ACCOUNTING FOR SONORITY VIOLATIONS: THE CASE OF GEORGIAN CONSONANT SEQUENCING

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ABSTRACT

Georgian is one of several languages which allows consonant sequences not predicted by the Sonority Sequencing Principle (SSP). The goal of the present study is to formulate a new generalization regarding consonant sequencing in Georgian, one not necessarily relying on the SSP. This generalization refers to observed preferences for combinations of certain feature specifications in the sequences. Support for these preferences is found in the acoustic properties of the sequences, which may indicate that they best satisfy requirements for cue preservation, while also being easier to articulate. Data from two native speakers, one male and one female, are analyzed. The results support the hypothesis that homogeneity of laryngeal features within a sequence, and the front to back order of the places of articulation present some articulatory advantages which may explain why they are preferred in the language.

1. INTRODUCTION

Georgian, among other languages, allows long consonant sequences, which are treated as surface violations of the SSP. In this paper I propose that the principle underlying the ordering of consonants is better understood by taking into consideration a number of constraints on the feature specifications of adjacent consonants. An acoustic study is carried out to test some of the hypotheses based on the new generalization.

I begin with a short discussion of the SSP (section 2). I present the possible consonant sequences of Georgian, focussing on two-consonant sequences (section 3). In section 4 I propose a new generalization based on the observed patterns. In section 5 I present and discuss the results of the acoustic study. Conclusions and directions for further research are discussed in section 6.

2. THE SONORITY PRINCIPLE

The SSP accounts for similar cross-linguistic ordering tendencies among segments. It requires complex onsets to rise in sonority toward the syllable nucleus, and complex codas to fall in sonority away from the syllable nucleus. At the same time, it has been observed that the notion of sonority is hard to define, mainly because it lacks a consistent phonetic correlate.

By most definitions, sonority is related to the notion of increased perceptibility of segments, sonorous segments being more salient than less sonorous ones. Salience may be understood in acoustic terms as higher intensity, or in articulatory terms as greater amount of airflow in the production of a sound, determined by the degree of openness of the vocal tract. In the view expressed by Ohala and Kawasaki (1984), for instance, perceptibility and salience refer to the ease with which a segment is correctly identified. They suggest that the salience of an acoustic signal may be given by maximal modulations in several acoustic parameters varying simultaneously (amplitude, periodicity, spectral shape, fundamental frequency). Preferred sequences of segments are then determined by large modulations in as many different parameters as possible, rather than by just one single parameter as a correlate of sonority.

This view is not necessarily incompatible with formal accounts of the SSP. Clements (1990), for example, defines the sonority scale in terms of the major class features [syllabic], [vocoid], [approximant], [sonorant]. The sonority of a segment increases with the number of plus specifications accumulated for these features. The values of these features are associated with the degree of openness of the vocal tract, with the plus values corresponding to a smaller constriction, and therefore to higher perceptibility than the minus values.

In an attempt to reconcile the two views, I propose that consonant sequencing in Georgian is best explained not directly by the SSP, but by certain feature specification constraints which reflect segment perceptibility requirements. In the next section I present the possible consonant sequences of Georgian by manner of articulation.

3. GEORGIAN CONSONANT SEQUENCES

The data presented here are collected during my work with 5 native speakers, and from grammars and dictionaries.

A three-way voicing contrast (voiced, voiceless aspirated, ejective) is found in the Georgian stop and affricate series, and a two-way contrast (voiced, voiceless) is found in fricatives:

(1) stops: b, d, g, pʰ, tʰ, kʰ, p', t', k', q'
affricates: dz, ḏz, tsʰ, tʃʰ, ts', tʃ'
fricatives: z, ʒ, s, ʃ, ɣ, ʁ, h
sonorants: m, n, r, l, v/w

Each consonant constitutes a possible simple onset. All of them occur in consonant sequences, except for /h/. In monomorphemic forms a maximum of 5 consonants can occur in word-initial position, and a maximum of 4 word-internally. Across a morpheme boundary, with the addition of inflectional prefixes, 7 consonants can occur word-initially, and 5 word-internally.

In this paper I look at sequences of two consonants (C1C2). The attested combinations are: stop-stop, stop-fricative, fricative-stop, fricative-fricative, stop-sonorant, sonorant-stop, sonorant-sonorant, fricative-sonorant, sonorant-fricative. Of these, I discuss here stop-stop, sonorant-stop, sonorant-sonorant, and sonorant-fricative sequences, leaving aside the rest for further study.

