ACOUSTIC CHARACTERISTICS OF THE GLOTTAL STOP IN KAYABI

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ABSTRACT

Spectrograms of the recorded speech of one male and one female speaker of the Kayabi language of Brazil demonstrate voiced variants of the normally voiceless glottal stop. The glottal stop is realized by several variants which are reflected in the spectrograms. These variants range from a period of complete closure, through various kinds of creak, to a more slowing down of vocal cord vibrations, or a combination of these.

INTRODUCTION

This presentation describes the Kayabi glottal stop in terms of their acoustic cues and cue patterns as observed in spectrograms. Some degree of glottal stricture from glottal trill, flap to glottal stop is perceived and identified by the listener as a glottal stop. Kayabi belongs to the Tupi-Guarani language family of Brazil as classified by Rodrigues (Rodrigues 1958). The Kayabi language is spoken by about 400 Indians living in Central Brazil, were the material on which this study is based was gathered.

1. METHOD

Data used for this research were mainly lists of isolated words of varying syllable types and lengths tape-recorded by one male and one female Kayabi speaker, using an Ader 4000 Report 'S' tape-recorder with a Sennheiser microphone. Spectrograms were produced with a Kay Digital Sonagraph 2300 at the University of Edinburgh.

2. RESULTS

The glottal stop in Kayabi is phonologically an articulation type, being in contrast with other stops. It occurs in syllable initial position and functions as a consonant. Examples of contrast area:

/ta7$t/ 'offspring' /ta7$t/ 'cloth'
/a7/ 'a little rain' /a7/ 'a little red'

/ta7$t/ 'a root vegetable'

Glotalized consonants also occur syllable initial at morpheme boundaries. They are mostly the result of elasethes, as seen in:

/iplay/ 'red' plus suffix /-i/ 'diminutive'

The various types of glottal activities are accompanied by a drop in intensity, which is maximum for the complete glottal closure. The duration of the intervocalic glottal stop ranges from 80-160 msec, which is shorter than the duration of other stops.

The auditory effect is always that of a glottal stop preceding the consonants /m/ /n/ /j/ /r/ /g/ can have the same variants as when occurring intervocally:

2.2 Pre-glotalized consonants

A glottal stop preceding the consonants /m/ /n/ /j/ /r/ /g/ can have the same variants as when occurring intervocally:

a. a gap of shorter or longer duration, reflecting a momentary and voiceless articulation

b. a series of short and irregular gaps between stronger glottal pulses, with or without slowing down of vibrations before and after these gaps:

c. a rapid lowering and raising of F0:

The duration of this glottal activity is about 70-100 msec, followed by a consonant of 20-60 msec. This consonant duration is shorter than the duration of the same consonant intervocally.

The auditory effect of the variants of the glottal stop preceding consonants is always that of a pre-stopped consonant.

3. FACTORS INFLUENTIAL IN THE CHOICE OF VARIANTS OF THE GLOTTAL STOP

Kayabi speech demonstrates a tendency towards a more lax articulation, especially in the speech of male adults. This results in incomplete or lax closures especially of /r/ and /j/, and a more open approximation for fricatives. Women tend to use a more tense and precise articulation with tighter closures and narrower constrictions, and often, a longer duration of segments.

The creak variants are more prevalent in male speaker with a lower F2. Female speakers do manifest creak, but show a tendency toward complete closure.

The creak variant is more common in open vowel, than in close ones. The glottal closure is longer the heavier the stress, with less closure or just creak with weaker stress. In faster speech and longer utterances the variants creak to slow vibrations are the more common.

4. CONCLUSIONS AND DISCUSSION

In Kayabi the target for the glottal stop articulation is of the category stop or closure realized by a scale of glottal stricture from complete and prolonged closure, several short closures, through creak to voice.

The unit of perception is composed of acoustic cues and cue patterns as seen in the spectrograms, which reflect glottal activity of varying degrees, the totality of which is perceived and distinguished as the phoneme 'glottal stop'.

REFERENCES


GLOTTAL STOPS IN GITKSAN: AN ACOUSTIC ANALYSIS

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ABSTRACT

A time-series analysis of Gitksan ejectives provides additional evidence for a typological distinction between fortis and lenis glottalic stops.

INTRODUCTION

In light of recent evidence of inter-language and inter-speaker variation [1, 2], it is apparent that the classical account of the glottalic airstream mechanism for ejectives [3] is in need of revision. This paper reports an acoustic investigation of plain and glottalized stops in Gitksan, a Tsimshianic language spoken in the Fraser River valley of British Columbia.

