REINFORCING VOICELESS FINALS IN TAIWANESE AND HAKKA: LARYNGOSCOPIC CASE STUDIES

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ABSTRACT

Controversy exists whether the syllable-final voiceless stops of (S)E Asian languages are reinforced with glottalization in all these languages, i.e. -ʔ͡p -ʔ͡t -ʔ͡k. For example, early laryngoscopic observation of finals in Cantonese, Taiwanese (Fukienese), and Thai found that after vocalization ceases, vocal folds and false vocal folds adduct, and, in some cases, there is engagement of the aryepiglottic sphincter. This paper confirms that Taiwanese and Hakka have reinforcement of finals with glottal stop and also the variable engagement of secondary reinforcement, in agreement with these early studies. We did not find final oral stops that lacked reinforcement with the vocal folds, a phenomenon that has been observed in Korean and Vietnamese. The method used in this study is based on transnasal laryngoscopy, which allows observation of many new details of the valve-like engagement of structures in the production of reinforcement.

Keywords: Taiwanese, Hakka, laryngoscope, articulation, reinforcing stops

1. INTRODUCTION

Many languages are reported to have reinforced voiceless final stops. That is to say, word-final voiceless stops have in addition to the oral closure part temporally overlapping closure of the vocal folds (a glottal stop) to suppress any voicing [7]. Often, the ventricular folds and even the aryepiglottic sphincter can engage for secondary reinforcement to add additional strength to the closure. For example, in early fiberscope studies, Iwata, et al. [6] gave a clearly-stated visual account of this process in Taiwanese, saying (p.69) "Closed glottis without vibration is consistently observed for the syllable final –t... Also it should be noted that a rapid adduction of the false vocal folds takes place immediately after the oral closure." And, it "… was also observed …glottalization was manifested by a decrease in the distance between the epiglottis and the arytenoids." There are three noteworthy features of reinforcement to extract from this account: (1) though the vocal folds close, the vocal folds are not the most secure closure in human speech, as they have a concave downward profile to open in response to airflow from below; (2) the ventricular (false) folds adduct just after oral closure; the ventricular folds are concave upward and are, therefore, more effective against upward airflow; and (3) there is, in some cases, engagement of the aryepiglottic sphincter, the ultimate valve [1, 2, 3, 4, 9, 10]. Iwata and colleagues [5, 6]) reported the reinforcing gesture by the same structures—ventricular and aryepiglottic folds—for Cantonese and Thai. This study of Taiwanese and Hakka also found this pattern.

Not all (S)E Asian languages apparently follow the pattern of Chinese varieties and Thai. Iwate et al 1990, [4] found that the"laryngeal gesture for final stops in Korean is characterized by a small degree of glottal opening, (p. 622) … only Korean employs the abductive type of laryngeal gesture in producing final stops" (p. 622). A similar result has been found by Michaud [8], who determined there was no closure of vocal folds in an EGG study of Hanoi Vietnamese, noting "… the final obstruents /p/, /t/ and /k/ are not accompanied by glottalization…" (p. 119). So, Korean and Hanoi Vietnamese [4, 8], do not employ glottal reinforcement of final oral stops. Our study of Vietnamese (not presented here) found the same result as Michaud [8]

2. METHODS

The speech of ten Taiwanese (6 males and 4 females) and two Hakka speakers (1 male and 1 female) was observed with the Olympus ENF Type V2 rhino-laryngoscope. The resulting images

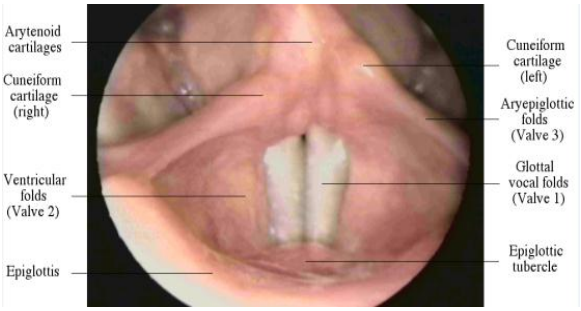
are especially sharp with high resolution and true motion tracking. The audio signal was generated with a Beyerdynamic TG-X 80 microphone mounted on a boom and placed near the participant's mouth. Digital video and audio were transferred to an Apple Macbook for capture with Quicktime Pro.

