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The Attributes of Glottal Stop in Phonetic Realization in Takibakha Dialects of Bunun

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Abstract. Plenty researches have proved that glottal stop is the distinctive phoneme in the consonant inventory in Bunun while glottal stops before voiced stops are problematic. This paper will focus on glottal stops' production, and distribution of in Bunun. Researcher aims to investigate the attributes of glottal stop in the syllable position to test whether it is a phoneme or a diacritic; what's more, whether the stress influences glottalization will be examined in this paper. On the other hand, some native speakers drop the glottal stops which are originally as the phoneme. The comparison between phonological patterning and phonetic realization helps us understand the differences in language inventory and real production.

Keywords: glottal stop, Bunun

1 Introduction

There is an overview of the phonetic inventory: both consonants and vowels in Takibakha. Section 1.1 gives an overview of Takibakha consonants and vowels. Section 1.2 discusses orthology in Takibakha. In section 1.3, we will take a look at the attributes of glottal stops in Takibakha. Two special subsections are reserved for the syllable structure of Takibakha (1.3.1) which is relative to the distribution of glottal stop and acoustic properties (1.3.2).

1.1 Phonetic inventory

1.1.1 Consonants

The following table is the consonant inventory in Takibakha. In Table1, affricate is not included. In Takibakha, the affricate in writing system is 'c' which can be pronounced as [t͡s] or [t͡ɕ].

	labial		coronal		velar		uvular	glottal
stop	p	b	t	d	k		q	ʔ
fricative		v	s	ð				h
nasal		m		n		ŋ		
liquid				l				

Table 1: consonant inventory in Takibakha

1.2 Orthology

From Huang (2013), there are three main dialects among Bunun including northern: Takitu'du', Takibakha'; medial: Takbanuaz, Takivatan; and southern: Isbukun, Isbubukun. She proposed that there are 16 consonants（p、b、t、d、 k、q、ʔ、c、v、s、z、h、m、n、ng、l）and 3 vowels (a, i, u) as distinctive phonemes in northern and central Bunun. From the below minimal pairs demonstrate that glottal stop is the distinctive feature in Bunun.

takiʔ	'defecate'	taki	'live'
maʔma	'tongue'	mama	'carry on'

Table 2: minimal pairs in Bunun

1.3 Glottal Stop

1.3.1 Syllable structure

From the above mentioned consonant inventory, glottal stop is the phoneme in Takibakha. Hussien indicates that glottal stop is common in many languages, but it may not be part of their phoneme set. Like in English, it plays prosodic function, whereas in some languages like Amharic, it can be part of their phoneme set. The acoustic characteristics of glottal stop and glottalized sounds have been studied from different angles in different languages and we will investigate the acoustic properties of glottal stop in 1.3.2. The glottal stop /ʔ/ is somewhat problematic in all Bunun dialects and this paper will focus on Takibakha dialect. From De Busser (2009), it points out another Bunun dialect: Takivatan is unusual in that its two 'indigenous' voiced stops are both implosives (note again that /g/ only occurs in loanwords). The bilabial implosive /ɓ/ does not occur in word-final position and is relatively rare (it represents only 2.25% of all consonants realized in actual text). In a small number of intervocalic positions, it is sometimes realized as a bilabial voiced fricative. This variant has only been observed in the following two words: Liban 'male proper name' [ˈliɓan] or [ˈliβan] qabaŋ 'blanket' [ˈqaɓɑŋ] or [ˈqaβɑŋ] The alveolar implosive /ɗ/ is considerably more common than /ɓ/. It shows no notable variation, except for the loss of release in final position. The status of the two implosive stops /ɓ/ and /ɗ/ is somewhat problematic. They were first mentioned in Li (1987), who describes them as preglottalized stops, but admits that – unlike with true preglottalisation – they "require an almost simultaneous closure of the two points of articulation, the glottal plus another supraglottal closure" (Li (1987:381)). While it may be true that and are in some Bunun dialects realized as egressive preglottalized plosives (/ˀb ˀd/), their Takivatan correlates require simultaneous constriction of the glottis and closure of the mouth cavity and typically involve an ingressive airflow. Ladefoged & Maddieson (1996:84-5) indicate that in most languages, though not all, implosives involve some form of glottal restriction. In this paper, we will also investigate preglottalized stops in Li (1987) but they will be named 'glottal stops before voiced stops'.

