Gemination at the junction of phonetics and phonology

Rachid Ridouane
Laboratoire de Phonétique et de Phonologie (UMR 7018) CNRS/ Sorbonne Nouvelle,
19, rue des Bernardins, 75005 Paris, France
Téléphone: (00) 33 148 25 21 9
rachid.ridouane@wanadoo.fr

ABSTRACT
Tashlhiyt Berber has contrastive singleton and lexical geminate consonants in all positions. In addition, it has two types of phonologically derived geminates: concatenated and assimilated ones. Within CV phonology, geminates, including post-lexical ones, are represented as single melodic units associated to two prosodic positions. This study examines the way these abstract autosegmental representations are reflected in the phonetic details of speech production. In particular, it investigates two questions: what are the acoustic and articulatory differences between singletons and lexical geminates; and are there any acoustic differences between the three types of geminates. Results show that the primary correlate which distinguishes singletons from geminates is duration, even for voiceless stops after pause. This primary correlate is enhanced by additional correlates which are crucial to perception of absolute initial and final geminates. The comparison between the three types of geminates shows that they all display the same temporal values which supports the assignment of the same timing representation to these three types of geminates. However, while assimilated geminates, like underlying ones, are enhanced by additional acoustic attributes, concatenated geminates are not. Implications of these results for the general issue of geminate behaviour are discussed, with particular interest on geminate Ambiguity and geminate Inalterability.

1. Introduction
Geminates, as reported in many languages of the world (Ladefoged and Maddieson 1996), have been the source of much debate in literature concerning their phonetic implementation, their phonological representation, as well as the way to account for their particular behaviour. Within CV phonology, a geminate is represented as a single melodic unit (a bundle of distinctive features characterising a segment) associated to two prosodic positions (Leben 1980). Such a representation, which relies crucially on the tenet that syllabicity is represented on a separate tier from the melodic one, has subsequently been the received analysis of geminate consonants, including post-lexical geminates. (1) gives the underlying representation of a singleton stop (1a), a lexical geminate (1b), a geminate created by concatenation of two identical stops across a morpheme boundary (1c) and a geminate derived by total assimilation (1d).

(1) a. X  
    k  

b. X X  
   k  k

c. X X  
   k  k

d. X X  
   d  k

This study examines the way these abstract phonological representations are reflected in the phonetic details of speech production, and the way they are related to the distinct behaviour of
different types of geminates (namely, Ambiguity and Inalterability). Two production studies are conducted to help handle this issue. The first one examines, based on acoustic and articulatory data, how underlying geminates are phonetically implemented in different prosodic positions, and questions the phonological relevance of these correlates. The second one deals with an aspect which also arises in connection with the phonological representations in (1): are phonologically derived geminates, either by concatenation (1c) or by total assimilation (1d), categorically identical to underlying geminates (1a)? and questions the autosegmental analysis of external sandhi assimilation.

1.1. The language investigated
Tashlihyt Berber, the language investigated, has all three types of segments represented in (1). And, as shown in (2), lexical geminates are attested in absolute initial and final positions, in addition to the more frequently attested word-intervocalic geminates.

(2) a. Singleton /tut/ [tut] ‘she hit’
   b. Lexical geminate /tut/ [tut] ‘forget him’
   /ttut/ [ttutt] ‘forget her’
   c. Concatenated geminate /tut tins/ [tuttins] ‘she hit hers’
   d. Assimilated geminate /rad tut/ [rattut] ‘she will hit’

Tashlihyt Berber is spoken in the Southern part of Morocco. This language is sufficiently homogeneous for all native speakers to communicate without difficulties. There is, however, a measure of dialectal variation. Following the work of Boukous (1994), Tashlihyt Berber may be subdivided into three main subsystems: (i) The occlusive subsystem spoken in Agadir and its suburbs, (ii) The fricative subsystem spoken in Haha which spirantizes in some contexts noncoronal obstruents /b, k, g/, and, (iii) The sibilant subsystem spoken in the Anti-Atlas area where /t/ and /d/ are realised in some contexts as [s] and [z] respectively. These three sub-dialects are all founded upon the same correlations, and share the same phonemic system, as is shown in Table 1.

