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Phonetic Realization of Medial Stop Consonants in Akuntsú\(^1\)

CAROLINA COELHO ARAGON

This paper presents the results of an investigation of voicing and timing properties of the Akuntsú language (Tupian family, Brazil) with a view to providing an account of the phonetic realization of medial stop consonants in stressed syllables. Results from syllable structure, consonant clusters, and acoustic analysis show that Akuntsú stops have variant surface realizations when in the onset of medial stressed syllables that include sequences of voiceless-voiced stop.

1. INTRODUCTION. In this paper, I present the preliminary results of an acoustic investigation of voicing and closure duration of medial stop consonants in Akuntsú to provide a description of their surface forms and distribution. Akuntsú is a member of Tuparian subfamily of the Tupian family. This is an indigenous Brazilian language spoken by five monolinguals, recently contacted Indians, who are the only remaining Akuntsú after a massacre in their region. They are located in the indigenous zone of the Omerê River, in Rondônia State (Brazil).

In this language, four phonemic stop consonants have been described: /p/, /t/, /k/, and /ʔ/ (Aragon 2008). It was found that the individual stop phonemes have four different allophones in stressed syllables: a voiceless singleton, a voiced singleton, a voiceless geminate, and what I am calling in this paper a voiceless-voiced consonant that is phonetically a consonant cluster (i.e., a sequence of a voiceless stop plus a voiced stop), but phonemically a single segment.

Aiming at providing the surface forms of medial stop consonants in stressed syllables, this paper first addresses the Akuntsú phonological background and discusses syllable structure. Second, it examines acoustic and phonetic characteristics of stops in stressed syllables, such as the percentage of voicing in the closure and timing of the closure. In addition, the phonation type of vowels is addressed to investigate the existence of glottalized consonants. Finally, the paper concludes with some important implications, pointing out remaining questions in need of further research.

2. GOALS. The main goals of this study are to investigate the following research questions:

1. What are the surface forms of the stop consonants in Akuntsú?
   In previous studies of Akuntsú (Cabrál and Aragon 2004, Aragon 2008), it was proposed that for each stop phoneme there are four stop consonants that occur on the surface: a voiceless singleton of [p], [t], and [k], its respective voiced counterpart, a voiceless geminate consonant [pp], [tt], and [kk], and a voiceless-voiced phonetic sequence [pb], [td], and [kg].

2. What is the evidence for a voiceless-voiced phonetic cluster in Akuntsú, as previously described?
   It is hypothesized that in a sequence of identical voiceless stops, as in VC\(C\)C\(V\), the second consonant may become [+voice], since it is placed at the onset of word-medial stressed syllables. For testing this hypothesis, a discussion on syllabification is addressed in §4. Note that this study is not concerned with the analysis of voiceless stops followed by voiced stops across a word-boundary, such as [atap’\#\#berek’].

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\(^2\) This paper only deals with the supra-laryngeal phonemes, not with the glottal stop.
‘long hair’ ([atap̚] ‘hair’, [berɛk̚] ‘long’) or across a morpheme-boundary, as in [kip̚+bi] ‘inside the wood’ ([kip̚] ‘wood’, [-bi] ‘in’); rather, this paper is restricted to the investigation of the voiceless-voiced realization morpheme-internally, when the target stop is in the onset of medial stressed syllables, such as in [at’dap̚] ‘hair’.

(3) Do stop durations behave as a continuum or as two separate phonetic categories: singleton and geminate?

Following previous studies, such as Maddieson 1985, McCarthy 1986, and Ham 2001, I consider the duration of closure the main acoustic feature for identifying geminate and non-geminate consonants in stressed syllables intervocically. Based on this assumption, this paper will answer the question of whether, in this language, there is evidence to assume two different phonetic timings of closure duration for stop consonants, i.e., short and long closure duration. It is hypothesized and proposed in this paper (see §5.3) that stop consonants have a tendency to have two distributions of timing of closure duration: long (>200 ms.) and short (<200 ms.). These two distributions (long and short) affect only word-medial voiceless stop consonants in stressed syllables.