According to Huang (2003), the syllable shape in the Takituduh and the Isbukun dialects of Bunun allows up to two moraic segments within a syllable and that closed syllables may appear in word-medial or word-final positions. In Bunun, a minimal syllable shape is CV instead of V. It indicates that onset consonants are obligatory in the language. Garellek (2013) also shows that glottal stops in vowel-initial words in English were found to be more common (when phrase-internal) after a word ending in a vowel. On the other hand, a maximal Bunun syllable on the surface is CGVC or CVGC. However, the language prohibits CVCC or CCVC (can be ruled out by constraints *CC: avoid consonant clusters as onset). From this paper, it shows that the syllable shape and the language must have onsets but prohibits consonant clusters. Therefore, Takibakha dialect has the tendency to have onset as in syllable initial position. We can predict that vowels in initial syllable will followed by a glottal stop in order to demonstrate that the minimum syllable structure not V but CV in surface representation. And when it comes to the glottal stop preceding another stop, we believe that it is a diacritic like /ˀb ˀd/ which is the glottal stops before voiced stops for it proofs that maximal syllable on the surface is CGVC or CVGC (Huang 2003) and prohibits CC cluster (*CC).

Reongpitya (1997) focuses on the characteristics in glottal stops. And in majority, glottal stops are apt to fall short of complete closure, especially in intervocalic positions. It also displays the distribution of the glottal stop in Lai.

1.3.2 Acoustic property

Garellek (2013) focuses on the acoustics properties in glottal stops. The motivation in this paper is that normally half of the languages take glottal stops as the phonemic inventory. The researcher points out that glottal stops are not fully glottal or stops but they may be phonetically realized in different ways which are a set of articulations ranging from laryngealized phonation, to sustained glottal closure (with or without additional supraglottal constriction). It also indicates that most languages tend to 'insert' glottal stops before vowel-initial words, at least in strong prosodic positions, e.g. phrase-initially. No other phonological insertion rule seems to be as widespread as glottal stop insertion across languages, and it is certainly puzzling that all languages which insert a consonant before vowel-initial words should insert the same sound.

It also provides some important aspects to determine which are most important in glottal stops, so that we can understand why glottal stop 'insertion' occurs.

1. How are glottal stops produced?
2. Do listeners perceive glottal stops as distinct from creaky voice?
3. When do glottal stops occur word-initially?
4. Why are glottal stops so common before vowel-initial words?

The study also conducts the experiment in glottal stop by EGG to investigate the prominence value of English and Spanish word-initial and word-final glottal stops.

Hall (2006) in chapter 2, it focuses on the intervocalic insertion of glottal stop. And it shows the waveform and the spectrogram of the glottal stop. In the figures of glottal stop, the sound in spectrogram is a blank bar as below. There is closure silence associated with the achievement of glottal constriction for glottal stop in emphatic forms. However, from the following figures of glottal stops, I don't think the glottal stop is prominent in the spectrogram. Therefore, viewing the spectrogram can be one way to distinguish whether there is glottal stop but when we cannot find the clear properties of glottal stops in the spectrogram, we have to search other efficient tools or manners to test glottal stops.

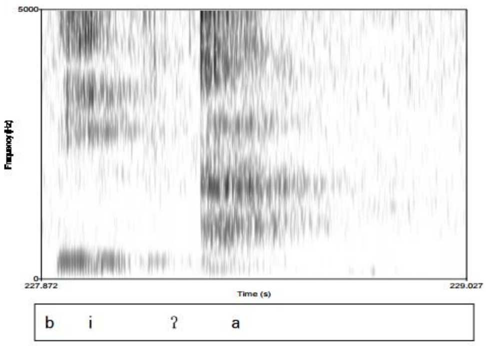

Figure 1: glottal stop in spectrogram Hall (2006)

Hussien's thesis indicates that glottal stop and ejective sounds form an important class of phonemes in most of the Semitic languages such as Amharic, which differ from other phonemes mainly due to their source of excitation. Therefore, the study of acoustic characteristics of speech including glottal stop and ejective sounds based on spectrum-based methods becomes difficult, as these methods reflect mostly the resonance characteristics of the vocal tract system. In the paper, Hussien presents the spectrogram of glottal stop as below.

