DURATIONAL CORRELATES OF SINGLETON-GEMINATE CONSTRAST IN HUNGARIAN VOICELESS STOPS

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ABSTRACT

This paper presents the results of a durational analysis of singleton and geminate stop consonants from Hungarian spontaneous speech. The durational correlates of three types of geminates (i.e., underlying, derived true and fake geminates) are also examined and compared to one another. Results show that single voiceless stops are realized with significantly shorter total and closure duration than geminates. Research findings on rates of closure phase suggest that phonological lengthening targets certain portion of the internal structure of stops. VOT seemed to be invariant and therefore irrelevant parameter in the distinction of short and long consonants. We can evince differences among geminate types: fake geminates are produced with tendentiously longer durations than underlying and true derived geminates, which result suggests closer similarity between the two latter types.

Keywords: geminates, duration, VOT, Hungarian, stop consonants

1. INTRODUCTION

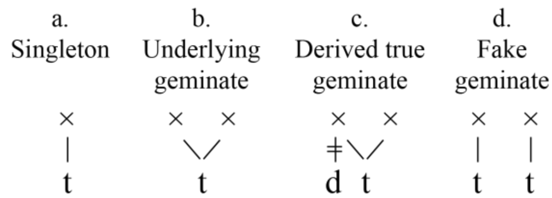
Many languages express semantic differences by using contrastive phonemic vowel and/or consonant length [18]. Generally, phoneme length contrast plays a more important role in the vowel system than in the consonant system. In some languages, consonant length is not contrastive, geminates only arise from morpheme concatenation; hence geminates may occur across morpheme boundaries, but not morpheme-internally (e.g., English *top pick* vs. *topic*, French *Il l'aime* vs. *Il aime*). Whereas, in other languages, morpheme-internal single and geminate consonants may form minimal pairs (e.g., Japanese *oto* 'sound' : *otto* 'husband') [10]. In Hungarian, length is a phonologically relevant feature both in vowel and consonant systems; for example: *kor* 'age' : *kór* 'illness'; *ép* 'healthy' : *épp* 'right now'.

Phonological quantity has a primary distinctive function in the vowel system in all phonetic positions [8, 19], though the distribution of long consonants (geminates) is restricted [30]. Geminates cannot stand word initially or next to another consonant in Hungarian. If the underlying geminate is flanked by another consonant on either side, it must surface as short (this process is called degemination) [21, 26].

Previous findings confirmed that duration is the main acoustic cue for the distinction between singleton and geminate consonants [11, 13, 29]. However, other factors, such as intensity, may contribute to this opposition [12, 17, 25]. Some acoustic phonetic investigations explored that phonemic length is not clearly manifested in the phonetic duration of Hungarian singleton and geminate consonants. In other words, duration of short consonants shows overlaps with that of long consonants [1, 9, 24]. A phonetic examination of long consonants categorized by their abstract phonological representations can provide a more accurate picture of the process of gemination.

Geminates can be distinguished into three types: underlying, derived true and fake geminates (see [21, 23, 29, 31]). Underlying or lexical geminates, whose autosegmental representation is seen in (1b), are part of the phonemic inventory of a language (e.g, Hungarian *sok* [ʃok] 'many' : *sokk* [ʃokː] 'shock'). Derived true geminates, represented in (1c), result from some assimilation processes (e.g., voicing assimilation, v-assimilation), for instance: *kalap* + *-val* (INSTR) > *kalappal* 'with hat'. Fake geminates, as shown in (1d), are merged sequences of identical consonants arising through morpheme concatenation, for instance: *zseb* + *-ben* (INE) > *zsebben* 'in pocket'.

(1)



Miller's [20] phonetic evidence showed no distinction between true and fake geminates for Levantine Arabic. In contrast, Oh–Redford [23] found differences in the phonetic correlates of English word-internal heteromorphemic geminates (e.g., *unnamed*) and those that arise across a word boundary (e.g., *fun name*). Besides the durational differences of the two types of fake geminates, speakers marked the boundaries between free morphemes by means of pitch changes and pauses.

Some studies analysed duration of segments with complex internal structure, such as stops or affricates, in terms of gemination. Ridouane [29] gives a review of the literature on the main temporal acoustic attributes affected by gemination in stops of 24 languages (Bengali, Italian, Japanese, Swedish etc.). It is reported that closure duration is the most important correlate of the geminate/singleton opposition for each language. Pycha's research [27, 28] showed that phonetic and phonological lengthening target different portions of the internal structure of affricates. The ratio of closure duration to total duration changed in significantly different ways for phrase-final lengthening vs. gemination.