(4) Are the syllable-final stops glottalized?

To investigate this issue, FFT spectra of modal and creaky vowels will be compared and discussed. Even though this is a difficult analysis to undertake due to some limitations, this paper attempts to show preliminary findings by examining vowels adjacent to stops, and voice quality. It is hypothesized that syllable-final stops in word-medial position are typically glottalized at closure (rather than at release); glottal stops are produced concurrent with the stop closure. Glottalized stops are conditioned by adjacent segments, stress, and speech rate, functioning as a clue for perceiving syllable boundaries. Note that, in Akuntsú, laryngealized vowels are not underlyingly contrastive (Aragon 2008).

3. PHONOLOGICAL BACKGROUND. This section provides an overview of the phonological system of Akuntsú, with its phonemic inventory and the surface forms of the stop consonants in this language.

<table>
<thead>
<tr>
<th>TABLE 1. Phonemic inventory: consonants (adapted from Aragon 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stop</strong></td>
</tr>
<tr>
<td>/p/</td>
</tr>
<tr>
<td><strong>Affricate</strong></td>
</tr>
<tr>
<td>/tʃ/</td>
</tr>
<tr>
<td><strong>Nasal</strong></td>
</tr>
<tr>
<td><strong>Glide</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2. Phonemic inventory: vowels (Aragon 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
</tr>
<tr>
<td>i</td>
</tr>
<tr>
<td>e</td>
</tr>
<tr>
<td>a</td>
</tr>
</tbody>
</table>

3 In this current study the term “geminate consonants” always refers to phonetically long consonants, i.e., phonetically sequence of consonants that are realized with single closure and burst events.

4 Word-final stops may be glottalized too, but I haven’t yet study them acoustically. Laryngealization might be a mark not only for a syllable-boundary in Akuntsú, as discussed in §5.5, but also for a word-boundary (Aragon in progress).

5 The high central nasal vowel is not phonemically contrastive in Akuntsú; at least no phonological evidence has been found so far to consider this vowel as part of the vocalic inventory. It might be that nasality leads to a neutralization of the front and central high vowels (Aragon in progress).
In Akuntsú, voiced consonants are not phonologically contrastive. The voiced counterparts of voiceless stops are treated as the surface form of the corresponding underlying voiceless stop. The surface forms are rule-governed variants, as shown further on in this section.

In (1) below the possible environments where stop consonants may become voiced are illustrated.

Note: stops only become voiced in syllable-initial position; voiceless and voiced stops vary freely syllable-initially; stop consonants in syllable-final position are unreleased [p̚, t̚, k̚].

(1)

<table>
<thead>
<tr>
<th>Position</th>
<th>Underlying form</th>
<th>Surface form</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>/pirita/</td>
<td>[piriᵊta] ~ [biriᵊda]</td>
<td>‘traíra (sp. of fish)’</td>
</tr>
<tr>
<td>Medial Intervocalic</td>
<td>/epapap/</td>
<td>[epaᵊpap] ~ [ebaᵊbap]</td>
<td>‘eye’</td>
</tr>
<tr>
<td>Medial Cluster</td>
<td>/kijtpit/</td>
<td>[kijᵊpit] ~ [gijᵊbit]</td>
<td>‘fish’</td>
</tr>
<tr>
<td>Final</td>
<td>/kip/</td>
<td>[kip']</td>
<td>‘stick/wood’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position</th>
<th>Underlying form</th>
<th>Surface form</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>/tato/</td>
<td>[taᵊto] ~ [daᵊdo]</td>
<td>‘armadillo’</td>
</tr>
<tr>
<td>Medial Intervocalic</td>
<td>/wato/</td>
<td>[waᵊto] ~ [waᵊdo]</td>
<td>‘alligator’</td>
</tr>
<tr>
<td>Medial Cluster</td>
<td>/kojtpe/</td>
<td>[kojtᵊpe] ~ [gojtᵊbe]</td>
<td>‘older sister’</td>
</tr>
<tr>
<td>Final</td>
<td>/et/</td>
<td>[et']</td>
<td>‘name’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position</th>
<th>Underlying form</th>
<th>Surface form</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>/komata/</td>
<td>[kõmãᵊta] ~ [gõmãᵊda]</td>
<td>‘bean sp.’</td>
</tr>
<tr>
<td>Medial Intervocalic</td>
<td>/iki/</td>
<td>[iᵊki] ~ [iᵊgi]</td>
<td>‘water’</td>
</tr>
<tr>
<td>Medial Cluster</td>
<td>/pkitpe/</td>
<td>[pitᵊkip'] ~ [bitᵊgip']</td>
<td>‘neck’</td>
</tr>
<tr>
<td>Final</td>
<td>/ek/</td>
<td>[ek’]</td>
<td>‘house’</td>
</tr>
</tbody>
</table>