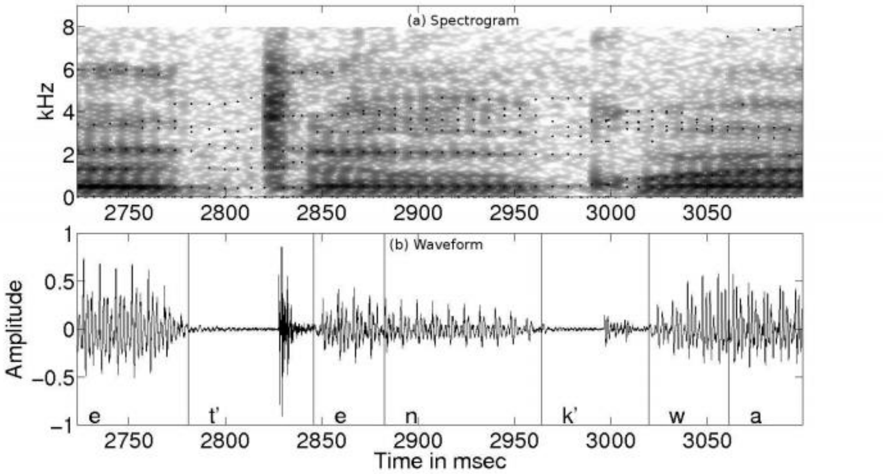

Figure 2: glottal stops in spectrogram in Amharic

Olive, Greenwood, & Coleman (1993) indicates that there's discontinuous transitions when producing glottal stops between vowels. Glottal stops typically occur during or immediately following the transition between adjacent vowels. In Chapter 5, the author shows the transition between vowels. The waveform and spectrogram present that in the instance of glottal stop occurs during the transition region, that is, during the movement from one vowel to the other. The glottal stop is identified as reduced amplitude and changed periodicity evident in the waveform and spectrogram. The book is based on English speech; therefore, glottal stop is not the phoneme in the language. However, it provides the waveform and spectrogram of glottal stop when producing two adjacent vowels (there's an insertion glottal stop intervocalically).

In You (2009), there are six stops in Isbubukun Bunun: three voiceless stops /p/, /t/, /k/, voiced stops /b/, /d/, and one glottal stop /ʔ/. On the VOT measurement of voiceless and voiced stops in Isbubukun Bunun, every four out of the total test stimuli that each subject articulates are taken into consideration. It indicates VOT does not play a role in the acoustic measurement of the glottal stop /ʔ/; therefore, we will leave out the VOT measurement of the glottal stop /ʔ/ in this section. The mean VOT (ms) values on stops in Isbubukun Bunun of 28 subjects are listed below.

Mean VOT (ms) on Isbubukun stops

	p	t	k	b	d
VOT (ms)	14.8	16.3	26.8	-80.4	-88.0

Table 3: VOT in Isbubukun, You (2009)

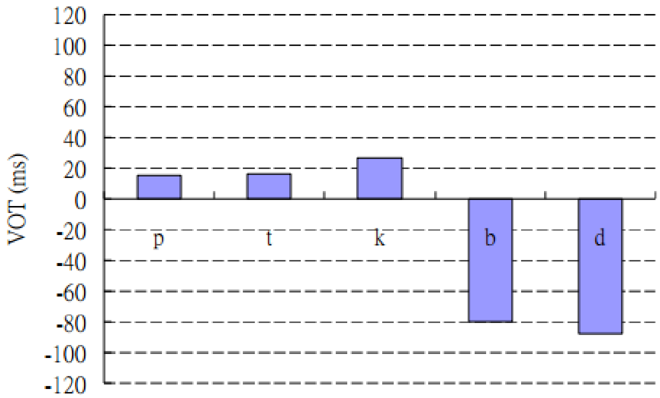

Figure 3: Isbubukun stops, You (2009)

The table above shows that voiced vowels have long duration in VOT (though they are in negative values).

