WHAT MAKES A GEMINATE? AN ACOUSTIC STUDY OF CONSONANTS IN GARO

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ABSTRACT

We investigate the phonetic properties of consonants in Garo, a Sino-Tibetan language, to examine the gemination process that applies to intervocalic consonants in coda position within a word. We compared nasals, liquids, and stops in onset positions, coda positions within a word and word finally, and sequences of identical consonants (concatenated geminates) as produced by four native speakers. We found that only consonants that are allowed in both coda and onset positions geminate. Geminated coda consonants are as long as sequences (concatenated geminates) and 50% (or more) longer than onset consonants (singletons). Geminated nasals and nasal sequences are identical, but geminated stops differ from stop sequences, as the former do not aspirate (short VOT).

Keywords: gemination, length, consonants, syllabification, Garo, Sino-Tibetan

1. INTRODUCTION AND PRESENT STUDY

Garo is a Sino-Tibetan language spoken in Northeast India by around 1.5 million speakers [1]. Most of the work on Garo has been impressionistic descriptions, so we know very little about its phonological and phonetic system. A recent phonological study [2] proposed the existence of surface geminate consonants and explained them as a result of an interaction between morphology and phonology. A'gitok [2] also points out that Garo geminates do not fit with the current geminate consonant typology since geminates are either underlying [3] or due to assimilation [4], but Garo geminates are a consequence of syllabification.

The claims in A'gitok [2], however, are based on the author's language knowledge. We do not know the phonetic properties of these surface geminates and what distinguishes them from singleton consonants. We also do not know if all the consonants geminate, or if there are additional considerations required for the phonological analysis of gemination.

Geminate consonants are typically longer in duration than singleton consonants, but the strength of the difference and the existence of secondary phonetic features depends on the consonant and the language [5–7]. So, although we predict that geminate consonants in Garo are longer than singletons, we do not know if this is true for all and what the ratio of the difference is.

2. GARO LANGUAGE AND GEMINATION

Garo is a monosyllabic agglutinating language, so words are long and morphologically complex. Garo has 17 phonemic consonants: /p, b, t, d, k, g, ʔ, m, n, ŋ, ɽ, s, w, l, t͡s, d͡z/ and 6 phonemic vowels: /i, e, ə, a, o, u/ [2, 6–8]. There are restrictions on the distribution of these sounds however: /b, d, g, ɽ, s, w, t͡s, d͡z/ are limited to onset positions, while /ʔ, ŋ, l/ are limited to the coda positions.

Garo syllables may have up to two onset consonants (e.g., [skʰo] "head") and up to two coda consonants where the second consonant can only be [ʔ] (e.g., [amʔ.na "to search"), but we also find a plain V shape (e.g., [o.a] "open-PRS").

In Garo words, if in a morpheme sequence the first morpheme ends in a closed syllable and the following morpheme starts with an onsetless syllable, the coda consonant of the first morpheme gets geminated [2], as in examples (1, 3). Burling [9] also reports that words like (1) sound identical to (2), but he does not identify a gemination process or discuss the existence of geminate consonants in the language.

(1) /t͡sa**n**-a/ → [t͡sʰa**nn**a] "count-PRS" *[t͡sʰa**n**a]
(2) /t͡sa**n**-**n**a/ → [t͡sʰa**nn**a] "count-INF"
(3) /no**k**-o/ → [no**kk**o] "house-LOC" *[no**kʰ**o]
(4) /nok-ko/ → [no**kkʰ**o] "house-ACC"
(5) /nok-na/ → [no**k**na] "house-DAT"

A'gitok [2] shows that Garo gemination is due to the language's syllabification requirements. He proposes that the right edge of morphemes need to align with the syllables. This alignment requirement prevents the coda consonant from resyllabifying as onset of the following syllable (*[t͡sʰa.na] in (1)), but instead, it geminates, preserving the original coda of the morpheme on the left and creating an onset for the morpheme on the right ([t͡sʰan.na] in (1)).

Depending on the consonant being geminated, we may find homophones (1-2) or minimal pairs (3-4). Minimal pairs arise in the case of voiceless stops because they are aspirated in onsets (4), but unaspirated when they geminate (3) or in coda (5). Despite the difference in terms of aspiration, closure duration (CD) might be an important phonetic property, since in most languages, CD and not voice onset time (VOT) is the primary property of geminate stops [5–7].

All the consonants that occur in the coda position geminate, but it is unclear if /ʔ/ geminates but A'gitok [2] suggests that it does not. This description, however, might be because the difference between the geminate and singleton /ʔ/ is not consonant duration (e.g., Maltese [5]). Due to space limitations, we will not discuss /ʔ/ in this paper.

