Gemination in Tarifit Berber: Doing one or two things at once?

Fayssal Bouarourou, Béatrice Vaxelaire, Rachid Ridouane, Fabrice Hirsch, Camille Fauth, Rudolph Sock

GEMINATION IN TARIFIT BERBER: DOING ONE OR TWO THINGS AT ONCE?

Fayssal Bouarourou[a], *Béatrice Vaxelaire*[a], *Rachid Ridouane*[b], *Fabrice Hirsch*[a], *Camille Fauth*[a] *& Rudolph Sock*[a]

[a]LilPa / Equipe de Recherche Parole et Cognition, U.R. 1339 & Institut de Phonétique de Strasbourg (IPS), Université de Strasbourg (UDS), France;
[b]Laboratoire de Phonétique et Phonologie (CNRS – Sorbonne Nouvelle), France
fayssalbouarourou@gmail.com

ABSTRACT

Acoustic and X-ray data have been collected for gemination in Tarifit Berber. The acoustic data show that consonantal closure of geminates is significantly longer than that of corresponding singletons, for all consonants examined (alveolars, velars and uvulars), in both voiced and voiceless contexts, for two subjects, in two speech rate conditions: normal and fast. Articulatory measurements obtained from mid sagittal profiles show that occlusion contact-extents are longer for geminate consonants than for their singleton counterparts. Results take into account the elasticity of speech signals and are discussed within the "doing one or two things" paradigm.

Keywords: gemination, Berber, X-ray data, acoustic data, speech rate

1. INTRODUCTION

This investigation, based on acoustic and X-ray data, for two native speakers, reports on gemination in Tarifit Berber (spoken in Northern Morocco). *Firstly*, it presents results of articulatory and acoustic investigations of singleton and geminate voiced and voiceless stops, produced in word initial, word medial, and word final positions, at a normal and at a fast speaking rate. Speech rate is varied in order to evaluate the resistance of the phonological contrast. Research results reported here should, *secondly*, serve as a prelude to perceptual investigations on *categorical perception* of gemination, in close relation to underlying articulatory and kinematic strategies. The current study is part of a vast programmatic articulatory, acoustic and perceptual research carried out on gemination, vowel quantity and abutted consonants in our laboratory, for different languages. All articulatory data were extracted from an X-ray database. The major tack of such research on linguistic factors, which rely mainly on temporal cues, is to determine whether the speaker is: 1) producing linguistic segments in a more or less sequential manner; 2) doing two things (*i.e.* phonemes) at once ([6]); or 3) doing the same thing once but for a longer period of time.

2. BACKGROUND

Several studies have sought to determine acoustic cues for gemination in many languages: *e.g.* [8] on Turkish and Bengali; [12] on Italian; [11] on Rembarrnga (a Northern Australian language); [9] on Estonian; [1] on Cypriot and standard Greek; and [5] on Iraqi Arabic and Swedish. The primary cue that was found by all these authors, on the *acoustic level*, was *consonant duration* (closure duration for stops). They all show that geminates are systematically produced with longer acoustic closure durations compared to singletons.

Some studies have also been carried out on the articulatory characteristics of geminate consonants. Both [3] for Italian and [2] for American English conducted electropalatographic investigations on stops, and have shown that the amount of tongue palate contact is larger for geminates (heteromorphemic geminates for English) than for single stops, and also that there is a general increase in the extent of tongue-palate contact with increasing closure duration. The same results were obtained by [7] based on EPG data from Turgovian Swiss-German. The latter study, in addition, showed that these articulatory differences were maintained even for voiceless stops in utterance-initial position, where durational differences between singletons and geminates are not detectable by listeners. [13] examined lip and tongue movements in single and geminate consonants in Japanese and Italian, and found out that the closing movements of the lips were slower for the geminates compared with single consonants.

[10] studied lip kinematics in long and short stops and fricatives, using a magnetometer system. Based on earlier work showing that the lips were moving at a high velocity at the oral closure, it was hypothesized that speakers could control closure/constriction duration by varying the position of a virtual target for the lips. According to this hypothesis, the peak vertical position of the lower lip during the oral closure/constriction should be higher for the long consonants than for their shorter counterparts. This would result in the lips staying in contact for a long period. The data show that this is the case for Japanese subjects and for one Swedish subject who produced non-overlapping distributions of closure/constriction duration for the two categories.

On a whole, however, articulatory data related to gemination reported in the literature are rare. So also are data that try to establish lawful relationships between articulatory and acoustic cues for this phonological feature.