2 Experiment

2.1 Stimuli

This paper selects 100 words from Bunun Takibakha tu Petasan. These words are all with glottal stops or are phonetically and perceptually involving glottal stops (e.g. glottal stops before voiced stops /b, d/). The specific stimuli can be found in the following appendix.

2.2 Participants

In this study, the researcher recruited three native speakers of Takibakha Bunun. The participants are in their 50s or 60s in 2017. In table 1, it presents the information of the three participants. No speech and hearing impairments were reported.

number	1	2	3
sex	male	male	Female
age	55-60	60-65	55-60
residence	Tamazuan (Dili village)	Isingan Shanglong village	Tamazuan Dili village
language	Takibakha Bunun	Takibakha Bunun	Takibakha Bunun

Table 4: Information of three native speakers

2.3 Procedure

2.3.1 Data collection

The participants were instructed to read the word-list and asked to go through the experimental tokens in his native language to identify tokens that might be unfamiliar to them. They were tested only in their own native language. In the experiment, each carrier sentence was embedded in the phrase in (1) below. The participants were asked to read 100 tokens for glottal stops and some minimal pairs which is the coreferential ones. Each stimulus was shown once on the slice from the computer screen.

(1) ________, bazbaz cak ________ muc'an
    _________, I say ________ say once.
    '_________, I say ________ once.'

The tokens were asked to read three times randomly from the computer. A total of 900 tokens (100 glottal & preglottal stop words *3 repetition *3 people) were collected in the experiment. The recording was conducted in two places. Speaker who is numbered 1 in table 1 was recorded at the NTHU Phonetics Laboratory with a digital recorder: Edirol R-09HR and with a high-quality headphone: Shure BETA 54. On the other hand, speakers who are numbered 2 and 3 in table 1 were recorded at the silent suite in Tamazuan (Dili village) with a digital recorder: H4 ROOM.

2.3.2 Data analysis

The acoustic analysis was done using the software-Praat. All the stimuli in Appendix were included when recording. However, segmentation and analysis of the tokens would not include the words without glottal stops. When it comes to segmentation, segmentation was performed basically according to the beginning and endpoint of the second formant (F2). Waveform would also take into account. If the starting point or the end point was not clear, the segmentation process was determined through the researcher's auditory judgment. The values of the duration of glottal stops were extracted with the help of a vowel-consonant output script developed at the NTHU Phonetics Laboratory.

2.3.3 Segmentation

In this section, the segmentation in spectrogram and waveform from praat is as follows. The segmentation of the stimulus will be categorized into 5 parts to analyze: word-initial, word-medial, word finals, and before voiced stops /b, d/.

(1) Word-medial: maqo’ngul ‘angry’ [ma'qoʔŋul]

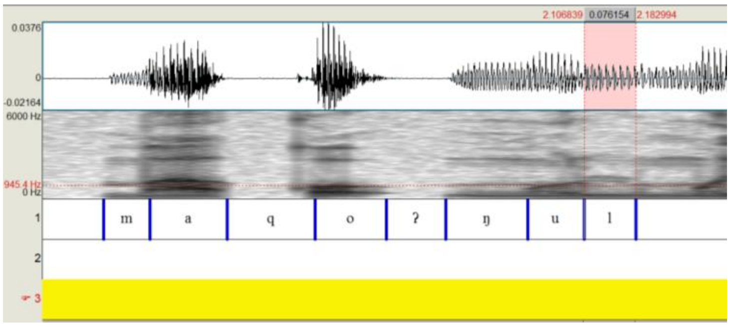

Figure 4: glottal stop in word-medial position

From the spectrogram, it is easily to find that glottal stop in word-medial position has the same attribute as the ones proposed by Hall (2006).

