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ON THE PHONETICS OF GEMINATES: EVIDENCE FROM CYPRIOT GREEK

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ABSTRACT

This paper examines the acoustic correlates of the geminate consonants of Cypriot Greek. Several measurements were obtained, including target segment duration, preceding vowel duration and quality, RMS for the geminates themselves, and voice quality differences in their production. It was found that for the segments whose duration can be most easily prolonged (i.e. /l/, nasals and fricatives) the most robust and consistent cue to gemination is length. In the case of stops, affricates and /r/, on the other hand, there are additional cues in the manner of articulation of the segments, with /r/ turning into a trill, and the stops and the affricate becoming aspirated. However, preliminary results from the other cues investigated suggest that gemination does not have a consistent effect on them either within or across speakers.

1. INTRODUCTION

Traditionally the distinction between singleton and geminate consonants is thought to involve a difference in duration (e.g. [1]). Indeed most studies of geminate consonants in various languages have shown duration to be the most robust correlate of gemination ([2], [3], among many]. However, few studies have sought evidence for other acoustic correlates of geminates, and the results of such studies are not consistent across languages. For example, according to [4], Malayalam sonorant geminates are not only longer than their singleton counterparts but also different from them in terms of quality, while gemination appears to affect the duration and quality of preceding segments as well. In contrast, [2] did not find any differences between single and geminate stops in Italian except in closure duration. Such results suggest, as Esposito and Di Benedetto point out, that duration is the universal attribute of geminates, whereas other differences (e.g. in quality or phonation type) may be language specific [2].

In previous studies ([5], [6], [7]), we compared single and geminate consonants in Cypriot Greek (the variety of Greek spoken on the island of Cyprus) and have shown that Cypriot geminates are consistently longer than singletons even across different speaking rates [5, 6]. However, the Cypriot geminates are not as long as geminates reported in other languages (c.f. [2], [3]). This finding, coupled with the fact that the only impressionistic study of the Cypriot geminates describes them as *fortis* [8], suggests that the articulation of Cypriot geminates may involve other parameters in addition to duration.

In this paper we briefly present our durational data for Cypriot geminates and discuss also additional parameters, namely, RMS amplitude, phonation differences in the consonants, and quality and quantity effects on the vowels surrounding the geminates.

2. METHOD

2.1. Materials

The target segments (presented in Table 1) were in intervocalic position in disyllabic words, that formed minimal (or near minimal) pairs, depending on whether the intervocalic consonant was single or geminate. Half of these minimal pairs were stressed on their first syllable and the other half on their final syllable. The vowels preceding and following the target consonants were the same for each set of four test-words with the same intervocalic segment. The test-words were embedded in the carrier phrase: [ˈipɛndu______ksɐfniˈkɐ ˈtʃɛfiɛn] 'she or he said to him ______ suddenly and left'.

2.2. Speakers and Procedure

The sentences were read by four native speakers of CYG, two males (DF and KR) and two females (AY and SP). The speakers read the sentences seven times from typed cards placed in random order and interspersed with fillers. KR and AY were recorded in the anechoic chamber of the Cambridge University Phonetics Laboratory; DF and SP were recorded in a sound-treated booth of a Nicosia television station. The materials (all on digital tape) were re-digitized and analyzed at the Ohio State University Phonetics Laboratory using Waves+ on a Solaris Unix workstation.

2.3. Measurements and Statistics

Duration measurements were obtained from simultaneous spectrographic and waveform displays. Additional measurements were obtained automatically using specifically designed programs. Here we present results from the following:

- The duration of the target consonants
- RMS amplitude of the target consonants
- Amplitude differences between the first and second harmonic (H1minusH2), 10ms into the vowel following the target consonant
- The duration of the preceding vowel
- F1 and F2 of the preceding and following vowels at mid-point and 10 ms from their boundary with the target consonant

The duration measurements followed standard criteria of segmentation. Separate measurements were taken for closure and VOT in stops, and for closure, fricated release and aspiration in affricates. For stops, RMS was measured in the VOT; for affricates, in the release portion, in which both frication and aspiration were included. The RMS values, which were in arbitrary units, were normalized by dividing the RMS of the target segment by that of the test word.