Example vocabulary of 40-50 items was developed that focused on lexical items with unreleased finals and on examples with a frame following the final. In the languages we studied the final stops with following context remained glottalized. The test items did not include examples with vowel nuclei /ɑ ɔ/ because such vowels produce tongue backing with the result of blocking visual observation of the glottal plane. With the fiberscope in place, Chinese language prompts were given to the participants in list and frame format; all examples were repeated three times. The probe was generally kept in the pharyngeal area for no more than 20-40 minutes to minimize potential discomfort.

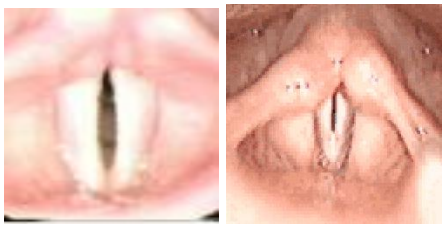
As this research required risk assessment, the first author's IRB board reviewed procedures. Informed consent letters in Chinese were signed by all participants.

In the analysis phase Quicktime Pro was used to segment the raw *.mov data files into triad repetition files. While the detailed analysis of the raw data files was not quantitative, it was evaluated using the Valves of the Throat Framework [2], as a way of relating the participant's articulatory gesture sequences to the states of the glottis. The valves framework employs a set of six cardinal gestures that appear in glottal states. These are: **Valve** 1 the *Vocal Fold Adductor/Abductor* to block downward airflow and allow egressive airflow through the vocal folds; **Valve 2** the *Ventricular Encroacher* to block airflow from below, as in a cough; **Valve 3** the *Aryepiglottic Sphincter* to retract the tongue, raise the larynx, and move the arytenoids toward the epiglottis sphincterically; **Valve 4** the *Epiglottal Compactor* to draw up the epiglottis to a position up and above the glottal plane; **Valve 5** the *Pharyngeal Wall Constrictor* to narrow the pharyngeal lumen; and **Valve 6** the *Glottal Depressor/Elevator* to shorten or lengthen the laryngeal vocal tract. The Valve Model has be developed from the study of languages from 17 language families. These valves operate in synergy to describe some of the key states that may arise within the course of a syllable, see Figure 1: (a) engagement of Valve 1 adducts the vocal folds with vibration for Voice, (b) Valve 1 engages with concave-convex setting to give Prephonation onset, to prepare for voicing onset and (c) Valve 1 engages with a gap and no vibration to mediate between voice and a following glottal state prephonation offset**,** as might occur in e.g. *tact*, (d) Valve 2 reinforces the vocal folds with the ventricular folds in moderate glottal stop, and (e) Valve 1,2,3,&4 engage the aryepiglottic folds atop the epiglottis to produce a strong glottal (epiglottal stop). A weak glottal stop occurs when Valve 1 alone is adducted with no vibration. Examples from [1, 2] are illustrations of the states of glottis also used in this study.

Figure 1: Glottal States of Voice, Prephonation, Glottal Stop, and Epiglottal stop.



a. Voice



b. Prephonation onset c. Prephonation offset

d. Glottal Stop e. Epiglottal Stop

At the end of a syllable there can be (i) an oral stop without any glottal reinforcement, i.e. Prephonation offset as in Figure 1c (not seen in the Taiwanese or Hakka data), (ii) an oral stop strengthened with engagement of Valve 1, a weak glottal stop (not shown here but similar to Voice just after cession of vibration), (iii) an oral stop reinforced with a moderate glottal stop, cf. Figure 1d, or (iv) an oral stop reinforced with a strong

(epiglottal) stop, cf. Figure 1e [2]. In order to determine which states of the glottis are present in syllables that end in /-p –t –k/), the video images are from Adobe Premiere Pro 2.0.