In this paper, durational differences between Hungarian singleton (1a) and geminate consonants are discussed. In addition, the object of this study is to examine the acoustic correlates of various gemination types (1b–d). This study focuses on the duration of the Hungarian voiceless stop consonant /p, t, k/ as well as the duration and ratio of their internal structure components (stop closure, VOT). The main question is how temporal cues play a role in the distinction between singletons and geminates. Furthermore, we are curious to see whether different types of geminates could be differentiated based on their durational patterns.

2. METHODOLOGY

2.1. Participants and material

Seven adult males (aged between 21 and 29) with normal voice quality and no reported history of speaking or hearing disability participated in this study. All participants are monolingual, native speakers of standard Hungarian. Data were drawn from the BEA database [6, 22]. Recordings were made in the same sound-proof room, with AT4040 microphones, using GoldWave sound editing software (sampling at 44.1 kHz, storage: 16 bits, 86 kbytes/s, mono). Participants were asked to talk about their job and free time activities.

We investigate the production of singleton and geminate stops in an approximately 6-hour long spontaneous speech sample. The data set contained 855 manually segmented stop consonants in intervocalic (V_V or V_#V) positions. We annotated 122 stops per speaker, on average. The distribution of voiceless stops is shown in Table 1.

There were 589 singleton and 266 geminate consonants in our corpus. Long consonants were distinguished into three types of geminates: underlying (e.g., *kettő* 'two'; 57 instances), derived true (e.g., *tudtam* 'I knew'; 197 instances) and fake geminates (e.g., *hattól* 'from six'; 12 instances).

Table 1: Occurrences (instances) of stops that were analysed regarding place of articulation and length.

Place of articulation	Length		Total
	Singleton	Geminate	
bilabial	123	31	154
alveolar	240	136	376
velar	226	99	325

2.2. Methods

Complex internal structure of stops suggests that the different phases of consonants reflect various articulatory gestures that can be traced back in the acoustic structure. Thus, the following acoustic parameters were analysed in this study:

- Total duration of consonant: C-boundaries were identified based on F2 measurements (at the offset of vertical striation of the second formant of the adjacent Vs) [5].
- Closure duration: time interval between the termination of the preceding V and the stop burst.
- Closure rate (in %): The proportion of closure duration compared to the total C-duration.
- Voice onset time (VOT): time interval between the release of the stop closure and the onset of quasi-periodicity [7, 16].

Annotation and measurements were conducted using Praat 5.3 software [2]. Statistical analysis was performed by SPSS version 19.0. We compared the durations of singletons and geminates using Wilcoxon signed-rank test. The confidence level was set at the conventional 95%. In order to test whether geminate types differ from each other, Kruskal–Wallis and Mann–Whitney U tests were carried out on the normalized values of durations. Not every participant produced all three types of geminates in spontaneous speech. In order to make the durations of various geminate types from different speakers comparable, data were normalized using the mean and the standard deviation (Z-scores normalization) in each participant. Thus, we could eliminate the differences derived from individual characteristics of articulation (e.g., different speech tempi).

3. RESULTS

3.1. Durational differences between singleton and geminate stops

The results of durational measurements are given in Table 2. The same pattern was obtained in each voiceless stop. In accordance with expectations, the means of total duration and closure duration were longer in geminates than in singletons, while the VOTs did not show considerable differences between short or long consonants.

Table 2: Mean and standard deviation of total duration, closure duration and VOT of the stops.

Consonant	Total duration (ms)	Closure duration (ms)	VOT (ms)
Singleton /p/	101 (±16)	79 (±14)	22 (±11)
Geminate /p/	137 (±20)	115 (±20)	22 (±13)
Singleton /t/	95 (±19)	71 (±18)	25 (±10)
Geminate /t/	143 (±31)	122 (±31)	22 (±10)
Singleton /k/	98 (±22)	63 (±18)	35 (±13)
Geminate /k/	143 (±29)	106 (±27)	37 (±13)

The total duration of singletons proved to be shorter than that of geminates in each speaker's production. Statistical analysis (Wilcoxon signed-rank test) revealed that the difference is significant in the case of /p/ ($Z = -2.201$; $p = 0.028$); /t/ ($Z = -7.646$; $p = 0.018$); and /k/ ($Z = -10.052$; $p = 0.018$) as well. The average ratio of duration of geminates to their singleton counterparts was 1.40 in bilabial, 1.50 in alveolar, and 1.49 in velar consonants.