<table>
<thead>
<tr>
<th>Labials</th>
<th>Dentals</th>
<th>Palatoalveolars</th>
<th>Velars</th>
<th>Uvulars</th>
<th>Aryepiglottals</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>t</td>
<td>t</td>
<td>k</td>
<td>k</td>
<td>q</td>
<td></td>
</tr>
<tr>
<td>tt</td>
<td>tt</td>
<td>tt</td>
<td>kk</td>
<td>kk</td>
<td>q</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>d</td>
<td>d</td>
<td>gg</td>
<td>gg</td>
<td>q</td>
<td></td>
</tr>
<tr>
<td>bb</td>
<td>b</td>
<td>bb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>n</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>s</td>
<td>s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>f</td>
<td>f</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>z</td>
<td>z</td>
<td>z</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>w</td>
<td>w</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>u</td>
<td></td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>

Table 1. List of Tashlihyt Berber phonemes.
2. Experiment 1: Phonetic implementation of lexical geminates

Gemination has been examined in numerous production studies. The main aim of these works was to determine the exact phonetic differences between geminate and non-geminate consonants. I present a brief review of the main results obtained from some of these studies starting with previous works on Tashlhiyt Berber.

2.1. Previous works on Tashlhiyt Berber geminates

Some authors (e.g. Dell and Elmedlaoui 1997) consider the contrast between singletons and geminates to be mainly a length contrast while others (e.g. Galand 1997) take it as a tenseness distinction. Within CV phonology, Dell and Elmedlaoui (1997) represent a geminate consonant as a single melodic unit linked to two adjacent prosodic slots (see 1b above). Arguments in favour of such a non-linear representation of geminates are well established from a cross-linguistic point of view (See Kenstowicz (1994) for a review. See also the phonological and morphological arguments presented in Dell and Elmedlaoui (1997) based on a variety of Tashlhiyt Berber spoken in Imdlawn Valley). However, discussions of geminate consonants within this framework have not been explicit as to which acoustic or articulatory features this representation is supposed to reflect (see Lahiri and Hankamer 1988). Unless they are sufficiently abstract prosodic slots, the distinction between a single linked segment and its double linked counterpart is generally understood as predicting a distinction of consonant length, all other features being the same (see Clements 1986). One of the purposes of this paper to establish whether or not this impressionistic notion of consonant length, on which the phonological descriptions rely, is related to well-defined acoustic and articulatory attributes.

This sequence representation of Tashlhiyt Berber geminates is challenged in numerous studies (e.g. Galand 1988, 1997, Ouakrim 1993, 1994, 1999, Louali and Puech 1994). A major argument generally set out against this representation is related to the distribution of these segments and the way they are syllabified. Most of these authors adopt the standard view of syllable structure, according to which geminate consonants arise from sharing of articulatory specifications across the coda position of one syllable and the onset position of the next. In this theory, geminates only occur in medial position and apparent geminates in absolute initial or absolute final positions should on closer examination prove to be distinguished by some other feature, such as tenseness, rather than by length per se. As already shown in (2) above, Tashlhiyt Berber contrasts singletons and geminates in absolute initial and final positions, even for voiceless stops. According to Galand (1997), the fact that duration in initial position can not distinguish such pairs in this position, since nothing is heard until the release, implies that other correlates are used by Tashlhiyt Berber speakers (such as greater strength of the release, for example). These correlates are considered to be manifestations of the feature [+tense] which characterises these segments and distinguish them from their [-tense] counterparts. One specific question which will be investigated in Experiment 1 concerns this supposed absence of durational differences between voiceless singleton and geminate stops in initial position.

2.2. Geminates in other languages

In addition to Tashlhiyt Berber, geminates, namely word-medial ones, have been investigated in numerous languages. A review of the main results obtained from 24 such languages are reported in Table 2. This table shows the effect of gemination on the three main temporal parameters examined (preceding vowel duration, closure duration and release duration).
Table 2. A review of the main temporal acoustic attributes affected by gemination in 24 languages (Vld = preceding vowel duration, Cld = closure duration, Rld = release duration).

