Lingual articulatory evidence of Japanese devoiced vowels: /u/ still there?

Rion Iwasaki [1,2], Kevin D. Roon [1,2], Jason A. Shaw [3], and D. H. Whalen [1,2,3]

[1]CUNY Graduate Center Program in Speech-Language-Hearing Sciences, [2]Haskins Laboratories, [3] Yale University Department of Linguistics

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119

1. High vowel devoicing in Tokyo Japanese

- In Tokyo Japanese, high vowels (/i/ and /u/) are typically devoiced between two voiceless obstruents (e.g., [ki̥ta] 北, *north;* [ku̥sa] 草, *grass*) (Fujimoto, 2015; Vance, 2008).
- Controversy remains over whether devoiced vowels are (a) deleted entirely or (b) merely unphonated (still present):
  - The deletion account predicts no indication of a devoiced vowel in acoustics.

Coarticulatory effects of a devoiced vowel on C_1

- Various acoustic studies have shown coarticulatory effects of a devoiced vowel on the preceding consonant (C_1) even when there are no other acoustic indications of a devoiced vowel (e.g., Beckman and Shoji, 1984; Faber & Vance, 2000; Tsuchida, 1994; Varden, 2010; Whang, 2018).
  - Indicating that devoiced vowels are still present.
- Articulatory data should be able to provide valuable insight into whether or not there are coarticulatory effects of the following vowel on C_1 even when the vowel is devoiced.
  - Previous articulatory work using EMA on devoiced /u/ in real words indicates that the lingual vowel gesture is optionally deleted (Shaw & Kawahara, 2018).

2. Research Questions

1. Do devoiced vowels have the same coarticulatory effects on the lingual articulation of the preceding /k/ as those of voiced vowels?
2. For further insight into the relationship between the phonation status of a vowel and coarticulatory effects, we also include whispered speech to compare with devoiced and voiced vowels.
   a) H1—deleted: the same tongue configuration of /k/ between /ki/ and /ku/ when the vowels are devoiced.
   b) H2—still present: the same differences in the tongue configuration between [ki̥] and [ku̥] as those found between [ki] and [ku].

3. Methods

- Using ultrasound to compare the tongue configuration at the time of the release burst of /k/ between /ki/ and /ku/ in either real or nonce words, including the devoiceable environment.
- *Speakers:* 3 native speakers of Tokyo Japanese (one man; 2 women):
  - M1: 28 year old; W1: 36 year old; W2: 38 year old.
- *Stimuli:* Four two-mora word pairs (/kVC_2e/); devoiceable vs non-devoiceable pairs were made by the voicing of C_2.

Vowel	Devoiceable	Non-devoiceable
/i/	/kike/	/kige/
	/kite/	/kide/
/u/	/kuke/	/kuge/
	/kute/	/kude/

- *Procedure:* Producing the stimuli in a carrier sentence with no pitch accent on the target words (orthographically presented in Japanese).
  a) Devoiceable: 10 times. All devoiceable vowels were devoiced.
  b) Non-devoiceable: 20 times (10 with modal voice, 10 with whisper).
  - Read aloud (or whispered) at a comfortable speech rate.
- *Data collection:* Collecting tongue images on the midsagittal plane using an Ultrasonix SonixTouch ultrasound machine (Frame rate: 59.94 Hz) with concurrent acoustic recording (44,100 Hz).