	Penultimate stress				Final stress			
	Singleton		Geminate		Singleton		Geminate	
	Word	**Gloss**	**Word**	**Gloss**	**Word**	**Gloss**	**Word**	**Gloss**
/p/	ˈpɐpɐ	‘pope’	ˈmɐpːɐ	‘ball’	pɐˈpɐ	‘daddy’	lɐˈpːɐ	‘boiled rice’
/t/	ˈkɔtɐ	‘hen’	ˈkɔtːɐ	‘knock’ *imp.*	pɔˈtɐ	‘drinks’	kɔˈtːɐ	‘s/he knocks’
/k/	ˈfɐkɐ	‘mouse trap’	ˈfɐkːɐ	‘hit’ *imp.*	kɐˈkɐ	‘bad’ *pl.*	fɐˈkːɐ	‘s/he hits’
/s/	ˈpisi	‘persuade’ *subj.*	ˈpisːi	‘stingy’ *acc.*	miˈsi	‘half’ *fem.*	kiˈsːi	‘ivy’ *pl.*
/ʃ/	ˈxɐʃɐ	‘being baggy’	ˈɐʃːɐ	name of village	pɐˈʃɐ	‘fat’ *fem.*	ɐˈʃːɐ	‘skin bags’
/tʃ/	ˈfitʃɐ	‘sea weed’	ˈfitʃːɐ	‘show off’	siˈtʃɐ	‘fig tree’	viˈtʃːɐ	‘whipping’
/m/	ˈsɐmu	‘Samos’ *gen.*	ˈɐmːu	‘sand’ *gen.*	pɐˈmu	‘rest’ *gen.*	mɐˈmːu	‘midwife’
/n/	ˈkɐni	‘it-does’	ˈkɐnːi	‘gun barrel’	kɐˈni	‘enough’	kɐˈnːin	‘shin’
/l/	ˈmilɐ	‘apples’	ˈmilːɐ	‘fat’ *n.*	miˈlɐ	‘s/he speaks’	piˈlːɐ	surname
/r/	ˈvɐɾɐ	‘beat’ *imp.*	ˈmbɐrːɐ	‘rod’	vɐˈɾɐ	‘s/he beats’	fɐˈrːɐ	‘pasture’

Table 1: The test-words and their glosses.

The data for each target consonant were statistically analyzed by means of 3-way analyses of variance (speaker × segment type [single/geminate] × stress [stressed/unstressed]), with speaker as a *random effects* factor; the confidence interval is $p<0.05$.

3. RESULTS

3.1 Target Segment Duration

Stops and affricates: As shown in Figure 1, the closure duration for the geminates was significantly longer than that of their singleton counterparts for all segments except /k/ [for /p/, F(1,3)=15.69; for /t/, F(1,3)=26.48; for /tʃ/ F(1,3)=29.92]. *Post-hoc* Scheffé tests showed that the result for/ k/ was due to DF and SP, who had the same closure duration for the singleton and the geminate. In all cases, stop closure was longer in stressed than in unstressed syllables [for /p/, F(1,3)=79.36; for /t/, F(1,3)=79.91; for /k/, F(1,3)=25.36; for /tʃ/, F(1,3)=23.96].

VOT was significantly longer for geminates than for singletons [for /p/, F(1,3)=25.51; for /t/, F(1,3)=29.6], except for /k/: Scheffé tests showed that this non-significant result was due again to speakers DF and SP. Further, the VOT results of /p/ and /t/ showed interaction between stress and segment type [for /p/, F(1,3)=11.42; for /t/, F(1,3)=22.5]. Scheffé tests showed that the interaction was due to the fact that the VOT of the geminates was significantly lengthened in stressed syllables, while the VOT of the singletons was unaffected by stress (see Figure 1).