Glottalized stops in Gitksan are notable for their lenis character [4, 5], in contrast to the unmistakably ejective nature of glottalized stops in other Pacific Northwest American languages, such as Salish or Kootenay (Upper Chinookan). For non-native listeners, Gitksan glottalized stops may, in certain instances, be perceptually confused with plain voiced stops, which they are actually in phonemic contrast. Previous work has suggested that glottalized stops in Gitksan utilize an implosive airstream mechanism (in prevocalic position) and a flata (f) scheme for most of their lenis character. The other Gitksan speaker, SH, is LH's mother. SH, now in her late 30's, was the informant for Hoard's 1978 paper.

The Gitksan items were tape recorded on a Marantz cassette recorder (CP430) and then digitized at a frame rate of 100 samples per second. The data were stored and processed on an IBM-PC. A simple but adequate index of the abruptness of the release burst was calculated as the square root of the energy of the first 358 milliseconds of the waveform.

The data were analyzed in terms of the following parameters: voice onset time (VOT), release burst amplitude, and the presence of aspiration. The release burst was defined as the energy between the beginning of the burst and the point where the energy drops to one tenth of the maximum burst amplitude. Aspiration was defined as the presence of a period of silence between the beginning of the burst and the onset of vocalization.

The results of this study show that the release burst of Gitksan glottalized stops is similar to that of plain stops in terms of amplitude and duration. The release burst is characterized by a high peak, followed by a period of silence, and then the onset of vocalization. The presence of aspiration is more frequent in the glottalized stops than in the plain stops.

The results of this study support the hypothesis that the glottalized stops in Gitksan are produced with an implosive airstream mechanism. The results also suggest that the glottalized stops are produced with a more abrupt release burst than the plain stops.

It is typical of dorsally articulated stops to have some aspiration. The absence of aspiration in some glottalized stops should not be taken as indicative of a less abrupt release burst. The presence of aspiration may help explain why there is a tendency to misjudge plain stops as glottalized. Only one instance of a prevoiced stop was observed in the data set (SH, on second elicitation of /taw/, [daw], 'ice'). No examples of implosion were encountered, on either plain or glottalized stops.

Voice onset Time: Hogan [4] reports a mean Voice Onset Time of 114 milliseconds for Chipewyan ejectives in single word utterances elicited under comparable conditions to the present study. Voice onset times for the Gitksan glottalized stops were somewhat shorter with a high variance (X = 89.2, SD = 31.3 ms). Voice onset times for plain Gitksan stops fell within the range of English voiced stops (X = 111, SD = 36.1 ms). The mean of the distribution for the glottalized stops was also at or below the critical voice onset time for Chipewyan. The mean of the distribution for plain stops was above the critical voice onset time for the VOT continuum for plain stops.

The amplitude envelope of vowel onsets for the glottalized stops was similar to the amplitude envelope of vowel onsets for the plain stops. The amplitude envelope of vowel onsets for the glottalized stops was generally lower than the amplitude envelope of vowel onsets for the plain stops.

Amplitude envelope of vowel onsets: For ejectives produced with a lenis glottalic configuration an abrupt vocalic onset may be expected, whereas with a fortis configuration the onset may be more gradual. A simple but adequate index of the abruptness of the vowel onset was provided by the peak amplitude of

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FIG. 1. Waveform of Gitksan ejectives

Plausible release characteristics: Fortis and lenis varieties of glottalized stops should be expected to differ in the amplitude of the noise burst associated with the oral release gesture. It would be reasonable to infer that the amplitude of the release burst is monotonically related to intra-oral air pressure and the strength of the compression gesture just prior to release. In the case of fortis and clearly ejective glottalized stops, the release burst is highly damped and followed by a period of silence (approximately 100 ms) before the onset of vocalization. This contrasts with the release characteristics of voiceless aspirated stops, which also have a substantial voice onset burst, but where the noise burst is relatively undamped and continues up to the onset of the vowel.

The contouring release characteristics of the ejective and aspirated stops are attributable to two factors: a) higher intra-oral air pressure during the compression phase of the ejective as the larynx is raised, b) the open configuration of the glottis for aspirated stops, which permits sustained turbulent oral airflow up to the vocal onset. In the case of (English type) plain voiced stops, where oral release occurs more or less simultaneously with voice onset, a substantially no early release burst is observable. In the case of prevoiced (Spanish type) aspirated stops, late voice onset times for glottalized stops as well as for two reference tokens encountered, on phonologically glottalized stops or otherwise.

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the third glottal pulse as a proportion of the maximum amplitude attained by the vowel. Figure 3 shows the distribution of $A_{\text{Lmax}}$ index for all tokens on the y-axis of the graph. It is clear that the $A_{\text{Lmax}}$ index does not distinguish glottalized from plain stops. It does however indicate a对自己的 speaker difference. SFs vowel onsets are more abrupt than LFS.