Stops in the onset of medial stressed syllables present more alternations than the one shown above. The allophonic variation of stops is determined by the phonetic characteristics of the adjacent segments, and, especially, by the position of the consonants in syllables and speech rates. The distribution of the stop surface forms is governed by optional rules. Medial stop variants are shown in the prose and in the rules presented below, followed by an example.

The first optional rule says that a voiceless stop can become voiced stop when it is in syllable-initial position:

**Rule 1 (Optional Voicing):**

\[ \text{vl stops} \rightarrow +vd /$ \_ \_ \]  

Example: /mepit/ [mẽᵊpit'] ~ [mẽᵊbit'] ‘son.of.woman’

In addition to this rule, there is another one that says: voiceless stops optionally become long when they are in the onset of non-initial stressed syllables. Initial stops word-medially geminate, forming both the coda of the first syllable and the onset of the next:

**Rule 2 (Optional Gemination):**

\[ C_i[\text{-continuant, - voice}] \rightarrow C_iC_i/V \_\_V \]  

Note: \( C_iS>C_i \)

Example: /otat/ [oₜat'] ~ [otₜat'] ‘fire’

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6 Stress is not relevant to the voicing process in this language.
The third optional rule says: a voiceless geminate consonant, the result of Rule 2, may become glottalized,\(^7\) as in rule #3 below. The results and additional discussion on the glottal feature are detailed further in §5.5

**Rule 3 (Optional Glottalization):**

\[C_{\text{[lit. continuant]}} \rightarrow C_{\text{[\_SC]}}\]

**Example:** /otat/ [o’tat’] → [o’tat’] (by Rule 2) → [o’t̚tat’] ‘fire’

Note that a long period of voicing during the closure duration was not identified, which means that variations such as: /opo/ → [o’bo] → *[o’bo]* were not found in the data (see §5 below for further discussion).\(^8\)

To sum up, besides the alternation between voiceless singleton and voiced singleton (sho\(\rightarrow\)no), the following alternations were also identified and attested word-medially:

(2) a. 

\[
\begin{array}{cccccccc}
/p/ & \sim & [pp] & \sim & [pb] & [p’p] & \sim & [p’b] & \sim & [b] & \text{‘my hand’} \\
\]

b. 

\[
\begin{array}{cccccccc}
[t] & \sim & [tt] & \sim & [td] & [t’t] & \sim & [t’d] & \sim & [d] & \text{‘eye’} \\
/wato/ & [k’a’to] & [k’a’to] & [k’a’td] & [k’a’t’to] & [k’a’t’d] & [k’a’d] & \text{‘alligator’} \\
/otat/ & [o’tat’] & [o’tat’] & [o’t’d] & [o’t’at’] & [o’t’d] & [o’d] & \text{‘fire’} \end{array}
\]

c. 

\[
\begin{array}{cccccccc}
[k] & \sim & [kk] & \sim & [kg] & [k’k] & \sim & [k’g] & \sim & [g] & \text{‘water’} \\
\]

4. SYLLABLE STRUCTURE. The syllable structure in Akuntsú has the pattern ((C)V(C)(C)) (Aragon 2008). Vowels always occupy the head of the syllable (nucleus position); the onset position can be occupied by only one consonant ((C)V), while the coda position can be occupied by one or two consonants (V(j)(C)).\(^9\)