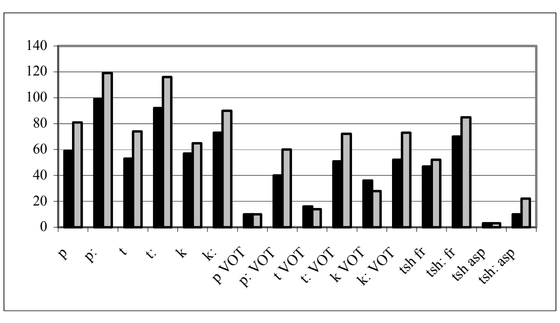

Figure 1: Mean durations (in ms) for stops and the affricate, separately for unstressed and stressed syllables (black and gray bars respectively). ‘tsh’ stands for /tʃ/.

The fricative portion of /tʃ/ was significantly longer for the geminate [F(1,3)=20.08], and not affected by stress (see Figure 1). The aspirated portion showed a *trend* for being longer in the geminate [F(1,3)=8.29, $p<0.06$], but also an interaction between segment type and speaker [F(3,80)=17.86]: Scheffé tests showed that geminates had longer aspirated portion in the data of all speakers except DF, who had no aspiration at all. There was no effect of stress on the aspirated portion of the affricate.

Sonorants: As shown in Figure 2, geminate sonorants were longer than singletons in both stress conditions [for /m/, F(1,3)=95.62; for /n/, F(1,3)=12.13; for /l/, F(1,3)=281.38; for /r/, F(1,3)=157.5].

Fricatives: Geminate /s/ and /ʃ/ were longer than singletons [for /s/, F(1,3)=13.98; for /ʃ/, F(1,3)=311.42]. As shown in Figure 2, both geminates and singletons were also longer in stressed than in unstressed syllables [for /s/, F(1,3)=11; for /ʃ/, F(1,3)=14.77].

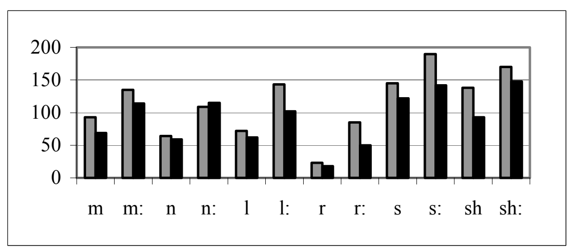

Figure 2: Mean durations (in ms) for the nasals, liquids and fricatives, separately for stressed and unstressed syllables (gray and black bars respectively). ‘sh’ stands for /ʃ/.

3.2. Target Segment RMS

Stops and affricates: The VOT portion of /t/ and /k/, and the fricative portion of /tʃ/ had similar RMS amplitude irrespective of gemination or stress (see Figure 3). In the case of /p/, however, there was interaction between speaker and segment type [F(3,80)= 4.17]. As Scheffé tests showed, this effect was due to DF; contrary to what was expected, in DF’s data the VOT of the geminate /p/ had *lower* RMS than that of the singleton.

Sonorants: The sonorants (/m/, /n/, /l/ and /r/) did show some differences in RMS between singletons and geminates, but not always in the expected direction. Specifically, in the RMS of /m/, there was interaction between speaker and segment type

[F(3,80)=12.59]. The investigation of this interaction showed that in the data of AY, DF and KR the geminate had *lower* RMS than the singleton. Interaction between speaker and segment type was also found in the data for /n/ [F(3,80)=5.05]; this turned out to be due to KR, the only speaker to have *higher* RMS in the geminate than the singleton. For /l/, RMS was higher for the geminate [F(1,3)=13.2], but there was also a three-way interaction [F(3,77)=6.09]. The investigation of this interaction showed that in the data of AY, the geminate /l/ had indeed higher RMS than the singleton, but only when stressed; all other comparisons, however, were non-significant. Finally, the RMS of /r/ was not affected by either gemination or stress.

Fricatives: There were no statistically significant differences in RMS between single and geminate /s/ and /ʃ/ (but see Figure 3).