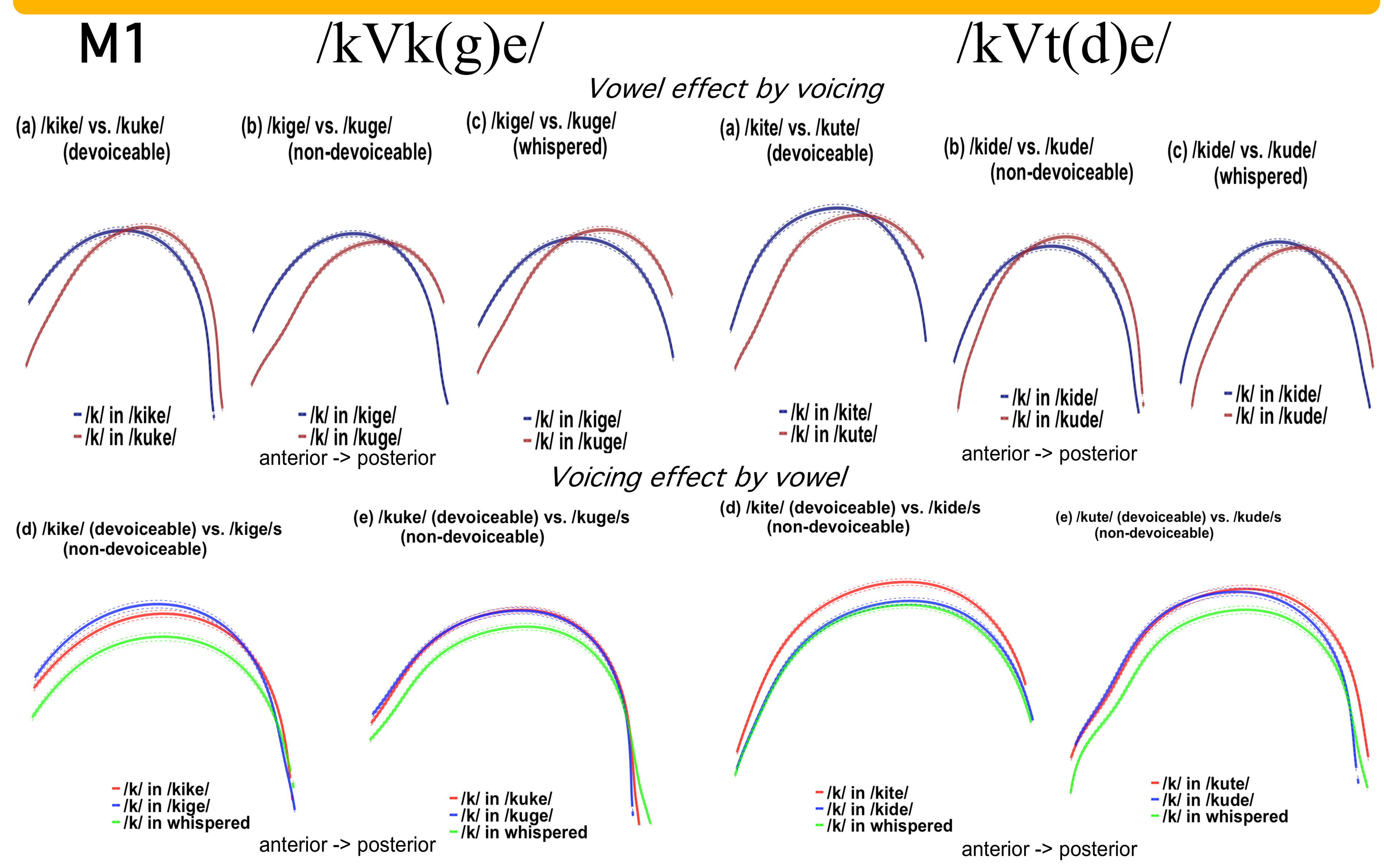
6. Discussion/Conclusion

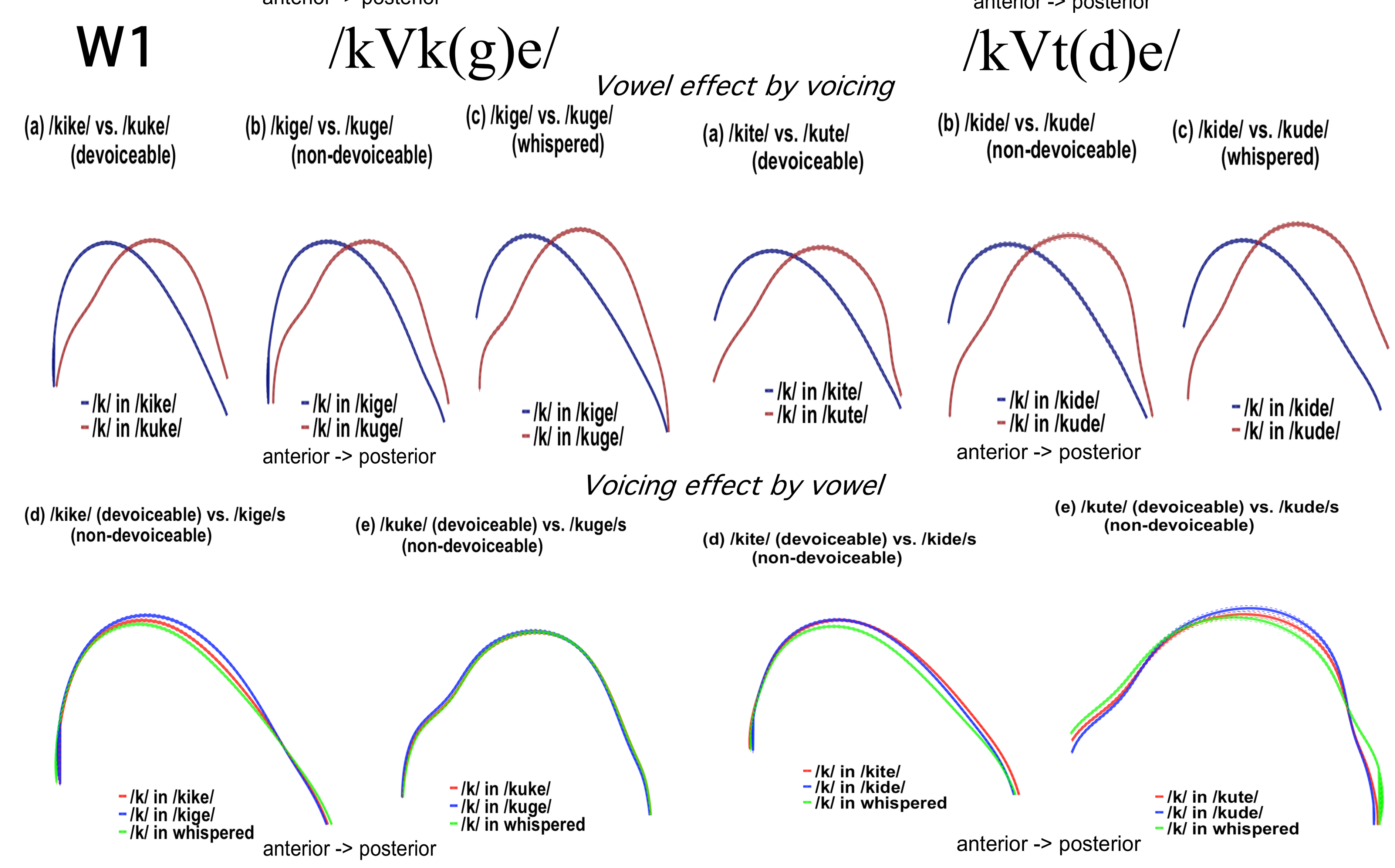
1. Observing consonant-vowel (CV) coarticulation across the voicing environments: **Supporting H2** and suggests that devoiced /i/ and /u/ **retain their lingual articulatory gestures.**
   - It's possible that the velar consonants are different segments ([kʲi] and [ku]; Maekawa & Kikuchi, 2005; Whang, 2018).
   - However, **the vowel effects in both acoustic and articulatory domains suggest CV coarticulation is present** even when devoiced.
2. **Occasionally higher tongue position** in the devoiceable environment.
   - To maintain the constriction in the presence of higher air pressure due to a larger laryngeal opening gesture?
   - Higher COG could be the acoustic target associated with devoicing.
3. Mostly **lower tongue position** with whispering (see Iwasaki et al., 2019 for whispered /i/).
   - Laryngeal maneuvering (e.g., Weitzman et al., 1976) alters the lingual articulation?

4. Analysis

- *Analysis frames:* For each token, tracing tongue contours from the last frame before the moment of the first /k/ release burst (Ahn, 2018) using GetContours (Tiede 2020).
  - Should capture the moment of the highest oral pressure (Stevens, 1998) .
  - Each tongue contour was head-corrected via HOCUS (Whalen et al., 2005).
- *Comparison:* Smoothing spline ANOVA (Gu, 2013) along with 95% Bayesian confidence intervals (CIs) converted into Polar coordinates (e.g., Mielke, 2015).
- Across three speakers, 32 out of 360 tokens (8.9%) were unanalyzable.