Furthermore, significant differences were found between the closure duration of all singletons and geminates that were analysed: /p/ $Z = -2.201$; $p = 0.028$; /t/ $Z = -2.366$; $p = 0.018$; /k/ $Z = -2.366$; $p = 0.018$.

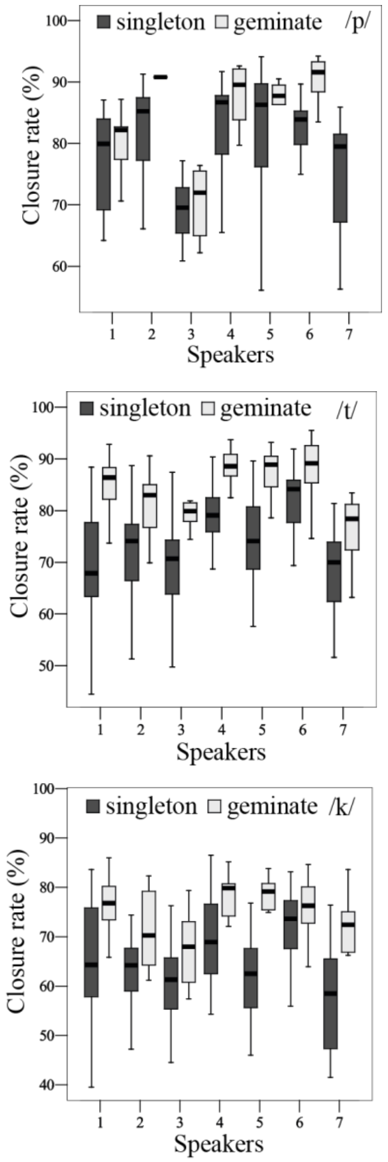
As opposed to the results above, VOT of bilabial and velar stops did not show any significant change due to gemination ($p > 0.05$). However, in the case of alveolar voiceless stops, VOT of singletons were significantly longer than VOT of geminates ($Z = -2.366$; $p = 0.018$).

3.2. Proportional changes in the complex internal structure of stops

Fig. 1 illustrates the proportion of closure phase in singleton and geminate stops of the seven participants.

The average rate of closure duration of singletons was 78.6% in [p], 73.2% in [t], and 64.1% in [k]. In contrast, it was increased in geminates: 84.0% in [pː], 83.6% in [tː], and 73.7% in [kː]. As can be seen, not only the total and the closure duration increased in gemination, but the closure rate as well. That is, phonological lengthening targets certain portion of the internal structure of stops; it particularly affects the closure phase.

Figure 1: Closure rate of singleton and geminate /p, t, k/ stops in the seven participants.



3.3. Durational correlates of various geminate types

The total duration, closure duration and VOT of various geminate types are presented in Fig. 2, 3 and 4, respectively. Although /p/ was excluded from statistical analysis because of limited amount of data, it is displayed in the figures for illustration. In the case of /t/, underlying geminates were realized with the shortest, and fake geminates were realized with the longest consonant duration. In the case of /k/, the shortest type was derived true geminates, while the longest type was underlying geminates. Statistical analysis did not show significant differences among geminate types concerning total duration of /t/ and /k/ consonants (Kruskal–Wallis test, $p > 0.05$ in both cases) and VOTs (Kruskal–Wallis test, $p > 0.05$ in both cases).

Moreover, in alveolar voiceless stops, 'geminate type' did not have a significant effect on closure duration (Fig. 3.). However, in the case of velar voiceless stops, Kruskal–Wallis test revealed significant differences among the closure duration of the three geminate types (χ^2 = 6.159; p = 0.046). Similarly to the total duration of /k/, derived true geminates were produced with the shortest closure duration, and underlying geminates were produced with the longest closure duration. Comparison between two groups were made by Mann–Whitney U test, which revealed significant difference only between derived true and fake geminates (Z = −2.131; p = 0.033). The closure duration of fake geminates proved to be significantly longer than that of derived true geminates.

Figure 2: Total duration of [p, t, k] stops regarding geminate types.

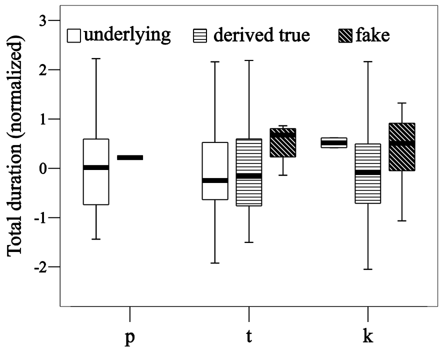


Figure 3: Closure duration of [p, t, k] stops regarding geminate types.