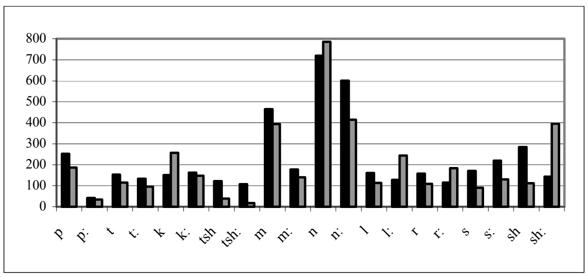

Figure 3:Mean normalized RMS for all segments. Gray bars for consonants in stressed syllables, black bars for consonants in unstressed syllables. 'tsh' stands for /tʃ/ and 'sh' for /ʃ/.

3.3. H1minusH2

As mentioned earlier, it has been suggested that geminate consonants in CYG are fortis [8]. Although the distinction between lenis and fortis has been shown to be quite elusive ([9]), recent evidence suggests that it can be quantified by examining the difference in amplitude between the first and second harmonic (H1minusH2) at the onset of the vowel following the target consonant [10]: in modal voicing the first two harmonics are of similar amplitude; in breathy voice the first harmonic has much higher amplitude than the second, while in pressed or creaky voice the reverse holds. On the basis of our observations, we expected that the geminate stops and the affricate would be accompanied by breathy voice (i.e. large positive differences between H2 and H1) and that at least the fricatives would be accompanied by pressed voice (i.e. negative differences between H2 and H1).

Our data did not provide strong support for the above hypotheses (mean values for H1minusH2 can be see in Figure 4). For the nasals and the fricatives, two-way analyses of variance [speaker × segment type] yielded statistically non-significant results, except for speaker, an effect that reflects individual differences in phonation (e.g. DF had consistently pressed voice, while AY had consistently breathy phonation).

For /p/ and /t/ there was indeed an effect of gemination, with vowels after geminates showing more breathy voice than after singletons in the data of all speakers [for /p/, F(1, 3)=24.4; for /t/, F(1,3)=19.39]. In the data for /k/ and /tʃ/ there was interaction between speaker and segment type [for /k/, F(3, 88)= 4.4; for /tʃ/F(3,87)=4.45]. Scheffé tests showed that in /k/ only speaker KR had a H1minusH2 difference, with geminate /k/ showing breathier phonation. This was also true of KR's and AY's /tʃ/ data. For the other speakers there were no H1minusH2 differences in the /k/ and / tʃ/ data.

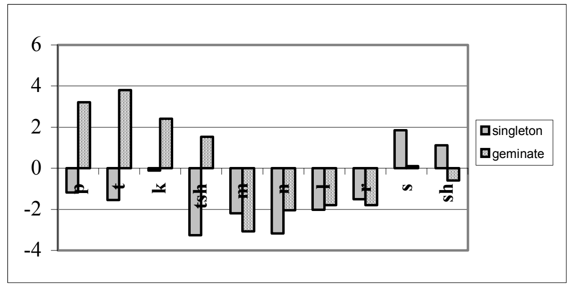

Figure 4: Mean H1minusH2 differences for each target segment, together for stressed and unstressed syllables. 'tsh' stands for /tʃ/ and 'sh' for /ʃ/.

3.4. Duration of Preceding Vowel

Vowels tended to be shorter before geminates, but the effect was not consistent either within, or across speakers and consonant types. Specifically, of the 20 possible comparisons between vowels preceding geminate and singleton consonants (10 segment types × 2 stress conditions) only those for /k/, /m/ and /r/ turned out to be significant (see Figure 5). Even in these cases the differences between the vowels preceding singleton and the vowels preceding geminate consonants were on average 12ms, and thus unlikely to be of perceptual relevance.

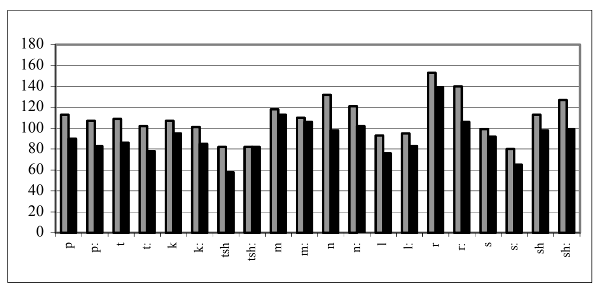

Figure 5. Mean durations (in ms) of the vowels preceding the target consonants. Gray bars for stressed vowels, black bars for unstressed vowels. 'tsh' stands for /tʃ/ and 'sh' for /ʃ/.

