GLOTTALIZATION AND TAIWAN MIN CHECKED TONE SOUND CHANGE

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ABSTRACT

This study investigates the glottalization of Taiwan Min checked tones with CV[p, t, k, ʔ] syllable structures. The results of Electroglottography (EGG) and acoustic measures showed that above 80% of [ʔ] and below 15% of [p, t, k] were deleted. Codas were most often realized as energy damping during the vowel final portion. Full stop closures were observed significantly more often among Tone 3 and sandhi tones. Codas are rarely realized with an aperiodic voicing. In the non-final position of the tone sandhi group, the occurrence of contact phases during the coda were less than 30%. Moreover, checked Tone 3 was produced with the shortest glottal contact quotient. However, in the final position of the tone sandhi group, the mid-frequency spectral tilt, H1*-A3*, and the glottal contact quotient were indistinguishable between the two checked tones, suggesting a sound change in voice quality.

Keywords: Cepstral Peak Prominence (CPP), voice quality merge, glottal coda deletion, glottalization categorization.

1. INTRODUCTION

1.1. Glottalization

The laryngealization / glottalization feature of the final voiceless codas can be transferred to the preceding vowels [17]; however, different co-articulatory patterns may surface due to an abrupt and gradual phasing between the glottalized codas and the preceding vowels. During an abrupt phasing, glottal consonants surface with a long-duration of closure like a stop, however, when gradual phasing occurs the preceding vowels can be accompanied by a glottalized voice quality [8]. Huffman [12] proposed that English vowel glottalization is an example of co-articulation between the vowel and following coda.

In English, voiceless codas [-p, -t, -k] can lead to the glottalization of preceding vowels. The glottalization is often realized as irregular periodicity, lowering the F0, damping amplitude, or producing diplophonia (alternation in shape, amplitude or duration of succeeding periods) in the preceding vowels [10 12, 19, 20]. In German, a canonical glottal stop can be realized with (a) a long closure, (b) a closure and glottalization on a preceding vowel, (c) no closure but with a glottalization on a preceding vowel, or (d) a glottal stop deletion [15]. In Yucatec Maya [9] glottalization can be manifested as either a modal voice without a glottal stop, a weak glottalization, a creaky voice or a full glottal stop. In Itunyoso Trique [8], glottal codas can surface as either a long duration of a glottal closure or as energy damping during a vowel when in the intervocalic position. In Coatzospan Mixtec [11] laryngealized / glottalized vowels are produced with an f0 decrease, an amplitude drop, a smaller H1-H2 and a shorter vowel duration.

1.2. Checked tones

Taiwan Min, checked tones 3 and 5 with a CV [p, t, k, ʔ] syllable structure, short vowels, and glottalized voice quality set themselves apart from unchecked tones 55, 13, 51, 31, and 33 [6, 7]. The tone letters reflect the pitch height, with larger numbers representing a high pitch.

Due to tone sandhi rules, /3/ → [5] / __ #[tone group] and /5/ → [3] / __ # [tone group]. In the non-final (sandhi) position of a tone group, surface tones 3, and 5 were underlying tones /5/ and /3/, respectively. In the final (juncture) position of the tone sandhi group, the surface tone and the underlying tone were similar. Thus, sandhi tones 3 and 5 were denoted as tones 3 /5/ and 5 /3/, respectively, whereas juncture tones 3 and 5 were denoted as tones 3 /3/ and 5 /5/, respectively.

Field work on Taiwan Min checked tones based on impressionistic auditory transcriptions involving hundreds of speakers found a deletion of [ʔ], onset lowering of F0 and more modal-like voicing with Tone 5 in the final position of a tone group when the checked tones were produced with surface tones that are identical to a underlying tone [1, 4, 5, 16].