In a (V(C)) structure, unreleased voiceless stops, glottal, nasals /m, n, ŋ/ and glides /j, w/ can occupy the coda position, whereas /r/ and /ʃ/ can only occupy onset position. The syllable structure types are illustrated in table 3 below:

<table>
<thead>
<tr>
<th>Syllable structure type</th>
<th>Initial</th>
<th>Medial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>/a.tap/ ‘hair’</td>
<td>/i.e.ko/ ‘vulture’</td>
<td>/o.t(op.a)/’see me’</td>
</tr>
<tr>
<td>CV</td>
<td>/k’i/ ‘liquid’</td>
<td>/t[a.t]a.kop/ ‘taxi (sp. of ant)’</td>
<td>/a.ra.mi.ra/ ‘woman’</td>
</tr>
<tr>
<td>VC</td>
<td>/ek’ / ‘house’</td>
<td>/e.aw.ka/ ‘you yawned’</td>
<td>/o.ip/ ‘I came back’</td>
</tr>
<tr>
<td>CVC</td>
<td>/t[i]t.pe/’fig’</td>
<td>/o.pi.k kep’ ‘my neck’</td>
<td>/ki.pek/ ‘papaya’</td>
</tr>
<tr>
<td>CVCC</td>
<td>/kij[t]pit/ ‘traira (sp. of fish)’</td>
<td>/e.kojt.pe/ ‘your oldest sister’</td>
<td>---</td>
</tr>
</tbody>
</table>

In clusters like /pitkip/ or /titpe/, the stop consonant that occupies the coda position is always voiceless, which never alternates to its voiced counterpart; strictly speaking the possible surface forms are: [pit’kip’] ~ [pit’gip’], but never *[pid’kip’] ~ *[pid’gip’], as shown below:

\(^7\) The term “glottalized stop” means that the glottal stop is formed concurrently with the supra-laryngeal stop, but only the supra-laryngeal stop has an audible release. “Glottalized stop” in this study does not mean an ejective.

\(^8\) The absence of surface *[ob’bo]* might due to an obligatory syllable-final devoicing rule found in this language. This fact would eliminate the need for a possible bleeding order that says: if the voicing rule is applied first, it bleeds the gemination and glottalization rules.

\(^9\) The only type of complex codas encountered in this language is (C)V(j)(C). For the glide, it might be that it is inserted before certain consonants (Aragon in progress). This matter will not be the focus of this current paper.
The discussion above leads us to explain why the order voiceless-voiced consonant rather than voiced-voiceless consonant is found in Akuntsú. From syllabification in Akuntsú, it is possible to assume that when a voiceless-voiced consonant is produced, the voiceless one is re-syllabified and placed at the coda of the preceding syllable. The voiced consonant remains in the onset position. In this way, the voiceless consonant placed at the coda position cannot alternate between voiceless and voiced syllable-finally; however, the consonant that occupies the onset position can become voiced. In addition, two non-syllabic segments at the same syllable position are not allowed in Akuntsú onsets, which justifies the syllabification process in Akuntsú. An illustration of this explanation is shown below:

(4) /otat/ → [ot.’dat̚] ‘fire’

Note that at an underlying phonemic level, they constitute just single intervocalic consonants, the onset of the syllable, as in /otat/; however, phonetically, they appear to have a different status, namely as both the coda of the preceding syllable and the onset of the following one, as in [ot.’tat̚] and [ot.’dat̚]. This means that the analysis of phonetic geminate consonants falls under the same process of syllabification shown above for the voiceless-voiced cluster, whereas the geminates are a sequence of two identical consonants with a syllable boundary placing them in two different syllables. Following this discussion, it is reasonable to assume that the voiceless geminate consonant can alternate between [tt] ~ [td] in the onset of medial stressed syllables. However, as Akuntsú syllable structure doesn’t allow a voiced consonant in coda position, neither a voiced geminate consonant nor a voiced-voiceless consonant is allowed in this language.

In turn, to verify the phonetic occurrence of the surface stops described here, the next sections will address acoustic arguments and more discussion on the examination of this matter.