Finally, it is not known if consonants limited to codas, i.e., /ŋ/ and /l/ geminate and what the prosodic domain for gemination is. A'gitok [2] claims that gemination does not occur between words in a phrase, so the likely domain is the phonological word.

The present study is a phonetic investigation of Garo geminate consonants to test if duration differentiates geminates from singletons and consonant sequences (concatenated geminates). We hypothesize that geminate consonants are longer than their singleton counterparts, and equally long as sequences. For stops, we hypothesize that the length of CD is the primary property, but VOT is also relevant due to the aspiration pattern discussed above.

We also test consonants at the end of a word to find if gemination applies across words. We hypothesize that gemination does not apply in this context, and consonants at the end of a word are equally long as singleton consonants within a word.

4. METHOD

Four native speakers of Garo (2 females; 18-25 years) were recruited from Tura in West Garo Hills. All were college educated and reported no speech, hearing, language, or cognitive problems.

The data was recorded in the music room of Hawakhana Baptist Church, Tura. After consent, the participants sat in front of a monitor where the stimuli were projected. Initially, they saw instruction slides and 9 practice items and then continued with the test items. They also had a short break after 30 minutes. The speech data was recorded in Praat [11] at 44.1 KHz using a head mounted Logitech H390 microphone connected to the computer via USB port.

4.2. Stimuli

Consonants in coda (geminate), onset (singleton), and sequence of two identical consonants (concatenated geminates) were recorded in the second syllable of real trisyllabic words and were preceded and followed by a vowel. Since /ŋ/ is not found in onset positions, the onset and sequence conditions were formed with /n/ in onset. Also, since /l/ is not found in the onset and /ɽ/ is not found in the coda position, we combine them into a single comparison. Consonants were also recorded at the end of a disyllabic word (noun) before the adjective [apsanko] "same", which starts with a vowel. We were not able to find any words ending with /l/ to fit with the phrase, so this condition was not tested for the liquids. See Table 1 for examples.

Condition		Example*
Coda VC.V	Nasal	/sa**n**-a-de/→[sa**n**.**n**a.de] "the act of nursing"
	Liquid	/sa**l**-a-ko/→[sa**l**.**l**a.kʰo] "drawings"
	Stop	/go**p**-a-na/→[go**p**.**p**a.na] "because of buring smth"
Onset V.CV	Nasal	/sa-**n**a-de/→[sa.**n**a.de] "to serve"
	Liquid	/sa-**ɽ**aŋ-ko/→[sa.**ɽ**aŋ.kʰo] "who (plural)"
	Stop	/go-**p**a-na/→[go.**p**a.na] "to shoot in imitation"
Sequence VC.CV	Nasal	/sa**n**-**n**a-de/→[sa**n**.**n**a.de] "to nurse"
	Liquid	/sa**l**-**ɽ**aŋ-ko/→[sa**l**.**ɽ**aŋ.kʰo] "days"
	Stop	/go**p**-**p**a-na/→[go**p**.**pʰ**a.na] "to bury smth in imitation"
Word end VC#V	Nasal	/meʔ-go**n** # apsanko/ → [meʔ.go**n**#] "the same stirrer"
	Liquid	N/A
	Stop	/pi-to**p** # apsanko/ → [pʰi.tʰo**p**#] "the same cheek"

* . = syllable; - = morpheme; # = word boundaries

Table 1: Examples of stimuli used in elicitation.

The target words were elicited in the carrier sentence (6) presented in a dialogue format after the question "*Is Derang going to think about the word called 'ka'donga' tomorrow?*" Participants had to read both the question and answer of the dialogue.

(6) Carrier sentence:

[m̥hm̥	deraŋ-ŋara	X	məŋ-gəppa	kʰattʰa-ni
no	Derang-TOP	X	call-ADJ	word-GEN

gəmən-sa	kʰnal-lo	t͡sʰant͡sʰi-gen-na-ba]
about-FOC	tomorrow-LOC	think-FUT-EVI-FACT

"No, Derang is going to think about the word called X tomorrow."

Using Praat [11], we measured the duration of nasals and liquids, and CD and VOT of stops. We run separate mixed-effects analyses in SPSS [12] for each measurement. In each analysis, the dependent variable was the Duration of the consonant or CD or VOT, the independent variables were Condition (coda, onset, sequence, and word), and Place of Articulation (labial, alveolar, and velar) when relevant, and the random effect was Participant.

5. RESULTS

5.1. Nasal consonants /m/, /n/, /ŋ/

There is a significant main effect of Condition, F(3, 9.08) = 11.03, p = .002, and of Place of Articulation, F(2, 6.66) = 9.4, p = .011, on the duration of nasal consonants. There is also a significant interaction between the two factors, F(5, 110.02) = 3.59, p = .005. Figure 1 summarizes the results.