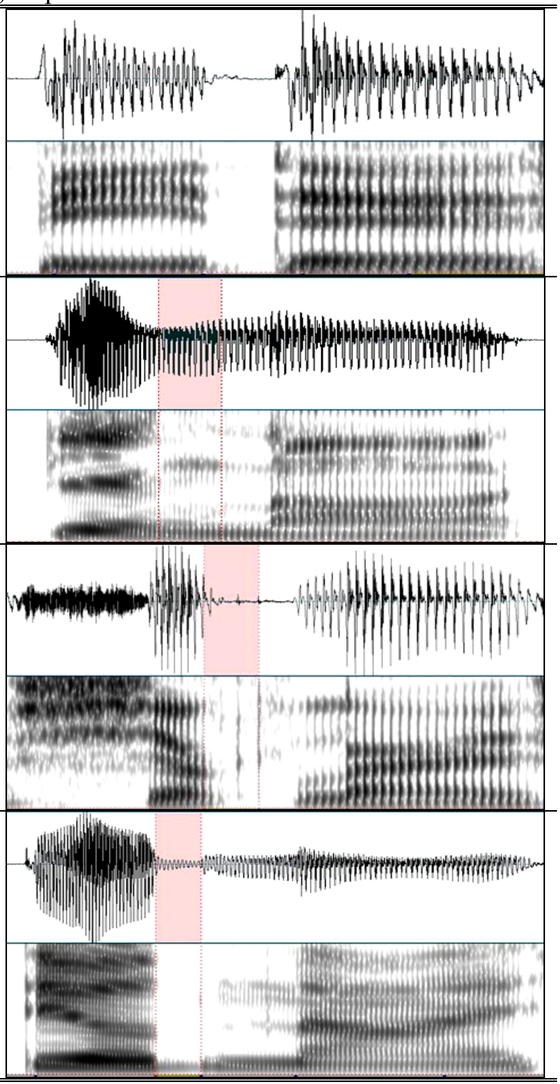
Articulatory studies using fiber optics have observed the adduction of ventricular folds during Taiwan Min checked tone syllables produced in citation form. When produced in a sentence or a phrase, glottalization sometimes disappeared [13].

An inverse filtered oral airflow study found that some speakers produced Taiwan Min checked tones with small amounts of airflow and a longer closed phase [18].

As Blankenship [3] points out, vowel glottalization is not consistently produced with creaky phonation. The glottalization of Taiwan Min can be realized with four different forms: (1) a modal vowel and a full stop closure, (2) vowels produced in a sequence of modal and glottalized phonation which are realized as amplitude damping or (3) aperiodic voicing and (4) a modal vowel without a stop closure (Figure 1).

This study intends to explore the glottalization pattern of Taiwan Min checked tones in the final (juncture) and non-final (sandhi) positions of the tone group. Particular attention was given to the glottalization of juncture tones 3 /3/ and 5 /5/ of which a sound change was reported.

Figure 1: Northern Zhangzhou dialect disyllabic words produced with (a) coda deletion /pit5 te33/ "pencil case", (b) damping /tek5 nã13/ "bamboo forest", (c) aperiodic voicing /sek 5 lai33/ "indoor", (d) stop /tek5 nã13/ "bamboo forest."



2. METHOD

2.1. Participant

Speakers were selected from the five major dialect regions on the west coast of Taiwan: Northern Zhangzhou (NZ), Northern Quanzhou (NQ), Central Zhangzhou (CZ), Central Quanzhou (CQ) and Southern Mixed (SM) regions [1, 2]. From each of the five dialect regions, eight native speakers were recruited. These included two females and two males in their 20's, and two females and two males older than 40 years of age. In all there were 40 speakers ((2 males + 2 females) $\times$ 2 age rages $\times$ 5 dialect regions). Other than one young male speaker from central Quanzhou, all speakers lived in their native dialect region until they were 16 years old. All participants also speak Mandarin.

2.2. Materials

The materials included 236 disyllabic words embedded in the carrier sentence "Please listen to the tone of __ first," and which consisted of all tone 33 syllables. All the words were familiar to the native Taiwan Min speakers in this study. Each of the 236 carrier sentences was repeated twice; all together, each speaker produced 472 sentences.

2.3. Experimental procedure

The speakers first read the order number for each sentence and then paused before reading the sentence. Each recording lasted around 35 minutes. The speakers were asked to pause after every hundredth sentence to get a drink of water before continuing. An experimenter was present in the recording room to monitor the EGG and acoustic signals and to alert the speaker when errors were made.

2.4. Instruments

The Glottal Enterprise EGG system EG2-PCS picked up EGG signals from the two electrodes placed around the thyroid cartilage on each side of the speaker's neck. A TEV Tm-728 II microphone placed 15 cm from the speaker's mouth picked up acoustic sound waves. Then, the recorded EGG and acoustic signals were transferred using Audacity software. Next, the EGG and acoustic data were preprocessed using EggWorks [23]. Praat was used for the manual transcription of the sound waves. The F0 data were analyzed using STRAIGHT algorithm [14]. Then both the EGG and acoustic measures, including vowel duration, F0, spectral measures, CPP and Contact Quotient (CQ_H) of glottal waveform were extracted with VoiceSauce [21] at 10% increments in the duration of each vowel.