3. HYPOTHESES

It is *hypothesised* on the *acoustic level* that, as reported in the literature, geminates would have longer closure durations than singletons (*hypothesis 1*). The duration of flanking vowels may be affected by that of geminate consonants (*hypothesis 2*): they would be shorter in this environment ([9]), in case of syllable isochrony. VOT could be longer for geminates, as their occlusion phase is usually remarkably long, thus retarding onset of voicing, due to high intra-oral pressure (*hypothesis 3*).

On the *articulatory level*, contact-extent, partly underlying consonantal closure, would be correlatively longer for geminates (*hypothesis 4*). If geminates do shorten adjacent vowels, jaw opening and constriction width may vary as a function of this coarticulatory influence (*hypothesis 5*).

4. METHOD

The entire *corpus* (plosives and fricatives) consisted of 54 sentences of 4 to 6 syllables, comprising 27 minimal pairs that were inserted in these meaningful carrier sentences. The speech material analysed here consists of 5 minimal pairs, contrasting singleton stops with their geminate counterparts, in three positions: word initial, word medial, and word final. The plosives examined were: /t, d, k, g, q/ *vs.* /tt, dd, kk, gg, qq/. All target sequences were inserted in the same carrier sentence: /ini___i umar/, meaning “Say___once”. The two subjects were seated comfortably at a distance of 20 cm from the microphone.

In the X-ray (25 frames/sec) experiment, these minimal pairs were produced once at a normal (self-selected) speaking rate.

In the acoustic experiment, all tokens were repeated twelve times by the two speakers, in the two rate conditions. All pairs of sentences had the same number of syllables. With the help of a grid, *measurement parameters* (semi-automatic, then corrected manually) for *vocal tract configurations* were determined related to tongue tip to alveolar ridge, tongue body-to-soft palate, and tongue body-to-uvula contact-extents (mm). Jaw opening (mm) and constriction width (mm) related to the subsequent vowel in word initial position, to the flanking vowels in word-medial position, and to the preceding vowel in word-final position, were also measured. Temporal events were detected on the *audio* signal, and specific timing relations between these events allowed determining acoustic durations (ms) which correspond to articulatory opening and closing gestures. Thus vowel durations were specified as intervals between onset and offset of a clear formant structure. Corollary, closure duration was measured, between vowels, from offset to onset of vocalic clear formant structures. VOT was also acquired as the interval between the burst-release of the plosive and onset of a clear formant structure of the subsequent vowel.

General remark on *acoustic measures*: It was expected following results usually reported in the literature on quantity contrasts that, in spite of any eventual compression that measured parameters might undergo, due to increased speaking rate, differences in consonantal closure (the privileged parameter of the phonological contrast) would nonetheless be maintained. Taking into account the elasticity of speech signals [4], which vary as a function of speakers, speaking rates, diverse contexts…, differences in *absolute values* between geminates and singletons were normalised. Thus, the proportion of consonantal closure within the CV2 syllable was calculated. It has indeed been shown [9] that it is within this CV domain that temporal contrasts for consonantal quantity are maximised. *In fine*, therefore, fine grained analyses of the data, together with our conclusions, will be drawn from these *relative values*.

5. RESULTS AND DISCUSSION

Analyses of variance (ANOVA) were carried out, for the acoustic data, for all variables (V1, consonantal closure, VOT and V2) in order to determine if there were effects for *gemination*, *speech rate* and *consonant type*. Two *main effects* proved to be statistically significant for the *consonantal closure* variable: *gemination* [(df=1,478, F=1426.27, p<0.0000)] and *speech rate* [(df=1,478, F=2940.624, p<0.0000)]. Hence, *post-hoc* pair wise comparisons (*Tukey's h.s.d.*) were carried out on mean values of absolute and relative values only for this variable, *consonantal closure*.

The *acoustic data* show that consonantal closure of geminates, in *absolute* values (see Figure 1 for an illustration), is noticeably longer than corresponding singletons, for all consonants (alveolars, velars and uvulars), and in both the voiced and voiceless contexts, for the two subjects, in the two speech rate conditions. This result is in line with *hypothesis 1*. This hypothesis is further consolidated as durational differences between geminates and singletons are maintained in fast speech, although consonantal closures undergo compression (from 119 ms [std=4 ms] in normal speech rate to 72 ms [std=4 ms] in fast speech rates for singletons, and from 246 ms [std=4 ms] in normal speech rate to 169 ms [std=3 ms] in fast speech for geminates).

Figure 1: On the left, mean values (ms), in normal speech rate showing the effects of gemination (/t/ *vs.* /tt/) on the measured acoustic parameters. On the right, the same indications are given for the fast speech condition (Speaker F).