5. ACOUSTIC ANALYSIS.

5.1 METHODS. This study is based on data collected among the Akuntsú speakers during my fieldwork trips, which include a corpus of spontaneous speech. I selected examples from two speakers, a female and a male. Data were recorded in digital format (WAV) with a Sony Portable Minidisc Recorder MZ-NH700 and a Zoom H4 recorder with a Sony ECM-MS957 stereo microphone with rotating mid capsule, at a sampling frequency of 44,100 Hz and a bit rate of 16. Since there are only five speakers in total, selection to control for variables was not possible. One of the subjects was an approximately 75-year old male; the other was an approximately 45-year old female; not all words were recorded from each speaker. It is worth pointing out that all the data were recorded in the rain-forest environment (outdoors), which has implications for the quality of the data, not being ideal for acoustic analysis.

Each token was analyzed using the Praat program, and the values of the duration of the closure were

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10 In Akuntsú, codas are moraic. Closed syllables ((C)V(C)) and diphthongs are counted as having two moras and open syllables as one mora (Aragon unpublished manuscript).
measured from the offset of the preceding vowel up to the onset of the release burst; in addition, any voicing during closure was measured from the beginning of the voicing up to the release of the burst. Closure duration and voicing during closure were measured in milliseconds (waveforms and spectrograms were analyzed in conjunction). The percentage of voicing during closure was found by dividing the voiced closure portion of each stop by its own entire closure duration value. Figure 1 below shows an instance of waveform measurements used in this current study:

FIGURE 1. An example of measurements of voiceless and voiced durations for the word /ipek/ [ip'bɛk] ‘duck’

5.2 VOICING DURING THE CLOSURE DURATION. The relationship between closure duration and voicing during the closure were examined. Figures 2–4 below represent tokens plotted for speaker 1 and speaker 2 according to their values for percentage of voicing (during the closure) by closure duration.\footnote{All measurements are in ms.}

Note that all tokens measured were taken from stressed syllables.

FIGURES 2. Percentage of voicing during the closure by closure duration for bilabial stops
The dots in figures 2–4 show that during closure, there are some stops that are fully voiced, presenting 100% of voicing, others that are fully voiceless with 0% of voicing, while other consonants are partially voiced, with a range of 20 to 65% of voicing. The graphics for bilabials, alveolars, and velars suggest that there are, phonetically, three different kinds of stops based on voicing characteristics. In other words, the results show consonants that have no voicing during the closure, and others that present partial voicing or full voicing.

The voicing data above respond to research question number (2): they show evidence for a voiceless-voiced phonetic cluster in Akuntsú, as previously described. However, the data for closure duration do not show clear evidence of two clearly separate groups (i.e., singletons versus geminates); the tokens overlap from both of the speakers, as seen, for example, in fig. 3 above. Nevertheless, this issue will be clarified in the next sections.
5.3 TIMING OF CLOSURE DURATION. Aiming at answering research question 3 (whether closure durations of stops behave as a continuum or whether they fall into two separate phonetic categories: a singleton and a geminate), the means of closure duration for the stop consonants are compared in figures 5–6 below, for each speaker. The acoustic events between singleton/geminate were determined by visual inspection using Prat.

Comparing subjects and place of articulation in the figures above, the results of ANOVA analyses revealed that there are significant differences in closure duration between stops classed as singletons and stops classed as geminates (the p-value is below 0.001 for both speakers). There is no interaction between place and length (p= 0.395 for speaker 1; p=0.397 for speaker 2), which means that the effect of place is the same across the two levels of length, i.e., short and long closure. In addition, there is no significant
effect of place of articulation on closure duration, for either speaker (p>0.05).

T-tests were performed on the data to ascertain whether the overall result between short and long closures interacts with each place of articulation. It was found that all pairwise comparisons for each place of articulation (singleton bilabial with geminate bilabial, and so on) reached a significance of p<0.001 for bilabial and alveolar stops for speakers 1 and 2; and with a p=0.001 for velars for speaker 2 and p<0.001 for speaker 1. Thus, even though there is a sizable overlap between the groups above, the means are statistically different.