(2) Word-final

a. mata’ ‘cannon’ ['mataʔ]

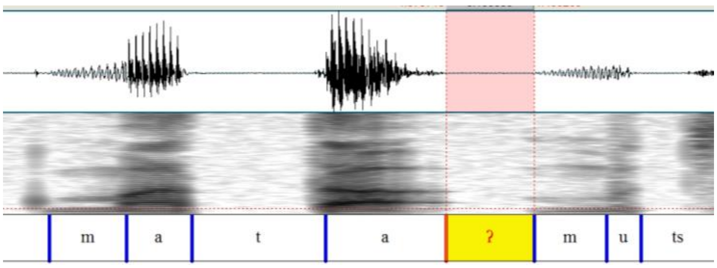

Figure 5: glottal stop in word-final position

When glottal stop in the word-final position, there will be a blank space. Compared with the word-final without glottal stop in b, the differnece is clearly.

b. tama ‘father’ ['tama]

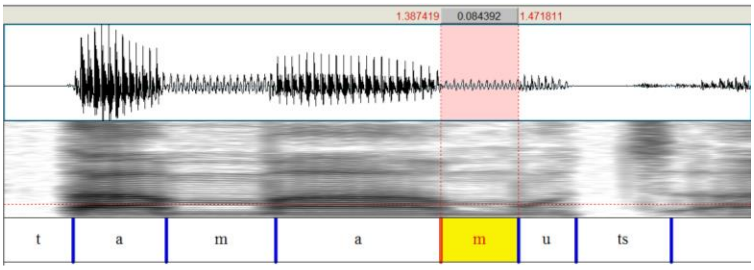

Figure 6: no glottal stop in word-final position

(3)

a. word-initial ’aq’aq ‘raven’ [ʔaq'ʔaq]

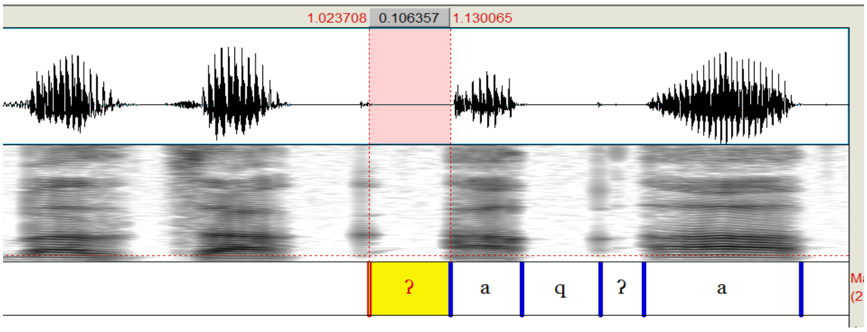

Figure 7: glottal stop in word-initial position

From the spectrogram, there is a slight bar precedes glottal stop in word-initial position. In token in b., a slight bar can be also found in the token with vowel in the word-initial position. Therefore, we can highly suppose that glottal stop precedes the vowel as syllable initial will have glottal stops in phonetic realization.

b. iu ‘medicine’ [iu]

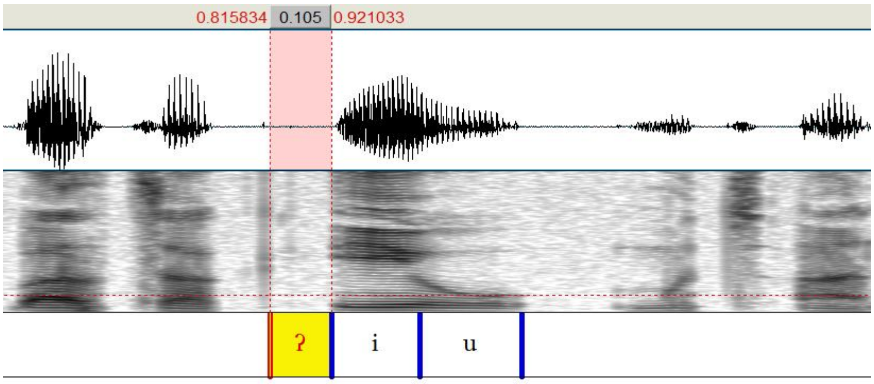

Figure 8: glottal stop in word-initial position

(4) glottal stops before voiced stops /b, d/

a. sidi ‘goat’ ['sidi]