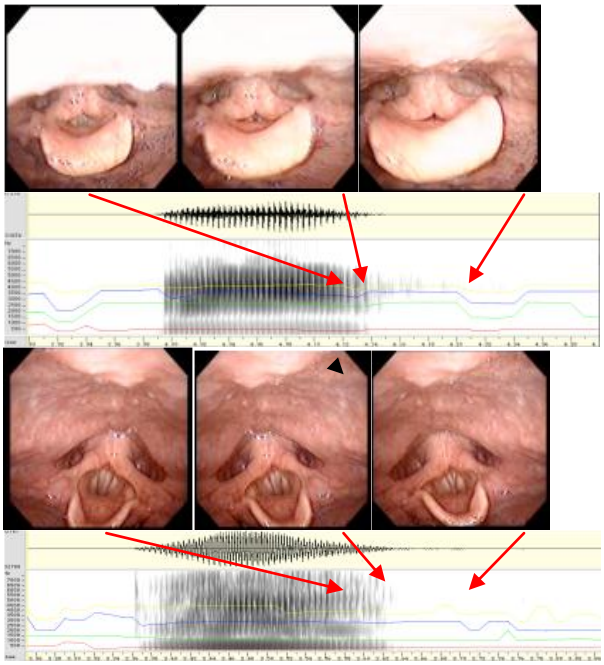
3. RESULTS

In order to have comparison across speakers and languages, landmarks from the spectrograms were used to determine reference points where stills were taken. These points are: (1) beginning of formant transition, (2) end of F2, and 60 ms after the end of F2. Formant frequencies are taken using Wavesurfer with video plugin in order to find the reference points for the synchronized laryngoscopic video and audio.

3.1. Taiwanese

The example for Taiwanese *pit* 'pen' is illustrated below in Figure 2.

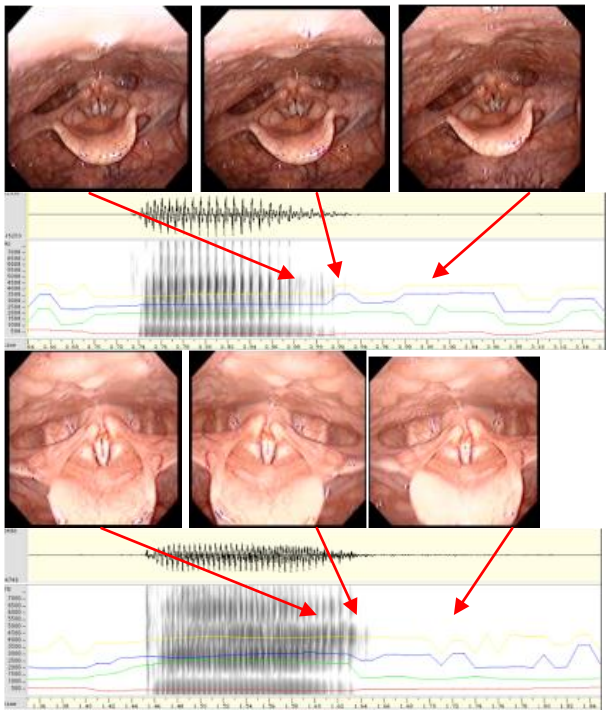
Figure 2: Display of two older speakers.



From left to right, the first images represent the beginning of formant transition, the second the end of F2, and the third 60ms after the end of F2. As is evident in the first slide sets, the aryepiglottic sphincter is in syllable finally nearly fully engaged cf. Fig 1c and in the second slide the ventricular folds are engaged in the last image second set.

By contrast, younger speakers have minimal strengthening in Figure 3. This difference may be sociophonetically conditioned, but more research on language change in Taiwan is needed.