I list below the patterns which emerge from a careful consideration of the rest of the data. First, 55% of stop-stop sequences consist of stops which share the same laryngeal feature, and at the same time the articulation of C1 is further front...
than that of C2 (e.g. dg, tsʰkʰ, p’k’). Second, if C1 and C2 do not agree in laryngeal features, then the force of release of C1 is stronger than the force of release of C2. In all such cases C2 is voiced, while C1 is either aspirated or ejective (e.g. k’h, t’h, t’h). This preference suggests a ranking of the force of the release, where an ejective or an aspirated release is perceptually stronger than a voiced release. Ejective stops are known to have high amplitude bursts, due to the compression of air in the vocal tract between the glottal and the oral constrictions. This is especially true of velar and uvular stops, where supraglottal air pressure is very high.

There seems to be a preference in the language for stop-stop sequences which follow one of the two generalizations above. Even in the few word-initial three-stop sequences attested in Georgian, the same generalizations hold. In two such sequences all the stops share the same laryngeal features and have front to back order of place of articulation (p’tsʰkʰ, p’tsʰk’). In one other sequence the first two stops are ejective, and the third one voiced (t’k’h).

Such sequences are not necessarily ruled out by the SSP in a syllable onset. They constitute sonority plateaus, a less serious violation than a sonority reversal. Sonority reversal does occur in Georgian, in sonorant-stop and sonorant-fricative sequences. A total of 35 sonorant-stop sequences are attested word-initially in Georgian, most of them beginning with [m] (e.g. mt’, mkʰ, ndz, rb, lb, lp’). The large number of [m]-initial sequences is due to the fact that in some or them [m] is the remnant of a historical prefix. Judging by native speakers’ pronunciations and intuitions regarding the number of syllables in a word, none of these sonorants are syllabic. A total of 11 sonorant-fricative sequences are found (e.g. lz, m/ G3A, r), and 10 sonorant-sonorant sequences, another sonority plateau (e.g. vn, ml, lm, rv).

Any of the pairs above can combine in longer sequences, in any order. The only combination that I could not find is one containing more than two adjacent sonorants. This observation is based not only on the inventory of Georgian consonant sequences, but seems to be an active constraint in the phonology of the language. Syncope in noun and verb morphology is sequences, but seems to be an active constraint in the phonology based not only on the inventory of Georgian consonant containing more than two adjacent sonorants. This observation is any order. The only combination that I could not find is one another sonority plateau (e.g. vn, ml, lm, rv).

(3) Nominative
mts’eral-i
but: mt’vral-i
*mt’vrl-is

Genitive
mts’eral-is
mt’vral-is
‘drunk person’

Other than this particular case, syncope is not blocked when it results in sequences unacceptable by the SSP.

In the next section I propose an account for the allowed sequences.

4. GENERALIZATION

I formulate below the generalizations based on the observed patterns of consonant combinations in Georgian:

(3) a. No more than two adjacent sonorant consonants are allowed in a sequence.
b. Two adjacent obstruents must share laryngeal features.
c. In a sequence of two stops, the place of articulation of C1 must be more anterior than the place of articulation of C2.
d. In a sequence of two stops which does not follow (b) or (c), the release of C1 must be stronger than the release of C2.

We have seen that (3a) is the only pattern which actually functions as an active constraint in Georgian, as seen in the syncope process. The other three are not illustrated in phonological processes. The question I ask at this point is whether there are any phonetic considerations that would support the observed preference for sequences following patterns (3b-d). Does this particular sequencing of consonants present certain advantages such as achieving maximum perceptibility or ease of articulation?

Homogeneity of laryngeal features may present an advantage in preventing changes in the configuration of the glottis over a short period of time, within a stop sequence. The front to back order of place of articulation may also reduce articulatory effort, since the first stop is released into an opening, rather than a more anterior closure.

Some perceptual advantages of such sequences were found by Byrd (1992), in a comparison of labial-soft alveolar and alveolar-labial stop sequences across a word boundary (‘bab#dan’ vs. ‘bad#ban’). Synthetic speech was used, and the degree of overlap between the two stops was varied to observe its effect on the identification of C1. C1 in bab#d could still be identified at a larger degree of overlap than C1 in d#b, suggesting that a tongue tip gesture is more easily hidden by a following labial gesture than vice-versa. Surprenant and Goldstein (1998) obtained similar results with natural speech p#t and t#p in English. The tokens used in the perception experiment exhibited the same considerable amount of temporal overlap. C1 in p#t was identified significantly more often than C1 in t#p. Work by Byrd (1994), Zsiga (1994) showed that coronal-dorsal sequences also allow more overlap than the opposite order.

A larger amount of overlap therefore constitutes an articulatory advantage, but only to the extent that it does not compromise perceptual cues for C1. Position in the word is a relevant factor here. C1 is particularly vulnerable in word-initial position, where, in the absence of transitions from or into an adjacent vowel, the only available cue for it is its release burst. Wright (1996) shows acoustic evidence from Tsou consonant sequences, suggesting that the timing between articulations is governed by such cue preservation requirements. He found that in word-initial stop-stop sequences a smaller degree of overlap is allowed, to ensure that the one available cue for C1 is preserved.