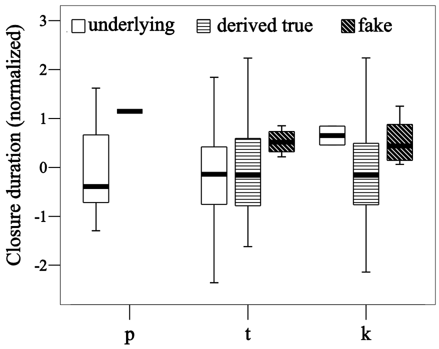
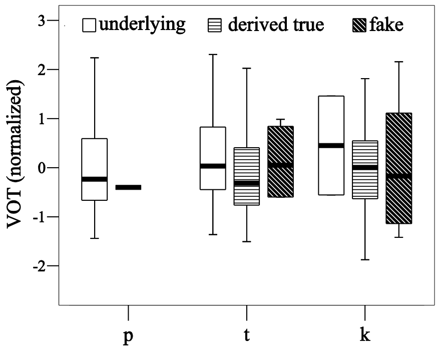


Figure 4: VOT of [p, t, k] stops regarding geminate types.



4. DISCUSSION AND CONCLUSIONS

Results of this study confirmed that phonological length contrast is expressed in significantly different durations of singleton vs. geminate stops in Hungarian. In general, geminates were one-and-a-half times longer than single voiceless stops. These results agree with those reported by Ladefoged's and Maddieson's [15] cross-linguistic survey: geminates are on average between one-and-a-half and three times as long as singletons across languages.

Similarly to other languages (such as Buginese, Madurese, and Toba Batak, see [3]; Italian, see [4]; Swiss German, see [14]), our results provided evidence that the most important cue in the length distinction of stops is closure duration, while VOT of singletons and geminates are not substantially different.

The comparison between the three types of geminates shows that the acoustic correlates of fake geminates differ from underlying or true derived geminates to some extent. The same acoustic correlates suggest similar representations of underlying and true derived geminates in the speech plan. In contrast, fake geminates seemed to be produced with tendentiously longer durations than true geminates, which raises the question whether fake geminates are represented as a consonant sequence rather than a single long consonant. For comparison, although the three geminate types display the same temporal values for Tashlhiyt Berber, significant differences are observed in the additional acoustic attributes and behaviour (e.g., duration of the preceding vowel, RMS amplitude) between true (underlying and assimilated) and fake (concatenated) geminates [29].

In summary, we can conclude that durational features are important factor in the linguistic functioning of Hungarian gemination. Still, further analyses on other features (e.g., intensity, spectral and temporal parameters of the adjacent vowels) are planned in our future work to support the distinction found in this study between Hungarian true and fake geminates.

Durational correlates of the stop length distinction may play an important role in the perceptual distinction of the contrasting sounds. Results of this study may contribute to various speech applications and second language learning.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Beke, A., Gyarmathy, D. 2010. Zöngétlen résmássalhangzók akusztikai szerkezete. *Beszédkutatás* 2010, 57–76.

[2] Boersma, P., Weenink, D. 2013. Praat: doing phonetics by computer [Computer program]. 5.3. http://www.praat.org/

[3] Cohn, A. C., Ham, W. H., Podesva, R. J. 1999. The phonetic realization of singleton-geminate contrasts in three languages of Indonesia. *Proc. 14th ICPhS,* San Francisco, 587–590.

[4] Esposito, A., Di Benedetto, M. G. 1999. Acoustical and perceptual study of gemination in Italian stops. *J. Acoust. Soc. Am*. 106(4), 2051–2062.

[5] Francis, A. L., Ciocca, V., Yu, J. M. C. 2003. Accuracy and variability of acoustic measures of voicing onset. *J. Acoust. Soc. Am*. 113(2), 1025–1032.

[6] Gósy, M. 2012. BEA – A multifunctional Hungarian spoken language database. *The Phonetician* 105-106, 50–61.

[7] Gósy, M., Ringen, C. O. 2009. Everything you always wanted to know about VOT in Hungarian. *IXth International Conference on the Structure of Hungarian,* Debrecen, Hungary. http://www.icsh9.unideb.hu/pph/handout/Ringen_Gosy_handout.pdf

[8] Gósy M., Beke, A. 2010. A magánhangzó-időtartamok a spontán beszédben. *Magyar Nyelvőr* 134(2), 140–165.