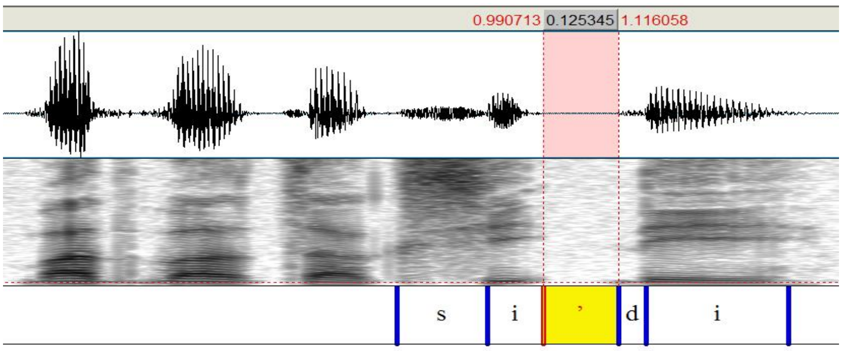

Figure 9: glottal stop before voiced /d/

b. qabinun ‘hide’ [qa'binun]

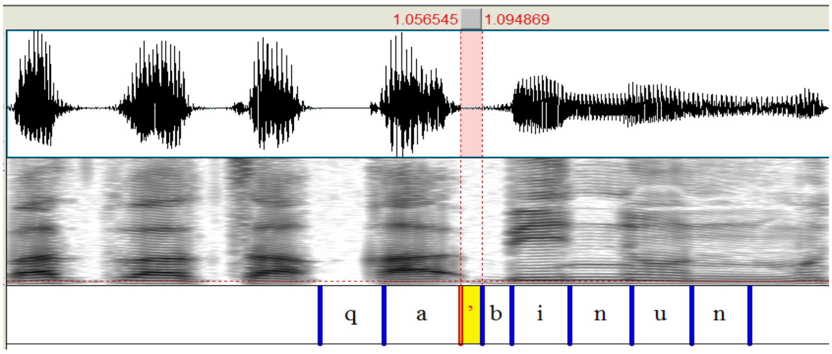

Figure 10: glottal stop before voiced /b/

VOT is the crucial feature for voiced stops cross the world. Voiced stops have negative VOT for the vocal cords start to vibrate before open the mouth to pronounce. From (4a, b), we can find that before the vibration, there is blank space which is the glottal stops.

3 Result

3.1 Glottal stops

The result will be divided into several groups to compare. First of all, the comparison is focusing on whether stress or syllable position would make the duration of glottal stops different. Stress and syllable position would be the possible factors to influence the duration of glottal stops. Table 5 and Table 6 will discuss two factors respectively. In Table 5, it presents glottal stops in stressed (word such as: ma’anak) and unstressed (word such as: mu’u) syllables in 3 speakers.

	stressed	unstressed
speaker 1	84.73	78
speaker 2	117.28	111.56
speaker 3	139.16	124.85
average	114.72	104.8

Unit: ms

Table 5

From Table 5, it indicates that the duration of glottal stops in stressed syllable is longer than the one in unstressed syllable. Therefore, it is predicted that stress would be the factor to influence the duration of glottal stops.

In Table 6, it shows glottal stops in different positions (onset: word such as *’aq’aq* and coda: word such as *li’li’*).

	onset	coda
speaker 1	75.8	78.23
speaker 2	112.3	113.94
speaker 3	134.7	128.31
average	107.62	106.8

Unit: ms

Table 6

From the above table, the duration of glottal stops in onset and coda shows no significant different. To demonstrate that only stress influences duration in glottal stops, Table 7 presents the comparison between stress and unstress in onset (stress onset: word such as *’aq’aq*/ unstress onset: word such as *ko’naz*) and the comparison between stress and unstress in coda (stress coda: word such as *pi’asang*/ unstress coda: word such as *anana’*). In Table 7, it presents that duration of glottal stops in stressed onset and in stressed coda would evidently longer than the corresponding ones in unstressed onset and in unstressed coda. However, the comparison between glottal stops in different positions: in stressed onset and unstressed onset/ in stressed coda and unstressed coda, the data points out there is merely different.