![Figure 3. Voice Onset Time and Abovent of Vowel Onset in plain and glottalized stops.](image)

Aperiodicity and frequency of vowel onsets: Frequency changes emerge in vocal fold vibration as overtone information about the glottal configuration. Kingston [2] distinguishes between tense and creaky voice onsets which follow tense and lax glottalized stops respectively. Tense voice is associated with stiff vocal folds, a high degree of general laryngeal constriction, and a higher than normal transglottal pressure differential to sustain phonation. Creaky voice, on the other hand, is associated with shortened but lax vocal folds, moderate medial compression of the vocal folds with a lax laryngeal configuration, and a lower than normal phonotonic translaryngeal pressure differential [5]. There is some uncertainty about the acoustic features that distinguish tense and creaky voices. The most prominent difference lies in the fundamental frequency of phonation, which is very low in creaky voice and somewhat raised for tense voice. A greater degree of aperiodicity of vocal fold vibration may be expected for tense and creaky voice than in modal voice, though the time-series and spectrographic expression may be different in the two non-modal voice qualities. In creasy voice there is gross variation in the period of vocal fold vibration, possibly due to insufficient airflow or subglottal pressure to sustain regular oscillation. In tense voice, the higher degree of stiffness in the vocal folds and surrounding laryngeal musculature, combined with higher levels of subglottal pressure produce a phonatory cycle that has a relatively longer phase of vocal fold vibration, possibly due to insufficient muscular tension in the larynx.}

**FIG. 4. Period by period frequency changes in vowel onset**

There are notable speaker differences in the frequency contours of vowels following glottalized stops. For LFS, whose glottalized stops are particularly tenser, the frequency at onset is low, with a gradual rather than abrupt vowel onset for the majority of tokens. In SFs, six of ten vowels following glottalized stops showed aperiodic onset, compared with two out of twenty for LFS. Measurements were also made of the period of the first eight glottal pulses. Figure 4 summarized the results.

<table>
<thead>
<tr>
<th>speaker</th>
<th>vowel onset</th>
<th>voice type</th>
<th>period (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>LL</td>
<td>tense</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>tenser</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>SH</td>
<td>creaky</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Summary and conclusions:**

To summarize, Gitkan glottalized stops in pretonic position are characterized acoustically by:

1. A relatively weak but delayed release burst, consistent with a tenser laryngeal airstream mechanism.
2. A shorter VOT than is typically observed for glottal ejective stops.
3. Vowel onsets that are more abrupt in the majority of tokens, though this feature varied with the speaker and was correlated with.
4. An absence of visible spectral glottalization in the waveform of the following vowel-onset for the majority of tokens (contour above), but this was not universal.
5. Substantial, but declining pitch period perturbation (jitter) over the first few glottal cycles of the vowel onset, with the period following (in the case of speaker SF) or staying steady (SH).
6. Significant speaker variation on all of the above features, with higher intensity demonstrating a more lenis pattern of articulation.

It is possible that the observed speaker differences are attributable, not to inherent variation in Gitkan glottalized stops, but to the differential effects of language shift. As mentioned earlier, LFS is less fluent than his mother, who, maintains full native speaker productive control over the language. Additionally, the speaker differences may be at least in part attributable to stylistic variation. SFs is a more conservative speaker, and her pronunciation may reflect the use of a more formal speech style. Regardless of the source of these speaker differences, it is possible to draw certain inferences about the underlying articulatory mechanism of Gitkan glottalized stops and to hazard some speculative comments as to their featural representation.

Analysis of the Gitkan data, taken in context of a growing body of data from other languages, suggests that a language typological distinction between fortis and lenis ejectives is warranted, where this term is understood in the traditional sense of the degree of voicing of the complex laryngeal and articulatory components which comprise the whole gesture [10, 11]. Reduced upward movement of the larynx would produce a weaker and shorter compression phase. This is consistent with the lower observed amplitude release burst and shorter voice onset for glottalized stops. A weaker medial compression, with lower overall muscular tension in the larynx will result in a non-abrupt vowel onset, but one which is more likely to begin with a creaky or laryngealized voice of vocal fold vibration. (While fortis ejectives have a glottal attack, tenser ones, begin with a laryngealized voice and hence both have a glottalized voice quality.)

Of the various competing laryngeal feature systems, that of Ladefoged [9] seems most naturally to accommodate the emerging picture of cross language variation in glottalic stops. The fortis-lenis contrast applied to ejectives is a typological rather than a distinctive phonetic feature. In languages such as Hausa whose glottalized stops fall on the tenser end of the continuum, the contrast between ejective and implosive airstream mechanisms appears more perceptually and physiologically. Reduction of the laryngeal constriction and movement in the vertical instabilities of the laryngeal configuration for tense voice.

Aperiodicity during the first 48 milliseconds or so of the vowel is evident from the whole waveform, but this was atypical. Only 26% of the Gitkan glottalized stops in pretonic position showed Aperiodicity during the first 40 milliseconds or so of the following vowel. However, there are possibly significant speaker differences on this parameter. For SF, six of ten vowels following glottalized stops showed Aperiodicity in the first 48 milliseconds.

**REFERENCES**