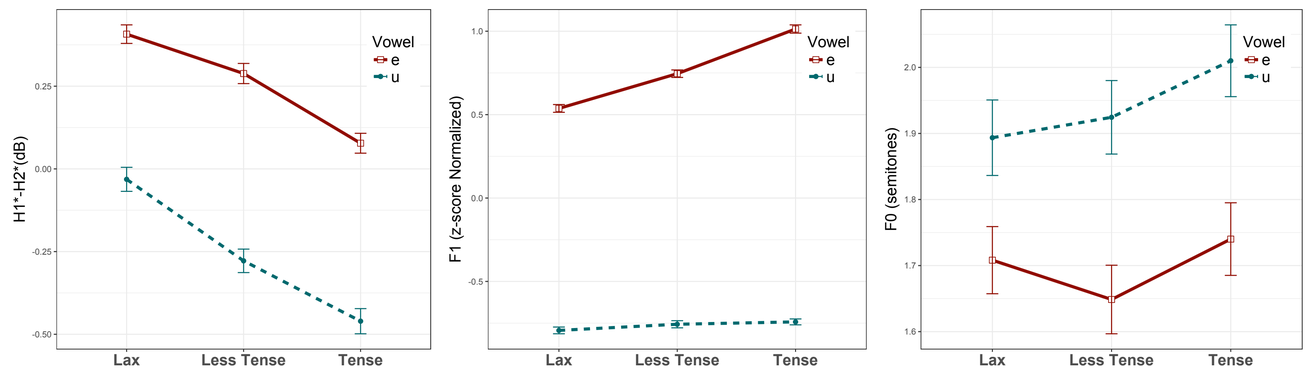

Fig. 2: Effects of phonation, F1, and f0 on the shadowing of the phonation steps.

- Significant step effects on phonation: Speakers do shadow different phonation steps with distinct H1*-H2*
- The co-varying vowel quality cues are also enhanced during shadowing
- However, /e/ and /u/ are significantly different: F1 is only enhanced for /e/ but not /u/
- The ambiguous phonation step is perceived as intermediate between natural tense and natural lax
- F0 is not significantly enhanced for either /e/ and /u/.

Further analysis and discussion

Why is F1 only enhanced for /be/ but not for /bu/?

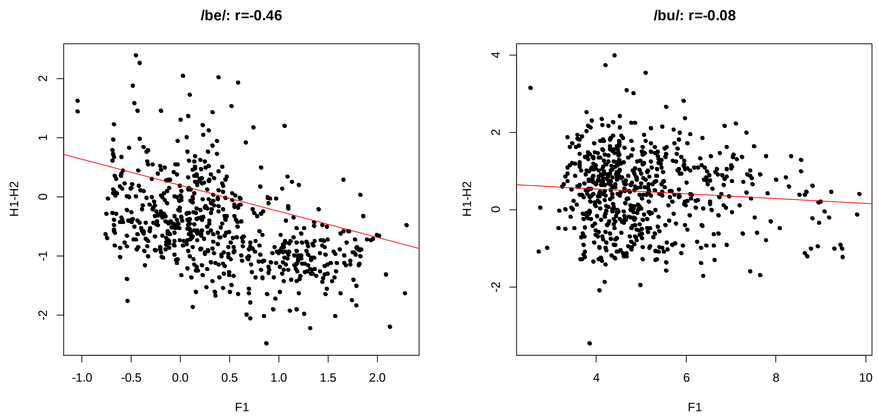

Fig. 3: Correlation between phonation and F1 for /be/ and /bu/.

- Strong correlation between the phonation cue (e.g.,H1*-H2*) and vowel formants (e.g., F1) for /be/; no correlation for /bu/
- Vowel quality cues are equally informative as phonation cues for /be/, but such perceptual equivalence has not been established for /bu/
- Indeed, vowel-splitting is more advanced for /be/

Who shadowed (more)?

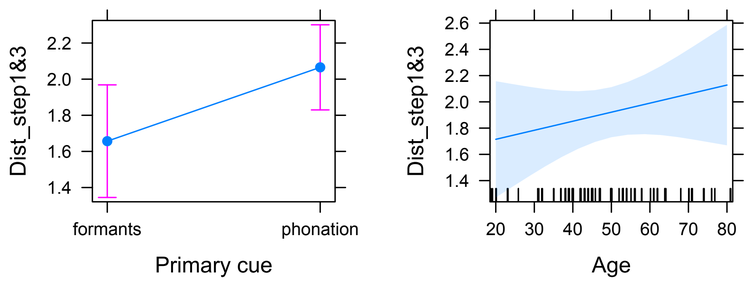

Fig. 4: Effects of the primary cues and age on the Euclidean distances of step 1 and 3

- Speakers who use phonation as the primary cue in their natural production
- Relatively older speakers

Conclusions

- Strong co-variation between co-articulated cues leads to perceptual equivalence
- When shadowing, listeners are sensitive to phonetic details [2] but are also constrained by phonology [7]
- Enhancement for /be/ is much stronger than for /bu/ because of the stronger co-variation between phonation and F1 for /be/
- Differences in F1 are part of the phonological representation for /be/, but not for /bu/
- F0 is not part of the phonological representation for either /be/ or /bu/

References

[1] P. S. Beddor. “A coarticulatory path to sound change”. In: *Language* 85.4 (2009). **[2]** C. A. Fowler et al. “Rapid access to speech gestures in perception: Evidence from choice and simple response time tasks”. In: *Journal of Memory and Language* 49.3 (2003). **[3]** J. Harrington et al. “The coarticulatory basis of diachronic high back vowel fronting”. In: *The initiation of sound change: Perception, production and social factors* (2012). **[4]** H. Kawahara et al. “Tandem-STRAIGHT: A temporally stable power spectral representation for periodic signals and applications to interference-free spectrum, F0, and aperiodicity estimation”. In: *Acoustics, Speech and Signal Processing, 2008. ICASSP 2008. IEEE International Conference on*. IEEE. 2008. **[5]** J. Kuang and A. Cui. “Relative cue weighting in production and perception of a sound change in progress”. In: *Journal of Phonetics* (to appear). **[6]** J. Kuang and P. Keating. “Glottal articulations in tense vs. lax phonation contrasts”. In: *J. Acoust. Soc. Am* 136 (2014). **[7]** H. Mitterer and M. Ernestus. “The link between speech perception and production is phonological and abstract: Evidence from the shadowing task”. In: *Cognition* 109.1 (2008). **[8]** J. J. Ohala. “The Listener as a Source of Sound Change”. In: *Papers from the Parasession on Language and Behavior Chicago Linguistic Society*. Ed. by C. S. Masek, R. A. Hendrick, and M. F. Miller. Chicago Linguistics Society. 1981. **[9]** Y.-L. Shue et al. “VoiceSauce: A program for voice analysis”. In: *Proceedings of the ICPhS XVII*. 2011.