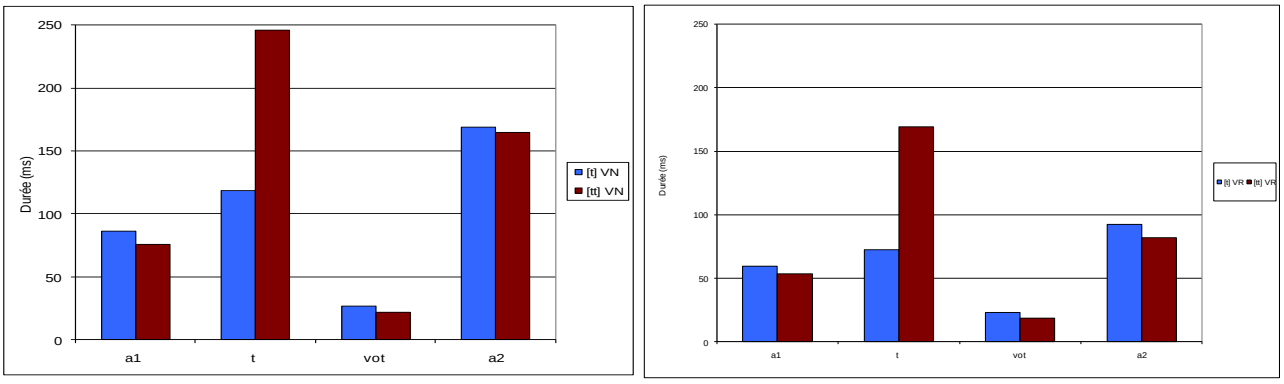
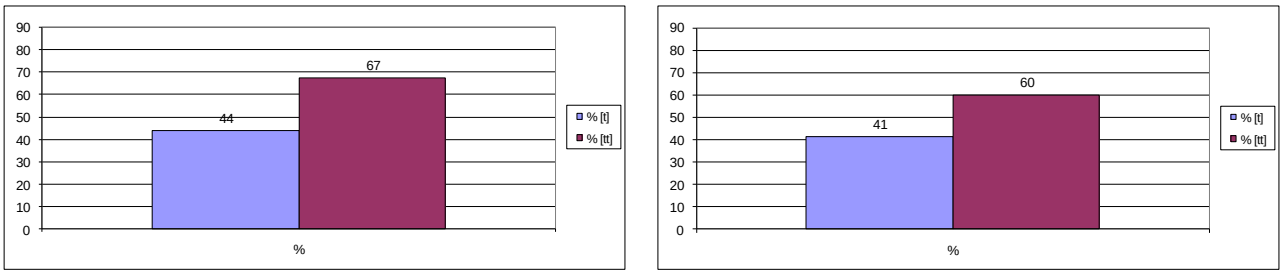


Figure 2: On the left, mean values (%), in normal speech rate showing the effects of gemination on the main acoustic parameter: consonantal closure for the apical consonants /t/ *vs.* /tt/. On the right, the same indications are given for the fast speech condition (Speaker F).



It was noticed that consonantal gemination did not affect the duration of adjacent vowels. It can be seen in Figure 1, as expected following statistical results reported *supra*, that gemination does not have any effect on the duration of V1, with a value of 76 ms (std=5 ms) before geminates, and a value of 86 ms (std=10 ms) before singletons. No repercussion is visible either on the duration of V2: 165 ms (std= 9 ms) before geminates *vs.* 169 ms (std=12 ms) before singletons. *Hypothesis 2* is consequently not verified. Likewise for VOT values which are also similar for both categories (*hypothesis 3*).

The *acoustic data* further show that consonantal closure of geminates, in *relative* values takes up a higher proportion of the CV domain [(df=1,478, F=108.2184, p<0.0000)], compared with their singleton counterparts, thus highlighting the robustness of the phonological distinction, regardless of compression induced by increased speaking rate [(df=1,478, F=228.5323, p<0.0004)]. Figure 2 is a typical illustration of such a result:

the apical geminate /tt/ has a value of 67% (std=4%) at a normal speaking rate, whereas the singleton is at 44% (std=3%). Proportions remain relatively stable in fast speech, as they are comparable in this speaking condition: 60 (std=5%) for geminates *vs*. 41% (std=4%) for singletons.