<table>
<thead>
<tr>
<th>Languages</th>
<th>Vld</th>
<th>Cld</th>
<th>Rld</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bengali</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>Lahiri and Hankamer (1988)</td>
</tr>
<tr>
<td>Bernese</td>
<td></td>
<td>++</td>
<td>-</td>
<td>Ham (1998)</td>
</tr>
<tr>
<td>Buginese</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>Cohn et al. (1999)</td>
</tr>
<tr>
<td>Burarran</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>Baker (1999)</td>
</tr>
<tr>
<td>Cypriot Greek</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>Arvantini and Tserdanelis (2000)</td>
</tr>
<tr>
<td>Hungarian</td>
<td>++</td>
<td>-</td>
<td>Ham (1998)</td>
<td></td>
</tr>
<tr>
<td>Iraqi</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>Hassan (2002)</td>
</tr>
<tr>
<td>Italian</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>Esposito and Di Benedetto (1999)</td>
</tr>
<tr>
<td>Jawon</td>
<td>++</td>
<td>-</td>
<td>Jaeger (1983)</td>
<td></td>
</tr>
<tr>
<td>Levantine Arabic</td>
<td>++</td>
<td>-</td>
<td>Ham (1998)</td>
<td></td>
</tr>
<tr>
<td>Madurese</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>Ham (1998), Cohn et al. (1999)</td>
</tr>
<tr>
<td>Pattani Malay</td>
<td>++</td>
<td>-</td>
<td>Abramson (1986)</td>
<td></td>
</tr>
<tr>
<td>Malayalam</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>Local and Simpson (1988)</td>
</tr>
<tr>
<td>Marathi</td>
<td>++</td>
<td>-</td>
<td>Lisker (1958)</td>
<td></td>
</tr>
<tr>
<td>Moroccan Arabic</td>
<td>++</td>
<td>+</td>
<td>Zeroual (2006)</td>
<td></td>
</tr>
<tr>
<td>Ngalakgan</td>
<td>++</td>
<td>-</td>
<td>Baker (1999)</td>
<td></td>
</tr>
<tr>
<td>Palestinian Arabic</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>Miller (1987)</td>
</tr>
<tr>
<td>Rembarrnga</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>McKay (1980)</td>
</tr>
<tr>
<td>Swedish</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>Hassan (2002)</td>
</tr>
<tr>
<td>Tamil</td>
<td>++</td>
<td>-</td>
<td>Keane (2002)</td>
<td></td>
</tr>
<tr>
<td>Toba Batak</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>Cohn et al. (1999)</td>
</tr>
<tr>
<td>Turkish</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>Lahiri and Hankamer (1988)</td>
</tr>
<tr>
<td>Zapotec</td>
<td>++</td>
<td>-</td>
<td>Jaeger (1983)</td>
<td></td>
</tr>
</tbody>
</table>

The only consistent acoustic characteristic shared by geminates in word-medial position is that they are significantly longer than their singleton counterparts. These systematic durational differences are reported in 100% of the 24 languages reviewed. Lahiri and Hankamer (1988), for example, investigated the timing properties of singleton/geminate voiceless stops in Turkish and Bengali. Their results show that closure duration is the most important correlate of the geminate/singleton opposition for both languages. In addition, VOT is longer for geminates in Turkish while vowel duration is unaffected. In Bengali, vowel duration is shorter before geminates (though not for all subjects), but VOT is unaffected. In his acoustic study on gemination in four different languages: Levantine Arabic, Standard Hungarian, Indonesian Madurese, and Swiss-German Bernese, Ham (1998) also found that the only acoustic correlate that distinguishes significantly geminates from singletons is closure duration. Positive VOT or burst duration do not contribute to the acoustic difference between these consonants in any of these languages.

In addition to temporal differences, singleton/geminate contrast may also be non-temporally implemented. Though these parameters have not been as much investigated as the temporal ones, several studies suggest that the phonetic implementation of gemination may have implications for most if not all of a form’s phonetic shape involving burst amplitude, vowel and consonant qualities and resonances. Local and Simpson (1988, 1999) are illustrative
examples of such studies. They showed that in Malayalam forms containing geminates differ systematically from those without geminates in terms of phonation, tense vs. lax articulations, consonant and vocalic resonances as well as patterns of articulatory variability in adjacent consonants (see also Payne 2006).

The phonetic characteristics of initial and final geminates have not been as much investigated as word-medial ones. This fact is unsurprising knowing that these segments are cross-linguistically rare (Davis 1999). Pattani Malay, which presents such geminates, is one of the few languages which has been investigated in depth (Abramson 1986, 1987, 1991, 1998, 1999). Results obtained from this language showed significant differences between forms with initial geminate and non-geminate voiceless stops in terms of burst amplitude and the fundamental frequency of the following vowel. A specific aspect concerns the temporal characteristics of such utterance-initial voiceless geminate stops: are they maintained or neutralised? As Abramson (1999: 591) has observed, there can be ‘no direct signal of the relative durations of stop closures in utterance-initial position’, since they exhibit no vocal tract excitation during their closure period. This makes it impossible to measure closure duration of utterance-initial voiceless stops from the acoustic signal. There are, however, some indirect means of measuring this duration, such as the aerodynamic measurements of oral air-flow (see Ridouane, forthcoming) or the electropalatographic measurements of tongue-to-palate contact over time (see Krachenmann and Jaeger 2003). This last articulatory procedure is the one used in this study. Under the obvious assumption that the phonetic closure correlates directly with the duration of linguapalatal contact, the aim is to examine whether or not significant durational differences will be maintained between voiceless singleton and geminate stops in utterance-initial position.