[9] Gráczi, T. E. 2012. *Zörejhangok akusztikai fonetikai vizsgálata a zöngésségi oppozíció függvényében*. PhD Thesis, Budapest: ELTE BTK.

[10] Hayes, R. L. 2001. The perception of novel phoneme contrasts in a second language: A developmental study of native speakers of English learning Japanese singleton and geminate consonant contrasts. In: Hayes, R., Lewis, W. D., O'Bryan, E. L., Zamuner, T. S. (eds), *Coyote Working Papers 12. Language in Cognitive Science*. University of Arizona, 28–41.

[11] Ham, W. 2001. *Phonetic and phonological aspects of geminate timing*. New York: Routledge.

[12] Idemaru, K., Guion, S. G. 2008. Acoustic covariants of length contrast in Japanese stops. *J. Inter. Phon. Assoc.* 38(02), 167–186.

[13] Khattab, G. 2007. A phonetic study of gemination in Lebanese Arabic. *Proc. 16th ICPhS,* Saarbrucken, Germany, 153–158.

[14] Kraehenmann, A., Lahiri, A. 2008. Duration differences in the articulation and acoustics of Swiss German word-initial geminate and singleton stops. *J. Acoust. Soc. Am*. 123(6), 4446–4455.

[15] Ladefoged, P., Maddieson, I. 1996. *The sounds of the world's languages*. Oxford: Blackwell.

[16] Lisker, L., Abramson, A. S. 1967. Some effects of context on voice onset time in English stops. *Language and Speech* 10(1), 1–28.

[17] Local, J., Simpson, A. 1999, Phonetic implementation of geminates in Malayalam nouns. *Proc. 14th ICPhS,* San Francisco, 595–598.

[18] Maddieson, I. 1984. *Patterns of Sounds*. Cambridge: Cambridge University Press.

[19] Mády, K., Reichel, U. D. 2007. Quantity distinction in ´ the Hungarian vowel system – just theory or also reality? *Proc. 16th ICPhS,* Saarbrucken, Germany, 1053–1056.

[20] Miller, A. M. 1987. Phonetic Characteristics of Levantine Arabic Geminates with Differing Morpheme and Syllable Structures in Papers from the Linguistics Laboratory 1985-1987. *Working Papers in Linguistics* 36, 120–140.

[21] Nádasdy, Á. 1989. The exact domain of consonant degemination in Hungarian. *Hungarian Papers in Phonetics* 21, 104–107.

[22] Neuberger, T., Gyarmathy, D., Gráczi, T. E., Horváth, V., Gósy, M., Beke, A. 2014. Development of a Large Spontaneous Speech Database of Agglutinative Hungarian Language. *17th International Conference on Text, Speech and Dialogue (TSD 2014),* Brno, Czech Republic, Springer, 424–431.

[23] Oh, G. E., Redford, M. A. 2012. The production and phonetic representation of fake geminates in English. *Journal of Phonetics* 40(1), 82–91.

[24] Olaszy, G. 2006. *Hangidőtartamok és időszerkezeti elemek a magyar beszédben*. Nyelvtudományi Értekezések 155. Budapest: Akadémiai Kiadó.

[25] Payne, E. 2006. Non-durational indices of Italian geminate consonants. *J. Inter. Phon. Assoc.* 36(1), 83–95.

[26] Polgárdi, K. 2008. Geminates and degemination in Hungarian: A loose CV analysis. In: Piñón, C., Szentgyörgyi, Sz. (eds), *Approaches to Hungarian 10. Papers from the Veszprém conference*. Budapest: Akadémiai Kiadó. 127–146.

[27] Pycha, A. 2009. Lengthened affricates as a test case for the phonetics-phonology interface. *J. Inter. Phon. Assoc.* 39(1), 1–31.

[28] Pycha, A. 2010. A test case for the phonetics-phonology interface: Gemination restrictions in Hungarian. *Phonology* 27, 119–152.

[29] Ridouane, R. 2007. Gemination in Tashlhiyt Berber: an acoustic and articulatory study. *J. Inter. Phon. Assoc.* 37(2), 119–142.

[30] Siptár, P., Törkenczy. M. 2000. *The Phonology of Hungarian*. Oxford: University Press.

[31] Siptár P., Gráczi T. E. 2014. Degemination in Hungarian: Phonology or phonetics? *Acta Linguistica Hungarica* 61, 443–471.