2.5. Data analysis

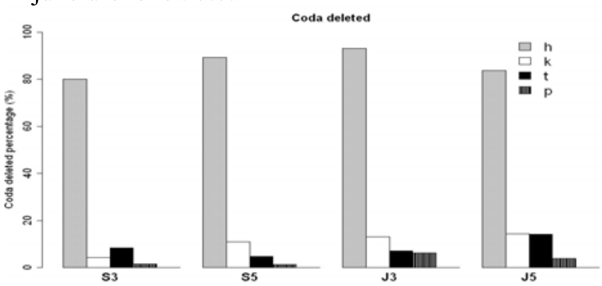
The checked tones were labelled for their glottalization pattern. Codas [p, t, k, ʔ] were labelled as <deleted> if the glottalized voice quality was not heard, or when no energy damping on vowels or stop closure following vowels was observed (Figure 1a). When a glottalized voice quality was heard, coda [p, t, k, ʔ] was labelled as <damping> if energy damping was observed at the end of vowels (Figure 1b), or as <irregular> when aperiodicity was observed (Figure 1c), or as <stop> when clear stop closures were observed (Figure 1d).

3. RESULTS

3.1. Coda deletion

As shown in Figure 2, the results of the linear mixed effect regression model with the subject and words as random factors showed that the deletion rates of glottal coda, /ʔ/, above 80%, were significantly higher than the deletion of oral codas, /p, t, k/, below 15%, in both sandhi (/ʔ/-/p/:β=-7.235, p<.001; /ʔ/-/t/:β=-5.710, p<.001; /ʔ/-/k/:β=-5.488, p<.001) and juncture positions (/ʔ/-/p/:β=-6.915, p<.001; /ʔ/-/t/:β=-6.449, p<.001; /ʔ/-/k/:β=-5.703, p<.001).

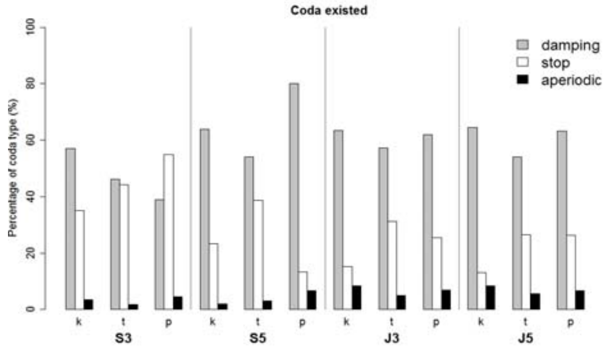
Figure 2: Coda deletion rate. S3: sandhi tone 3 /5/, S5: sandhi tone 5 /3/. J3: juncture tone 3 /3/, J5 juncture tone 5 /5/.



3.2. Glottalization categorization

The results of the logistic mixed effect model (2 tones × 2 prosodic position) with the speakers and words as random factors on glottalization types revealed the significant effects of tone (β= -0.4681, p<.01) and prosodic position (β = -1.366, p< .001) on the glottalization types. The results show that Tone 3 is 1.6 ($e^{0.4681}$ = 1.6) times more likely to be realized with a full stop closure than Tone 5 (β=-0.4681, p < .01). Moreover, a sandhi tone is 3.92 ($e^{1.3656}$ = 3.92) times more likely to be produced with a full stop closure than a juncture tone (β=-1.3656, p < .001). In sum, oral coda /p, t, k/ was realized more often as a full stop closure among Tone 3 and among sandhi tones (Figure 3).

Figure 3: Glottalization pattern for /p, t, k/

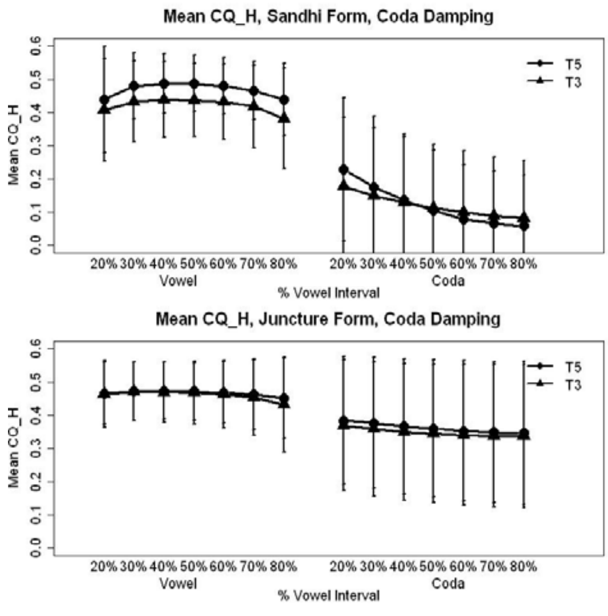


3.2. Acoustic measure for coda glottalization

The following analysis focuses on the more frequently observed glottalization patterns, namely energy damping and full glottal stop.