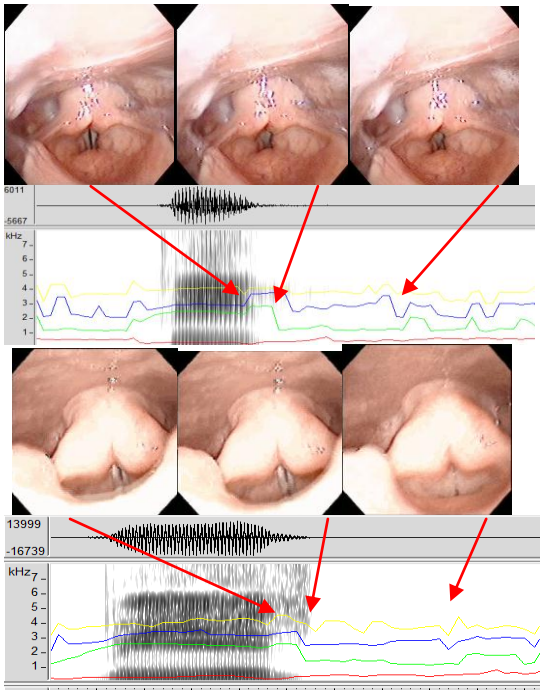
Figure 3: Display of two younger speakers with very minimal engagement of the ventricular folds**.**



3.2. Hakka

The example for Hakka is also *pit* 'pen'

Figure 4: Male Sixian Hakka and female Hailu speaker. Both have ventricular incursion.



Both Hakka speakers have ventricularization atop the vocal folds.

4. DISCUSSION

The function of reinforcement with syllable-final oral stops is for "suppression of any audible burst or frication when it is released." (p. 73) Ladefoged & Maddieson [8]. If in clipped articulation, maximum speed of suppression of a phonating glottis is wished, then Valve 2 must engage before Valve 3, the Aryepiglottic Sphincter, Figure 2. Note that one can see in upper part of Figure 2, Valve 3, the Aryepiglottic Sphincter is becoming more engaged over the course of the syllable.

The interactions of Valves 1, 2, & 3 in the above example demonstrate how the valves act in synergy. In some cases it appears that cooperation of the valves stems from physiological proclivities. The ventricular folds can adduct only if there is at least some engagement of the vocal folds [9]. There is no report of a sound that uses the ventricular without the vocal fold engagement. When the airflow is through the glottis then Valve 3 is last to engage. In other cases linguistic considerations are paramount. In the case of reinforcement, the usual synergy is the sequence Valve 1, then 2, then 3.

The Hakka speakers we studied were all of the older generation and all of them showed reinforcement with closure of the vocal and the ventricular folds, but the manner of engagement was not identical. The engagement of Valve 2 in the male speaker showed greater engagement near the tubercule of the epiglottis and weaker engagement near the arytenoids, whereas the female speaker had engagement that covered the vocal folds entirely. This difference shows that in some speakers Valve 2 reinforcement is focused in the anterior portion of the folds.

The glottalization of syllable final stops persists when there is a syllable following a CVC syllable. Unlike some Western languages, the reinforcing/strengthening of final syllables is obligatory even in the context of disyllabic compounds, suggesting that such reinforcement is *not* attributable to boundary effects.

As this research has shown, syllable-final voiceless stops can be strengthened in different ways: weak glottal, moderate glottal, or epiglottal reinforcement. Moreover, that strengthening is hierarchical with the engagement of Valve 1, weak glottal stops, for young speakers, Valves 1&2, moderate glottal stops for most older speakers, and Valves 1,2&3, strong glottal stops, or epiglottal stops, for some precise speakers of the older generation. The basis for the hierarchy is partly physiological, as the vocal and ventricular folds arose from a single origin and was split in two with the vocal fold the dominant structure. The other valves are higher and generally follow the action of Valves 1&2.

Finally, our results seem to suggest that loss of glottalization is taking place in production of final voiceless stops among younger speakers. This process may be diachronic change of checked syllables.

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6. REFERENCES

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