3.5. Spectral Differences in the Preceding and Following Vowels

At present we have only preliminary data regarding F1 and F2 of the vowels preceding and following the target consonants in the test words. These data however strongly suggest that the presence of a geminate does not affect the quality of the surrounding vowels, either in their steady state or in the transitions to and from the geminate. As an indication, in Figure 6, we present an F1 by F2 plot of the mid-point values for /ɐ/ in the test words [ˈsɐmu], [ˈɐmːu], [pɐˈmu] and [mɐˈmːu].

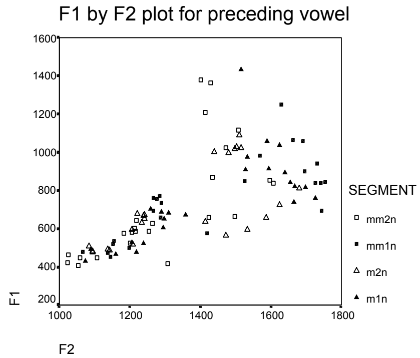

Figure 6: F1 by F2 plot for the mid-point of /ɐ/ in the test words ['sɐmu] (m1n), ['ɐmːu](mm1n), [pɐ'mu] (m2n) and [mɐ'mːu] (mm2n). Data for all speakers and tokens.

4. DISCUSSION AND CONCLUSION

In this paper we have presented evidence from several types of measurements on the acoustic characteristics of geminate consonants in CYG. As expected, duration was a very robust cue for gemination for all the types of consonants involved. In addition to duration, however, we have also investigated several other types of evidence both relating to acoustic characteristics of the geminates themselves and to their possible effect on surrounding segments. We were prompted to undertake this investigation for two reasons: first, because of the claim that has been made in the literature about the fortis articulation of the geminates consonants of CYG [8]; and second, because of the recent findings that gemination may indeed involve several acoustic parameters in addition to duration [4].

However, neither of these proposals has been supported by our data. First, there were no differences in RMS between singleton and geminate consonants of any type. Similarly there appear to be no differences in phonation (of the type associated with a fortis articulation), except in the case of the geminate stops which are heavily aspirated, and as such have already a secondary cue to gemination. Third, gemination does not affect the duration of the vowel preceding the geminate in any consistent way, a result replicating those of [5]. Finally, gemination does not appear to affect the quality of either the vowel preceding or that following the geminate consonant.

Although further investigation is necessary before final conclusions can be drawn (e.g. we are currently in the process of eliminating from our data cases of false boosting of H2 due to its proximity to F1), it appears that the claim that geminate consonants in CYG are fortis is incorrect. Similarly, in this language, as in many others investigated so far, there does not appear to be any consistent cue of gemination across and within speakers, except duration. This casts doubt on the generality of the Malayalam data [4], and appears to vindicate other studies, such as [2] and [3], which show duration to be the main and consistent cue to gemination.

On the other hand, it should also be noted that CYG does resort to additional cues to *enhance* gemination in the cases where duration would be less salient, i.e. in the case of the geminate stops. Although in many languages investigated so far the difference between single and geminate stops lies in closure duration alone, in CYG, aspiration provides a second, consistent and powerful cue. (It is also worth noting that aspiration extends to the affricate as well.) The presence of this additional cue could be related to the fact that CYG is one of the few languages that allow geminates word-initially: unlike closure duration, aspiration is hard to miss, even utterance-initially. For the segments, however, that can be prolonged more easily, i.e. for sonorants and fricatives, duration remains the main cue. We are now in the process of examining other possible differences in the *quality* of these consonants, and, in the light of [11], plan to also investigate the perceptual relevance of the additional cues occasionally used by the speakers. In the meantime, it appears that geminates, in CYG at least, are indeed long consonants.

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