As shown in Figure 4, the mean CQ_H of a coda, below 30%, was shorter than for the preceding vowels in the sandhi position; however, in the juncture position, the mean CQ_H was lengthened to be similar to the CQ_H of the preceding vowels. The mean CQ_H during the codas of tones 3 and 5 showed a merged pattern in both the sandhi and juncture positions. It is proposed that vocal folds stay relatively open during the codas of sandhi checked tones; however, a vocal fold showed a longer closed phase for the juncture checked tones.

Figure 4: Contact quotient of final coda



3.3. Acoustic measure for vowel glottalization

Generally speaking, during vowels preceding a coda stop or coda energy damping the CQ_H of unchecked sandhi tones was significantly longer than that of checked tones. Moreover, the mean CQ_H of sandhi tone 5 /3/ was significantly longer than that of sandhi tone 3 /5/. However, the CQ_H of juncture tones 3 /3/ and 5 /5/ were indistinguishable due to an increase of CQ_H for juncture tone 3 /3/ (Table 1).

Stevens, K. N., Hanson, [22] found that the smaller the H1*-A3* values, the more abrupt and simultaneous the glottal closures become. The higher H1*-A3* values of juncture checked tone 5 and sandhi checked tones 3 /5/ suggested least abrupt glottal closure than juncture tone 51 and sandhi tone 5 /3/ (Table 1).

The CPP, an index of voicing periodicity, showed that Tone 3 was produced with less periodic voicing than unchecked tone 31 or juncture tone 5 /5/ (Table 1).

Table 1: Glottalization Related Measures. D: Energy Damping.

	Sandhi		Juncture	
	Stop	D	Stop	D
CQ_H	5>3 ***	5>3 ***		
H1*-A3*	3>5 ***	3>5 ***		
CPP			5>3 **	5>3 *
CQ_H	31>3 *		3>31 ***	3>31 ***
H1*-A3*				
CPP	31>3 ***	31>3 **		
CQ_H	51>5 ***		51>5 **	51>5 *
H1*-A3*			5>51 *	5>51 **
CPP				

In sum, in the sandhi position, checked tones are produced with less periodic voicing and a shorter glottal close phase than are unchecked tones. Moreover, sandhi tone 5 /3/ was produced with a longer close phase during glottal vibration and a more abrupt glottal closure than was sandhi tone 3 /5/. However, in the juncture position, tones 3 /3/ and 5 /5/ were indistinguishable in terms of their CQ_H or H1*-A3*.

4. DISCUSSION

This study explored the glottalization of Taiwan Min checked tones and found that glottal coda [ʔ] was mostly deleted. In syllables with oral coda [p, t, k] glottalization was mostly realilzed with energy damping during the final portion of the vowels. Glottalization was rarely realized with aperiodic voicing, suggesting that Taiwan Min checked tones are not produced with creaky phonation. Sandhi checked tones are produced with a shorter glottal close phase than are unchecked tones. Sandhi tone 3 /5/ was produced with a short CQ_H and high H1*-A3* suggesting a less abrupt and non-simultaneous glottal closure than tone 5 /3/. However, such distinctions are lost between two juncture checked tones.

It is proposed that glottalization during the final portion of a vowel is due to the transference of laryngealization from the upcoming voiceless coda [10]. In many South-East Asian languages, including Yi, Hani and Jingpho, phonation contrasts in vowels arise from the transference of laryngeal features of post-vocalic consonants to preceding vowels [17]. If glottalized voicing during vowels is the result of anticipatory co-articulation between the vowel and the subsequent glottalized codas, then coda deletion may lead to a loss of vowel glottalization.

Since sandhi tone 3 /5/ is most likely to be produced with full stop closure, after coda deletion, it is proposed that the short CQ_H may be lengthened and high H1*-A3* may be lowered for sandhi tone 3 /5/. In fact the CQ_H lengthening can be observed among juncture tone 3 /3/ (Table 1). The lengthening of CQ_H may lead to merged of CQ_H of two juncture checked tones (Table 1). The relationship between the deletion of the final codas and the merge of voice quality deserves further study.

The deletion of voiceless codas may lead to two potential changes for vowel glottalization. On the one hand, glottalization within the vowel may be treated as a property of the vowel by listeners; thus, even after a coda deletion, the glottalized voice quality is retained as an intrinsic property of checked tones. On the other hand, vowel glottalization may be regarded as a result of contextual co-articulation. Thus, after the removal of the conditioning environment, the final coda, the context-induced co-articulatory effect may disappear. As a consequence, vowels may be de-glottalized after a coda deletion. Further comparisons between the vowel quality of unchecked tones, checked tones with a full stop closure, and checked tones with deleted codas may reveal the relationship between coda deletion and a change in glottalization.

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