Bonferroni posthoc tests reveal that in Coda, nasals are 29 ms longer than in Onset (p < .001) and 35 ms longer than in Word (p < .001), but 15 ms shorter than in Sequence (p = .023). Nasals in Onset do not differ statistically from nasals in Word (p = 1) and nasals in Sequence are the longest (p < .001).

We ran separate mixed-effects analyses for each place of articulation, to explore the significant interaction. We found /m/ and /n/ in Coda do not differ statistically from in Sequence (p = 1), but /ŋ/ is 34 ms shorter in Coda than in Sequence (p = .009). Also, /ŋ/ in Coda does not differ statistically from in Word (p = .153).

With respect to differences between the three places of articulation, we found that /m/ is 19 ms longer than /n/ (p<.001), while /ŋ/ does not differ statistically from /m/ (p=.297) or /n/ (p=.067).

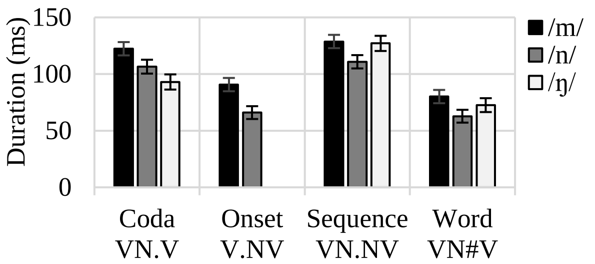

Figure 1: Mean duration of nasal consonants by place of articulation and condition. Error bars = Standard Error

Overall, we found that nasals are the longest in Coda and Sequence and the shortest in Onset and Word. This is compatible with nasals being geminated in coda position. In Coda, however, nasals are shorter than in Sequence, but their difference is only 15 ms and statistically significant only for /ŋ/. Given the length difference of /ŋ/ in Coda and Sequence and the lack of difference in Word, /ŋ/ does not participate in the gemination pattern.

5.2. Liquid consonants /l/, /ɽ/

There is a significant main effect of Condition, F(2, 5.69) = 26.95, p = .001 on the duration of liquid consonants. Bonferroni posthoc tests reveal that Coda /l/ (M = 102 ms, SE = 5.38) is 52 ms longer than Onset /ɽ/ (M = 50 ms, SE = 5.38, p < .001), but Coda /l/ does not differ statistically from the Sequence of liquids (M = 88 ms, SE = 5.6, p = .255). Also, the Sequence of liquids is 38 ms longer than Onset /ɽ/ (p < .001).

Overall, we found that liquids in Coda are equally long as in Sequence, and liquids are the shortest in Onset. It is hard to draw strong conclusions since there were no liquids in the Word condition and only /l/ is in coda and only /ɽ/ is in onset positions.

5.3. Stop consonants /p/, /t/, /k/

5.3.1. Voice Onset Time (VOT)

There is a significant main effect of Condition, F(3, 9.38) = 36.59, p < .001, and Place of Articulation, F(2, 124.61) = 7.94, p < .001, on VOT. The interaction of the two factors is not statistically significant, F(6, 124.46) = 0.99, p = .438. See Figure 2.

Bonferroni posthoc tests reveal that in Coda, VOT is 37 ms shorter than in Onset (p < .001) and 35 ms shorter than in Sequence (p < .001), but it does not differ statistically from the VOT in Word (p = 1). Also, in Onset, VOT is 40 ms longer than in Word (p < .001), but it does not differ statistically from the VOT in Sequence (p = 1). Finally, in Word, VOT is 38 ms shorter than in Sequence (p < .001).

With respect to VOT differences between the three places of articulation, we found that the VOT of /p/ is 11 ms shorter than /k/ (p < .001), but /t/ does not differ statistically from /p/ (p = .136) or /k/ (p = .247).

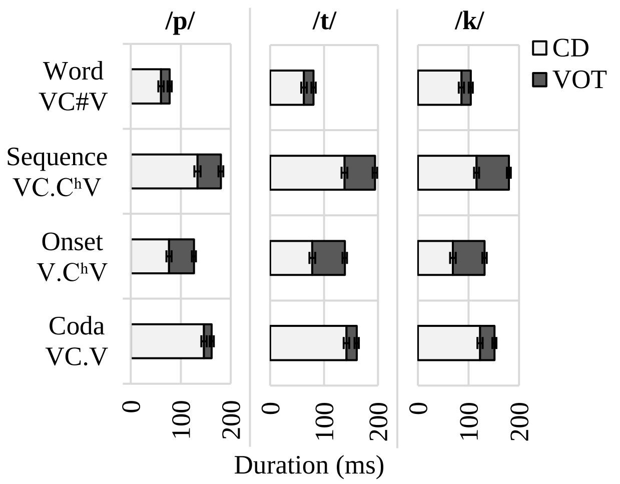

Figure 2: Mean CD and VOT in stops by place of articulation and condition. Error bars = Standard Error

Overall, we found that VOT in Coda is similar to VOT in Word and both are the shortest in comparison to Onset and Sequence. This is consistent with the stops being unaspirated in coda. In Onset and in Sequence, stops have equally long VOT, consistent with being aspirated in onset.