The acoustic study presented in the following section is designed to determine whether the preferred C1C2 sequences in Georgian present any articulatory or perceptual advantages. Are there any particular strategies, for instance, that native speakers resort to in order to reduce articulatory effort in such sequences, while at the same time preserving (a) place cues, (b) laryngeal contrasts and (c) manner cues?

5. ACOUSTIC STUDY

Three questions are asked in the acoustic study:

(i) do stop-stop sequences (including affricate-stop and stop-affricate) show any amount of temporal overlap?

If position in the word is a relevant factor, the prediction is that more overlap will be found in word-internal sequences, where more cues are available for C1, than in word-initial sequences, where only the release burst is available.

If the order of place or articulation is relevant, the prediction is that more overlap will be found in front-to-back sequences (e.g. dg) than in back-to-front ones (e.g. gd). The absence of a
release burst for C1 is taken to indicate the presence of a large amount of overlap.

(ii) Stop-stop sequences with mixed voicing (e.g. k’b) are rare cross-linguistically. Is voicing independently controlled in each member of the sequence, or does voicing assimilation occur?

In this case articulatory and perceptual requirements are harder to reconcile than in the previous case regarding place of articulation. Voicing assimilation would reduce articulatory effort only at the expense of laryngeal contrasts. Therefore, if articulatory requirements are more important, the prediction is that voicing assimilation occurs in mixed stop-stop clusters. If perceptual requirements are more important, the prediction is that voicing is independently controlled in each member of the sequence.

(iii) Manner cues in word-initial sonorant-stop/fricative sequences are also hard to preserve. Can word-initial [m], for instance, be identified before a stop or fricative?

If preserving the cues is more important, the prediction is that they can be identified in the signal. If reducing articulatory effort is more important, then we expect a number of strategies to be found, such as deletion of the sonorant, or insertion of an epenthetic vowel, as well as, perhaps, voicing assimilation.

For the purpose of this study, two native speakers of Georgian were recorded, one male and one female. The tokens analyzed here consist of word-initial and word-internal C1C2 sequences, matched as well as possible for vocalic environment. Most of the word-internal sequences were obtained by adding a vowel-final prefix to a form containing the word-initial sequence. Morphological boundary effects were also controlled for. The results are summarized in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>word-initial</th>
<th>word-internal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1 release</td>
<td>C2 release</td>
</tr>
<tr>
<td>male speaker</td>
<td>100%</td>
<td>96%</td>
</tr>
<tr>
<td>female speaker</td>
<td>100%</td>
<td>92%</td>
</tr>
</tbody>
</table>

Table 1. Occurrence of C1 and C2 release bursts in word-initial and word-internal sequences

The results indicate that C1 is systematically released (100%) in both word-initial and word-internal position, by both speakers. The amount of overlap is therefore controlled, so that the C1 cues are not lost.

Voicing in these sequences was also observed. It was found that the word-initial voiced sequences (bg, dg, gd, dzg) often have no voicing, especially in the tokens of the female speaker. Vocal fold vibration thus seems not to be maintained throughout the duration of the entire sequence. For both speakers, the C1 release in gd is followed by a short period of voicing, which looks like a vocalic portion. Since this sequence is the only one with a back-to-front order of place of articulation, this vocalic portion could be interpreted as an epenthesis. The vocalic portion is found in the word-initial gd sequences, as well.

In the sequences of aspirated stops and affricates (t\(^k\)k, k\(^t\)t, t\(^s\)s, k\(^t\)s, k\(^p\)k, p\(^t\)t), both C1 and C2 have an aspirated burst, in both positions. It may be that the glottis is held open throughout the entire sequence, or that it has several opening movements during the sequence. Such information would not be available from acoustic data. Although the first alternative may seem to involve less effort, several opening movements of the glottis in voiceless consonant clusters were reported by Löfqvist & Yoshioka 1980.

In sequences of ejective stops and affricates (p\(^k\)k, t\(^k\)k, t\(^j\)k) each consonant has a very strong burst, followed by some aspiration and glottalization. This aspiration is not due to air flow from the glottis, since in ejective the glottis is tightly closed during the oral constriction and at its release. It can only result from the release of air pressure built up between the glottal and the oral constrictions. This pressure is higher in [t\(^j\)] than in [p\(^j\)], and highest in [k\(^j\)], where the supraglottal cavity is the smallest. Correspondingly, a larger amount of aspiration is found at [k\(^j\)] release than at other places or articulation.