	Stressed onset	Unstressed onset	Stressed coda	Unstressed coda
1	85.62	67.52	91.8	74.75
2	119.62	106.55	113.4	104.16
3	141.93	129	147.2	118.81
total	115.72	101.02	117.46	99.57

Unit: ms

Table 7

To sum up, stress is the primary factor that influences the duration of glottal stops and there is no significant difference between onset and coda.

3.2 Glottal Stops before Voiced Stops: /b, d/

To begin with, comparison between the above-mentioned glottal stops and glottal stops before voiced stops: /b, d/ is presented to decide whether there is any difference between the two glottal stops.

	Glottal stop	**Preglottal stop**
1	81.36	73.27
2	114.42	107.07
3	132	113.72
average	109.76	98.02

Unit: ms

Table 8

In Table 8, it presents that the duration of the above-mentioned glottal stops is evidently longer than glottal stops before voiced stops: /b, d/. It is a strong evidence to demonstrate that glottal stops before voiced stops:/b, d/ are not the phoneme but the diacritic: /ˀb, ˀd/.

When it comes to glottal stops before voiced stops: /b, d/, from the above conclusion, we would predict that the duration of glottal stops before voiced stops: /b, d/ in stressed syllable would potentially longer than the one in unstressed syllable. The following tables are the results of distinct comparison of the duration of glottal stops before voiced stops: /b, d/.

In Table 9, it shows that the duration of glottal stops before voiced stops: /b, d/ in stressed syllable is shorter than the one in unstressed syllable. The result totally reverses our previous prediction that the duration in unstressed syllable is shorter than in the stressed syllable.

	stressed	**unstressed**
1	69	75.45
2	106.2	113.23
3	111.36	117.79
average	96.18	102.163

Unit: ms

Table 9

The possible reason for the duration of unstressed glottal stops before voiced stops is longer than the duration of stressed ones is that the duration of negative VOT of voiced stops /b, d/ in stressed syllable is longer than the one in unstressed syllable. Therefore, glottal stops before voiced stops in stressed syllables are shorter in order to produce longer VOT.

In Table 10, the comparison of glottal stops before voiced stops in reduplication tokens is as follows (word such as *madungdung*). And the result in table 10 which points out that the duration of glottal stops before voiced stops in stressed syllable of reduplication tokens is shorter the same as the result in table 9.

	stressed	**unstressed**
1	60.77	69
2	108.66	115.5
3	100.44	97.22
average	89.96	93.9

Unit: ms

Table 10

To conclude, stress is the vital factor that influences the duration of glottal stop which means that duration of glottal stops in stressed syllable is evidently longer than the one in unstressed syllable. However, syllable position (onset/ coda) shows no significant difference in duration of glottal stops. When it comes to duration of glottal stops before voiced stops: /b, d/, it is indeed different from the above-mentioned glottal stops. Therefore, it is the evidence that because of the short duration of glottal stops before voiced stops, it is the diacritic but not the phoneme in Takibakha. On the other hand, the duration of glottal stops before voiced stops in stressed syllable is shorter than the one in unstressed syllable. The possible explanation can be VOT in stressed voiced stops is longer that makes duration of glottal stops before voiced stops shorter than the one in unstressed syllable.

4 Conclusion and Other Findings

From the above results, stress is the primary factor that influences the duration of glottal stops while syllable position would not take into account as the factor.

When conducting the segmentation, researcher find that glottal stops such as kambu' 'get cold' and cucu' 'bosom' in final position tend to drop which means glottal stops are not pronounced in coda in word-final position. What's more, intervocalic glottal stops such as seta'an 'sweat' and uva'az 'child' are likely to coarticulated with creaky voice which is cross-linguistic.

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游立君 (2009) 郡社群布農語子音與母音的聲學特徵.