5.3.2. Closure Duration (CD)

There is a significant main effect of Condition, $F(3, 9.63) = 100.78$, $p < .001$ on CD. Place of Articulation was not statistically significant, $F(2, 125.38) = 2.42$, $p = .093$. The interaction between the two factors is statistically significant, $F(6, 125.07) = 6.78$, $p < .001$.

Bonferroni posthoc tests reveal that CD in Coda is 62 ms longer than in Onset ($p < .001$) and 67 ms longer than in Word ($p < .001$), but it does not differ statistically from CD in Sequence ($p = .437$). In Onset, CD is 54 ms shorter than in Sequence ($p < .001$), but it does not differ statistically from CD in Word ($p = 1$). Finally, in Sequence, CD is 59 ms longer than in Word ($p < .001$). When we ran separate mixed-effects analyses for each place of articulation to explore the significant interaction, we found the same results as described here for each stop.

Overall, we found that CD is longest in Coda and Sequence and shortest in Onset and Word. This is compatible with stops being geminated in coda.

5.3.3. CD and VOT

To look at CD and VOT results together, in addition to ms, we calculated the % of the stops' duration occupied by CD and VOT. In Sequence, where there are two stops, the first unaspirated and the second aspirated, there is a combination of long CD ($M = 129$ ms; 70% of the stop) and long VOT ($M = 56$ ms; 30% of the stop). In Onset, where stops are aspirated, CD is short ($M = 75$ ms; 57% of the stop), but similar to Sequence, VOT is long ($M = 57$ ms; 43% of the stop). Almost half of the stop's duration is its VOT. In Coda, where stops are unaspirated and geminated, similar to Sequence, CD is long ($M = 137$ ms; 87% of the stop), but VOT is short ($M = 21$ ms; 13% of the stop). Finally, in Word, stops are in coda position but not in an environment for gemination to occur. Similar to Onset, CD is short ($M = 70$ ms; 80% of the stop) and a similar to Coda, VOT is also short ($M = 18$ ms; 20% of the stop).

6. DISCUSSION AND CONCLUSION

The purpose of this paper was to investigate whether duration differentiates geminate consonants from singletons and consonant sequences in Garo and whether gemination applies in phonological domains larger than the phonological word. We tested three consonant classes (stops, nasals, and liquids) in different positions: word coda, word onset, word finally, and in sequences of identical consonants word medially. Stops' VOT and closure duration (CD) were tested separately.

The results confirm A'gitok's [2] description of Garo that intervocalic consonants in coda position, within a word, geminate. We found that these coda consonants are 46%-105% longer than their onset counterparts and very similar in length to consonant sequences. The only exception was the velar /ŋ/, which is no longer in coda than in other positions, indicating that it does not geminate like the other consonants. If [2] is correct and gemination occurs to create an onset for the following onsetless syllable, then the lack of gemination in /ŋ/ can be explained from the fact that /ŋ/ is not allowed in onset positions, but it is only found in coda, for both native and loan words. /l/, on the other hand, seems to geminate despite being found in codas only. In contrast to /ŋ/, we do find /l/ in onset, but only in loanwords, e.g., [lau] "gourd". So, perhaps the phonotactics for /l/ have changed due to the loanwords. We also have to keep in mind that the results for the liquids are not very strong since we are comparing the duration of /l/ in coda to the duration of /ɽ/ in onset. It is possible that there are inherent duration differences to the sounds that make /l/ appear geminate, when it is not.

In stops, we tested both CD and VOT. As expected [5–7], we found that CD is the primary cue of length in stops: coda CD is 83% longer than onset CD and equally long to stop sequences. VOT is also a cue of gemination since the geminated stops do not aspirate and have roughly 60% shorter VOT than aspirated stops (onset).

Our results also indicate that gemination only applies within a phonological word. The consonants we tested at the end of a word before a word that starts with a vowel are 33%-45% shorter than coda consonants within the word and very similar in length to the onset consonants. Word final stops do not geminate or aspirate, which confirms the descriptions [1,9] that stops in Garo aspirate in onset position.

According to A'gitok [2], gemination arises because it is the only way to satisfy the requirement for onsets without violating the requirement for alignment between the right edges of morphemes and syllables. The results of this study indicate however, that additional considerations are required to explain gemination in Garo. A complete analysis needs to address exceptions to gemination, such as /ŋ/, the interaction with the aspiration of stops, and limit the domain to the phonological word.

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