Articulatory results given here are based on raw data, and rarely on statistics, due to experimental conditions (exposure to X-rays). Some of them should therefore be considered as tendencies. Measurements obtained from mid sagittal profiles show that contact-extents (maximum value for contact) are longer for geminate consonants than for their singleton counterparts (see *Figure* 3 for an example, and Table 1 for values). This observation is valid, in an intra-speaker pair-wise comparison, for all linguistic categories examined *i.e.* alveolars, velars and uvulars, for voiced and voiceless consonants, and for both speakers (thus corroborating *hypothesis 4*). Minimal differences in all instances were clear-cut, *i.e*. 5 mm (with a 0.5 mm error margin). It should be noted that this difference in obstruent strategy is always systematic across several images. Jaw opening and constriction width are being analysed in order to account for *hypothesis 5*.

Figure 3: This figure shows velar contact extents for /g/ (left) vs. /gg/ (right). Speaker F.

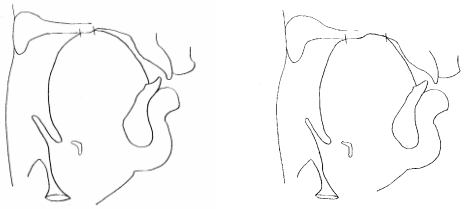


Table 1: This table gives raw data for singletons *vs*. geminates. Speaker SF.

plosives	/t/	/tt/	/k/	/kk/	/q/	/qq/	/d/	/dd/	/g/	/gg/
closure duration (ms)	104	170	122	193	107	251	84	215	101	198
contact extent (mm)	11	16	10	15	30	35	11	17	8	21

6. CONCLUSIONS

A close look at both the articulatory and the acoustic data suggests that speakers are doing the same thing once, for a longer period as: 1) only a single and prolonged contact is observed for geminates; 2) the nature of this contact is qualitatively (but not quantitatively) similar to that of the singleton's; 3) the acoustic signal, consequently, does not reveal rupture in the consonantal silent phase.

Currently, a categorical perception test is being elaborated. Broadly, stimuli of several consonantal duration continua in V_V contexts will be used. The phonemic boundaries along these continua will be assessed by collecting identification data in a set of native and non-native subjects. A simultaneous investigation of the articulatory and acoustic data should allow linking phonemic boundaries to underlying articulatory configurations, as can be revealed by frame-by-frame analyses of the X-ray data.

7. REFERENCES

[1] Arvaniti, A., Tserdanelis, G. 2000. On the phonetics of geminates: evidence from Cypriot Greek. *Proc. 6th International Conference on Spoken Language Processing* 2, 559-562.

[2] Byrd, D. 1995. Articulatory characteristics of single and blended lingual gestures. *Proc. 18th International Congress of Phonetic Sciences* 2, 438-441.

[3] Farnetani, E. 1990. V-C-V lingual coarticulation and its spatiotemporal domain, In Hardcastle, W., Marchal, A. (eds), *Speech Production and Speech Modelling*. Dordrecht: Kluwer, 93-130.

[4] Gaitenby., J. 1965. The elastic word. *Haskins Laboratories, Status Report, Speech Research* 2, 1-12.

[5] Hassan, Z.M. 2002. Gemination in Swedish and Arabic with particular reference to the preceding vowel duration: an instrumental and comparative approach. *Proceedings of Fonetik TMH-QPSR* 44, 81-84.

[6] Klapp, S.T. 1979. Doing two things at once: The role of temporal compatibility. *Memory and Cognition* 7, 375-381.

[7] Kraehenmann, A., Lahiri, A. 2008. Duration differences in the articulation and acoustics of Swiss German word-initial geminate and singleton stops. *Journal of the Acoustical Society of America* 123, 4446-4455.

[8] Lahiri, A., Hankamer, J. 1988. The timing of geminate consonants. *Journal of Phonetics* 16, 327-338.

[9] Lehist, I., Tatham, M., Morton, K. 1973. An instrumental study of consonant gemination. *Journal of Phonetics* 1, 131-148.

[10] Löfqvist, A. 2005. Lip kinematics in long and short stop and fricative consonants, *Journal of the Acoustical Society of America* 117, 858-878.

[11] Mckay, G. 1980. Medial stop gemination in Rembarrnga: A spectrographic study. *Journal of Phonetics* 8, 343-352.

[12] Pickett, E.R., Blumstein, S.E., Burton, M.W. 1999. Effects of speaking rate on the singleton/geminate consonant contrast in Italian. *Phonetica* 56, 135-157.

[13] Smith, C.L. 1995. Prosodic patterns in the coordination of vowel and consonant gestures, In Connell, B., Arvaniti, C. (eds.), *Laboratory Phonology 4: Phonology and Phonetic Evidence*. Cambridge: Cambridge University Press, 205-222.