Appendix

Word	IPA	Chinese	Word	IPA	Chinese
tas'a	['tas.ʔa]	一	libus	['li.bus]	森林地
i’iupqulbu	[i.ʔiup.'qul.bu]	吹風機	qedang	['qe.daŋ]	血
iu	[iu]	藥	maz'av	['mað.ʔav]	不好意思
maqo'ngul	[ma.'qoʔ.ŋul]	氣不過	poqpoq	['poq.poq]	閃光
simang'ut	[si.'maŋ.ʔut]	鼻塞	maqo'ngul	[ma.'qoʔ.ŋul]	氣不過
mindia	[min'dia]	選擇	madungdung	[ma.'duŋ.duŋ]	很謙虛
sidi	['si.di]	羊	qatabang	[qa.'ta.baŋ]	蟑螂
daputdaing	[da.put. 'daiŋ]	青椒	madoqlac	[ma.'doq.lats]	白色
mumu'dan	[mu.'muʔ.dan]	脖子	silupdaing	[si.lup.'daiŋ]	大腸
matabal	[ma.'ta.bal]	砍	tibuklav	[ti.'buk.lav]	胃
mata'	['ma.taʔ]	火炮	qani'an	[qa.'ni.ʔan]	白天
binano'az	[bi.na.'no.ʔað]	女生	buan	[buan]	月亮
madangqac	[ma.'daŋ.qats]	紅色	'aq'aq	[ʔaq.'ʔaq]	烏鴉
sadu	[sa.'du]	看	madadangqac	[ma.da.'daŋ.qats]	都是紅色的
pi'asang	[pi.ʔa. 'saŋ]	三八	ma'anak	[ma.'ʔa.nak]	打
asa	['a.sa]	喜歡	anana'	[a.'na.naʔ]	很痛
qudu'	['qu.duʔ]	龍葵	mama	['ma.ma]	舌頭
sibutbut	[si.'but.but]	拉	pe'anan	[pe.'ʔa.nan]	柄（刀）
nal'ung	['nal.ʔuŋ]	山黃麻	lili	['li.li]	蕨類
izuk	['i.ðuk]	橘子	mamu'mu'	[ma.'muʔ.muʔ]	治療病患
mu'u	['mu.ʔu]	你們	tinga'pan	[ti.'ŋaʔ.pan]	背袋
'ukdu'an	[ʔuk.'du.ʔan]	便祕	taldanav	[tal.'da.nav]	洗臉；洗澡
madodoqlac	[ma.do.'doq.lats]	都是白色的	ten'a	['ten.ʔa]	聽
va'u	['va.ʔu]	肩膀	uva'az	[u.'va.ʔað]	孩子
qodan	['qo.dan]	雨	laqbing	['laq.biŋ]	明天
madia	[ma.'dia]	很多	tama	['ta.ma]	爸爸
mu'dan	[muʔ.'dan]	喉嚨	danum	['da.num]	水
pa'ic	['pa.ʔitɕ]	苦瓜	madasdas	[ma.'das.das]	灑秧苗
li'li'	['liʔ.liʔ]	過貓	lai'ian	['lai.ʔian]	綠豆
lulu	['lu.lu]	脛骨	opop	['op.op]	青蛙

lu'lu'	['luʔ.luʔ]	傷口	maboqliboqli	[ma.boq.li.'boq.li]	黑白花點
alim	['a.lim]	脾臟	duduk	['du.duk]	生薑
ising	['i.siŋ]	醫生	mataqdung	[ma.'taq.duŋ]	黑色
ingsai	[iŋ.'sai]	空心菜	ning'av	['niŋ.ʔav]	海
cucu'	['cu.cuʔ]	乳房	laqalilu'un	[la.qa.li.'lu.ʔun]	硃砂根
mabazu	[ma.'ba. ðu]	搗	bunbun	['bun.bun]	香蕉
man'asqaz	[man.'ʔas.qað]	自殺	qabinun	[qa.'bi.nun]	把東西藏起來
su'u	['su.ʔu]	你	mabulav	[ma.'bu.lav]	黃色
bunglai	[buŋ.'lai]	鳳梨	qoda	['qo.da]	喝(邀請)
seta'an	[se.'ta.ʔan]	流汗	kambu'	['kam.buʔ]	感冒

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