5.4 VOWEL FORMANT TRANSITIONS. Lindblom (1963), Ladefoged (2000), and others have argued that stop consonants have an important effect on the neighboring vowel formants. Usually, stops in syllable-final position tend to present the following interferences in vowel formant transitions: $p$ lowers (F2); for $t$ there is a little movement of F2 upwards and its second formant tends to be flatter than the one for bilabial and velar; and finally, for $k$ the second and third formant tend to be close together. However, the transitions associated with place of articulation are not always so straightforward. In Akuntsú, high central and front vowels do not show clear formant movement when adjacent to velar stops. By observing below the spectrograms and waveforms of figures 7(a-b), there is movement of formant transitions (at the offset of the vowel): in fig. 7(a) the F2 is going down, as an indication of labial articulation, and in fig. 7(b) the F2 is going a little bit upwards-pointing towards 2000 Hz, as a characteristic of alveolar consonants.

FIGURES 7. (a) on the left illustrates waveform and spectrogram of the word for ‘duck’; (b) on the right, the word for ‘fire’; (c) and (d) on the bottom, the word for ‘water’

(a) [ɪpˈb̥ɛk̑] ‘duck’

(b) [ʊˈt̥a] ‘fire’
However, in the token analyzed for water, in figs. 7(c-d), there is no F2 formant transition going towards F3 (characteristic of velars) a result already expected for high central vowels analyzed in this language. It may be explained by the small cavity of the front part of the mouth during the production of the syllable (-ki), resulting in a “higher resonance of the back cavity” (Ladefoged 2003:165). This characteristic makes the onset of the vowels in figs. 7 (c-d) similar to the locus equation values found for vowels that are adjacent to an alveolar stop.

In addition, figures 7(a-d) show that some of the adjacent vowels are being produced with an irregularity in the waveform represented by intervals between the glottal pulses (which is one of the characteristics of creaky-voiced vowels (also termed laryngealized vowels)). In turn, the next section will discuss the presence of laryngealized vowels in word-medial position and their connection to glottal gesture.

5.5 LARYNGEALIZATION. In this section, spectral tilt\(^{12}\) and syllable distribution will be discussed to attempt to answer the research question 4: Are the syllable-final consonants glottalized?

In Akuntsú, the difference in amplitude between H1-H2 in creaky-voiced vowels is higher than the H1-H2 values found in normal mode of vibration (modal vowels). Below, spectral tilt of low vowels is compared, in particular [a] vowels\(^{13}\) preceded by long closure duration. Figure 8 illustrates the difference between modal and creaky vowels. For the figures below, [a] vowel of the first syllable of each token was measured; the coefficient between H1-H2 for an instance of modal voice is equivalent to -3.8 dB and for an instance of creaky voice is equivalent to -10.6 dB.

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12 Spectral tilt is one of the methods used to compare the phonation types (creaky, modal, and breathy voice) through analyzing the difference in amplitude between the first harmonic (H1) and the second harmonic (H2).

13 Low vowels were preferred because their F1 doesn't affect H1 and H2.
As observed above, the illustrations show the same word, /atap/ ‘hair’, being pronounced with two different types of phonation: one carries creaky-voice on its first vowel (V1), as seen in the rightmost picture, and the other carries almost no mark of creaky voice, as seen in the leftmost one.

Both tokens present a closure-duration value in the order of 370 and 311 ms, respectively, which lead us to assume that these consonants are produced with a long occlusion. For both tokens, [at'ap'] and [at'tap'], the analysis of formant transitions suggests that an alveolar consonant is being produced and that the difference of phonation type (shown in the spectral tilt illustrated in fig. 8 above) is what distinguishes the two tokens above. The illustration in figure 8 above is an example out of other tokens analyzed that presents the same behavior.