5. Results

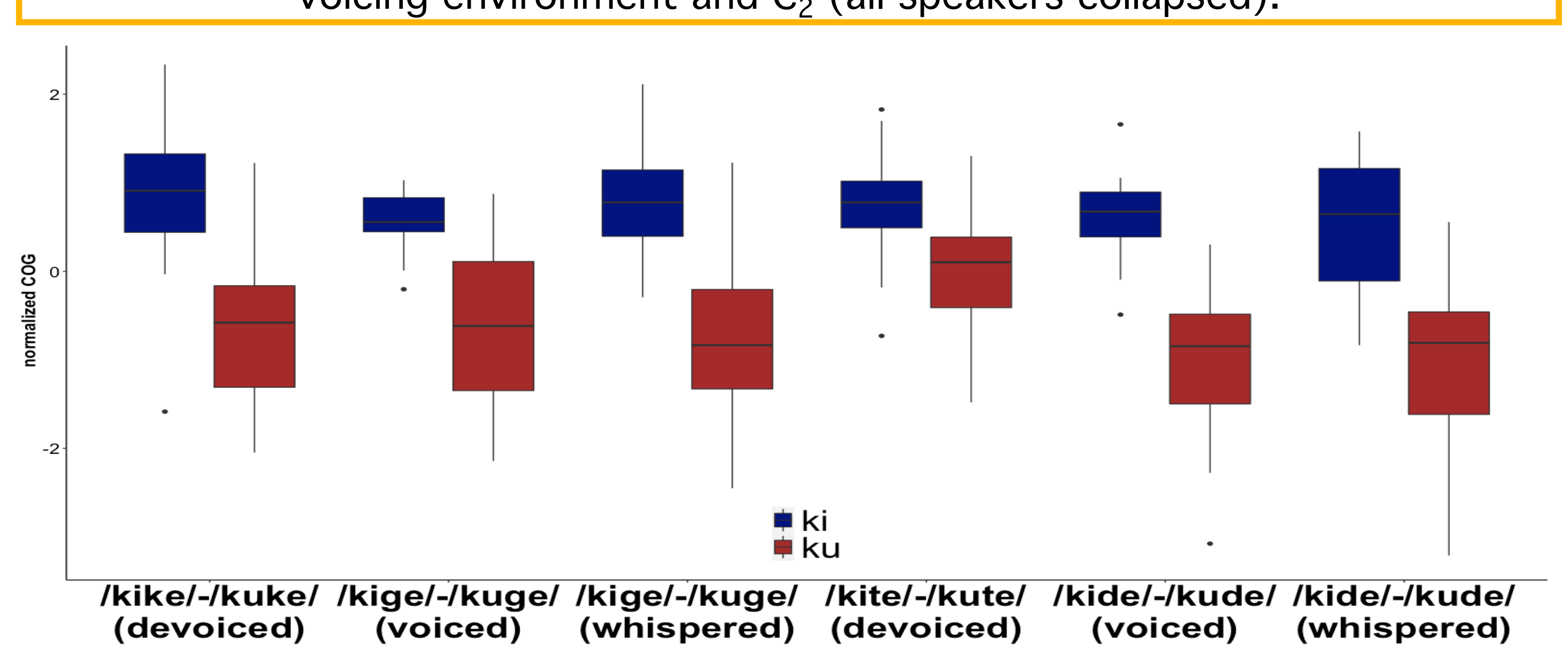




- Speaker W2 showed similar maintenance of the vowel (see extra materials).
- All speakers showed **the vowel effect across the voicing environments** (devoiceable, non-devoiceable, and whispered) regardless of C_2: The tongue was more anterior for /ki/ and more retracted for /ku/.
- The voicing effect on /k/ **depended on the vowel, C_2, and the speaker.**
  - The tongue was higher or lower when the vowel was devoiced.
  - The tongue tended to have the lowest position when whispered.

Will these tongue differences appear in acoustics?

Normalized center of gravity (COG; e.g., Whang, 2018), comparing /ki/ and /ku/ by voicing environment and C_2 (all speakers collapsed).



- The consistent lowering effect of /u/.
- COG tended to be higher when the vowel was devoiced.
- Comparable between whispered and modal voice.