Glottalization for both C1 and C2 is seen fairly systematically in word-internal position, but word-initially only C2 release shows glottalization, which often continues into the following vocal. This may suggest that in word-initial position the glottis is maintained closed throughout the sequence, and is not opened up before the C2 oral release. In this way, information as to the laryngeal properties of C1 is lost. It may be that this information is less important to preserve word-initially than word-externally. If in a word-initial consonant sequence C2 is ejective, then C1 can only be ejective, as well. It was mentioned earlier that Georgian does not contain word-initial sequences in which the force of release of C1 is stronger than that of C2. Thus, in word-initial position, the only cue that is maintained is the place cue, found in the oral release burst. Word-externally, however, the cue to laryngeal mechanism must be maintained, the one to place being more easily recoverable.

5.2. Overlap by order of place or articulation

Another prediction made is that if any amount of overlap is allowed, more overlap is possible in sequences with a front-to-back order of articulation than in the opposite order, without
losing any place cues. In order to test this prediction, I compared the duration between C1 and C2 bursts in word-initial and word-internal front-to-back and back-to-front sequences. The two opposite orders are not attested for all the sequences, so only a few minimal pairs could be found to be used for these measurements. The list is given below:

(3) Wordlist

<table>
<thead>
<tr>
<th>Word-initial sequences</th>
<th>mean</th>
<th>std. dev.</th>
<th>t(5)</th>
<th>p &lt; .05</th>
</tr>
</thead>
<tbody>
<tr>
<td>word-initial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dg</td>
<td>100</td>
<td>22.4</td>
<td>4.76</td>
<td>.001</td>
</tr>
<tr>
<td>gd</td>
<td>136</td>
<td>18.7</td>
<td>3.65</td>
<td>.001</td>
</tr>
<tr>
<td>tʰkʰ</td>
<td>112</td>
<td>10.9</td>
<td>6.38</td>
<td>.001</td>
</tr>
<tr>
<td>kʰ</td>
<td>155</td>
<td>5.9</td>
<td>2.7</td>
<td>.014</td>
</tr>
<tr>
<td>tʰkʰ</td>
<td>56.8</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kʰtʰ</td>
<td>72.8</td>
<td>15.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>word-internal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dg</td>
<td>78</td>
<td>6.8</td>
<td>5.3</td>
<td>.001</td>
</tr>
<tr>
<td>gd</td>
<td>114</td>
<td>16.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tʰkʰ</td>
<td>84</td>
<td>16.8</td>
<td>3.65</td>
<td>.001</td>
</tr>
<tr>
<td>kʰtʰ</td>
<td>113</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mean inter-burst interval for front-to-back and back-to-front order of place of articulation

For all sequences, the difference in inter-burst interval is found to be statistically significant, suggesting that a larger degree of overlap occurs in front-to-back (shorter interval) than in back-to-front sequences (longer interval). This result supports the hypothesis that front-to-back sequences allow a larger amount of overlap without risking the loss of C1 cues.

5.3. Voicing control in mixed sequences

Voicing was observed in the stop sequences kʰ, tʰb, tʰ in word-initial and word-internal position. Voicing appears to be tightly controlled in the two ejective-voiced sequences. C1 burst is followed by a period of silence leading up to the glottal release, after which voicing for [b] begins. In some of the tokens of the male speaker, voicing for [b] starts right at C1 release.

In the aspirated-voiced sequence, however, C2 is entirely voiceless and aspirated for the male speaker, in both positions. For the female speaker C2 is voiceless only word-initially, but fully voiced word-internally. Voicing control is more difficult in this sequence, especially word-initially, where the glottis, which is wide open during C1, cannot close fast enough to start vocal fold vibration for C2. The movements of the glottis are less extreme in ejective-voiced sequences, where the glottis is entirely closed for C1, and needs to open just enough to start voicing for C2.

5.4 Cues for [m] in m-obstruent sequences

The sequences of consonants observed here contain a word-initial bilabial nasal followed by an ejective (mt’, mts’, mk’), a voiced stop (mb, mg, md, mdz), a voiced fricative (mz, m₂, m₃), an aspirated stop (mṭ’, mṭs’, mṅ, mṡ), and a voiceless fricative (ms, m₀, mṛ). For the most part voicing is independently controlled in the nasal and the following obstruent. With respect to cues other than voicing, some differences are found between the two speakers. In 78% of the tokens of the male speaker, [m] has a burst. The strategy which is most often employed by this speaker is inserting a vocalic portion (mVC2). In only 30% of the tokens of the female speaker [m] has a burst. No vowel insertion is found in her tokens. In fact, in 11 out of 60 tokens [m] is absent.

6. CONCLUSIONS

While these results are limited by the type of information than can be extracted from the acoustic signal, they nevertheless suggest that C1C2 sequences in Georgian are sensitive to simultaneous requirements to reduce articulatory effort and maximize discriminability. Such requirements may not be entirely incompatible with the requirements encoded in formal accounts of sonority. A more detailed articulatory study is needed, however, to reveal more detail of the gestural timing and laryngeal control.

REFERENCES