Up to this point of the discussion, we can assume that the glottal feature is one of the facts that motivate creaky voice in surrounding vowels in this language. However, it is not the only factor. Aragon (2008) stated that the likelihood of creaky-voiced vowels is not only restricted to the presence of an adjacent glottal stop,\(^\text{14}\) as exemplified below:

\[(a)\] [k̂i'p̄] ‘knife’
\[(b)\] [k̂o'q̄] ‘parrot sp.’
\[(c)\] [ōt̄ːt̄ā] ‘fire’
\[(d)\] [īm̄ɛn̄] ‘her husband’

To discuss this matter, Carvalho and Aragon (2009) showed that by comparing vowels in stressed syllables with those in non-stressed ones, the vowel quality in stressed syllable position tends to be much more marked by constricted glottis than in vowels in non-stressed syllable position. In addition to stress, the quality of adjacent consonants is another factor that motivates creaky voice in Akuntsù,\(^\text{15}\) as seen in the example (5d) above, in which the laryngealization may be motivated by the contiguity of a nasal consonant (Rodrigues 2003).\(^\text{16}\)

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\(^{14}\) In addition to these contexts, Carvalho and Aragon (2009) showed that “in the narratives of past traumatic or stressful events, for instance, one often finds laryngealization or creaky voicing spread all over the syllables of a word and in such case the creaky voice is optionally spread all over the syllables” (2009:4).

\(^{15}\) Syllable position, stress, and adjacent glottal stops are likely locations for the occurrence of laryngealization cross-linguistically (Gordon and Ladefoged 2001).

\(^{16}\) In this study, Rodrigues argued that there is a relation between nasalization and laryngealization attested in different Brazilian Indigenous languages, where the nasality provokes the manifestation of the glottal feature and vice-versa (Rodrigues 2003:19). This occurrence was also found among Tupari speakers (Rodrigues and Alves 1992).
Having introduced some of the main motivation of laryngealization in Akuntsú, I turn to the epenthesis of glottal feature syllable-finally. Its motivation seems to be mainly due to speech rate and style. In slow and careful speech, the speakers tend to reinforce the perception and, therefore, the clarity of the speech through a natural process of fortition \(^\text{17}\) (Donegan and Stampe 2009). The epenthesis of a glottal stop in such a context also tends to increase the perception of the syllable boundary. It was noted earlier in this study that two consonants intervocalically tend to be placed in different positions, the first one being placed in the coda position of the preceding syllable and the second one remaining in the onset position. Thus, it suggests that in a slow and careful speech, a sequence of identical consonants may be separated by glottal to limit the syllable boundary. In addition, the second voiceless consonant in a VC'CV structure may become voiced, as in [ot‘tat’] ~ [ot‘dat’] ‘fire’.

6. DISCUSSION. This study has explored the possible surface realizations of the stop consonants in Akuntsú. The primary goal was to determine the surface forms of each stop phoneme (Research Question 1). These findings will be discussed further in this section. The secondary goal of this study was to study the evidence of a voiceless-voiced sequence (Research Question 2). On the basis of the findings, there are three different stops based on voicing characteristics: (a) full voicing, i.e., voiced stops (b) partial voicing, i.e., a voiceless-voiced cluster, and (c) no voicing at all, i.e., voiceless stops. The third goal was to answer the question as to whether timing duration of stops behaves as a continuum or whether it shows two separate categories: a singleton and a geminate (Research Question 3). Based on the preliminary results, it was demonstrated that there is a tendency of medial stops to pattern in two ways: stops with a longer closure duration, and stops with a shorter duration.

After analyzing the formant transitions and phonation types of vowels, it was observed that syllable-final stops might be optionally glottalized in careful and slow speech, mostly to assign syllable boundary. And, as such, stops may present two distinct aerodynamic movements within the closure duration, as follows: (1) The first part of the closure does not involve open vocal folds (characteristic of voiceless sounds), but rather it is produced by a closure of the vocal folds simultaneously with the closure of the mouth. The articulatory organs, then, move according to the place of articulation characteristic of the target stop consonant. This movement describes what has been called a glottalized stop (Research question 4); (2) The second part of the closure involves the closure of the vocal folds where air passes, causing their vibration. Thus, these two consecutive movements result in a glottalized voiceless-voiced sequence: [t'd], [p'b] or [k'g].

Now, going back to the first research question, it is possible to assume that in Akuntsú the surface stops are as following:

<table>
<thead>
<tr>
<th>Syllable-initial when non-intervocalic</th>
<th>Syllable-initial when intervocalic</th>
<th>Syllable-finally</th>
</tr>
</thead>
<tbody>
<tr>
<td>/p/</td>
<td>[p], [b]</td>
<td>[p']</td>
</tr>
<tr>
<td>/t/</td>
<td>[ś], [d]</td>
<td>[t']</td>
</tr>
<tr>
<td>/k/</td>
<td>[k], [g]</td>
<td>[k']</td>
</tr>
</tbody>
</table>

All in all, stop closure in stressed syllables intervocally may be either: (i) voiceless with a large range of timing during the closure, (ii) glottalized or (iii) voiced; whereas at the release may be either: (i) voiceless or (ii) voiced.

Although the distribution above has not been described, to my knowledge, in other Tupían languages, examples of the glottal feature and phonetically long consonants have been found among other Tupían languages.\(^\text{18}\) Galúcio (2005) reported that Puruborá has ejective allophones for at least dental and velar

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\(^\text{17}\) According to Donegan and Stampe (2009), fortition is a kind of phonetically motivated process that optimizes individual segments, that is, allows them to be easily perceived and articulated.

\(^\text{18}\) Some of the Eastern Tupanao languages were also described as having glottal feature associated with stop consonants. As for example in Wanano:
voiceless stop in stressed syllables (cf. Storto and Demolin 2012). Alves (1991) has also described Tupari as having ejectives allophones for bilabials, alveolars, and velars, as illustrated in example (6) below. Also, based on the regular evidences found in modern Tupian languages, Rodrigues (2007) reconstructed glottalized stops for the Proto-Tupian (for more details see also Rodrigues and Cabral 2012).

Tupari (adapted from Alves 1991)
(6) a. [pɛ'p'ã] ‘butterfly’
   b. [po'tã] ‘wild pig’
   c. [po'kã] ‘turtle (sp.)’

7. CONCLUDING REMARKS. This paper has shown the possible surface forms found in the onset of medial stressed syllables in Akuntsú (shown in table 4 above). In syllable-initial position in non-stressed syllables, there are only alternations between voiceless and voiced singleton stops. The data presented so far showed that the mean value of the closure duration for bilabials is shorter than for alveolars. The velars tend to have a greater mean value of closure duration than the alveolar and bilabial stops in the onset of non-initial stressed syllables.

In addition, this paper has shown through acoustical and phonological analyses that stop consonants that are initial in stressed syllables involve variations between short and long duration. Stops also present instances of a glottalized feature as a mark of syllable boundary in this language. Besides it, the syllabification discussion has shown that identical stop consonants are placed at different syllable positions, i.e., in the coda of the first syllable and in the onset of the second one, and then, given the voicing rule application, stops in the onset of a syllable may become voiced, which may result in a voiceless-voiced sequence or in a glottalized voiceless-voiced surface forms.

In future research, further analysis should be undertaken to detail the acoustic properties, including, for example: an accurate description of vowel duration to compare the length of stop consonants (adjacent to vowels) to the length of stops in closed syllables word-finally. This investigation will provide phonetic arguments for the claim of re-syllabification (Maddieson 1985) proposed in §3. Perhaps the most interesting future research question that this paper raises is regarding the distribution of the glottal stop and its phonemic status in different syllabic positions in Akuntsú, i.e., where it should be considered an underlying consonant or, rather, a purely epenthetic consonant (not phonemic).

REFERENCES

ARAGON, CAROLINA C. 2008 Fonologia e aspectos morfológicos e sintáticos da língua Akuntsú, Universidade de Brasília MA thesis.

(1) [k'ũʔa] ‘lice’ (Stenzel 2004:60)
(2) [pũʔi] ‘blow (a flute)’ (Stenzel 2004:63)
In addition, with regard to homorganic [voiceless + voiced] production in word-medial position, Epps described in Hup an underlying /b/ in reduplicated contexts that is “usually pronounced as [pb]” (Epps 2008:79).


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