2.2. Speech material and Methods

The speech material analysed in this first production study is listed in Table 3. It consists of 36 forms opposing obstruent singletons to their geminate counterparts in three positions.

Table 3. List of stimuli with the target obstruents occurring in three positions: initial, intervocalic and final positions.

<table>
<thead>
<tr>
<th>Initial</th>
<th>Intervocalic</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>tid “those, fem.”</td>
<td>itid “for those, fem.”</td>
</tr>
<tr>
<td>tt</td>
<td>ittid “soap”</td>
<td>ittid “come nearer”</td>
</tr>
<tr>
<td>k</td>
<td>kif “like”</td>
<td>ikkin “earthenware”</td>
</tr>
<tr>
<td>kk</td>
<td>kkis “take off”</td>
<td>ikkis “he took off”</td>
</tr>
<tr>
<td>d</td>
<td>dis “with him”</td>
<td>idis “stomach”</td>
</tr>
<tr>
<td>dd</td>
<td>ddid “I went”</td>
<td>tiddi “height”</td>
</tr>
<tr>
<td>g</td>
<td>giz “I am”</td>
<td>igi “he was”</td>
</tr>
<tr>
<td>9g</td>
<td>9giz “go down”</td>
<td>iggi “floor”</td>
</tr>
<tr>
<td>s</td>
<td>sin “two”</td>
<td>isin “for two”</td>
</tr>
<tr>
<td>ss</td>
<td>ssir “lace”</td>
<td>issin “know”</td>
</tr>
<tr>
<td>z</td>
<td>zid “go forward”</td>
<td>izid “he went forward”</td>
</tr>
<tr>
<td>zz</td>
<td>zziz “oil”</td>
<td>izzit “for oil”</td>
</tr>
</tbody>
</table>

These forms are in minimal or near minimal pairs, in which the vowel preceding or following the target segments is the same (i.e. the vowel /i/). In two cases, nonsense words were chosen
due to a lack of actual Tashlhiyt Berber words with the relevant structure. Five Tashlhiyt Berber native male speakers were asked to read the token words five times in isolation, each time in a different random order. Test items were mixed with distracters not containing singleton/geminate contrasts. The data were recorded on a high-quality magnetic tape recording system, and sampled at 44100 Hz. Broad-band spectrograms of all utterances and visual displays of the corresponding waveforms were created and analysed using the Praat software package (Boersma 2001). Measurement criteria were established after visual inspection of both the spectrogram and the waveform. Four temporal and three non-temporal parameters were considered. These parameters constitute some of the most frequently observed acoustic correlates claimed to be involved in the singleton/geminate (or tense/non-tense) opposition.

\[ a. \text{Temporal parameters:} \]
- Duration of the pre-consonant vowel (V1d).
- Closure duration for stops (C1d).
- Consonant duration for fricatives (Frd).
- Release duration (Rld).

\[ b. \text{Non-temporal parameters:} \]
- Lenition (Frication) in stop closures (complete vs. incomplete seals).
- Presence or absence of release (i.e. burst-full vs. burst-less stops).
- Stop release amplitude (Root Mean Square amplitude).

Durational values for utterance-initial voiceless singleton and geminate stops were obtained based on temporal information about the articulatory closure using electropalatography (EPG3). For the annotation of linguapalatal contact duration, the onset was defined as the first frame at which there was complete contact of row one and/or two of the pseudopalate and the offset as the last frame before the partial or total contact release. In order to provide a statistical analysis of these EPG measurements, the data recorded were composed, in addition to the forms containing initial dental voiceless stops in Table 2, of 4 additional forms presented in Table 4. Each form was recorded ten times by two native speakers.

<table>
<thead>
<tr>
<th>Form</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>tili</td>
</tr>
<tr>
<td>tt</td>
<td>ttiti</td>
</tr>
<tr>
<td>t</td>
<td>tut</td>
</tr>
<tr>
<td>tt</td>
<td>ttut</td>
</tr>
</tbody>
</table>

\[ 2.3. \text{Results} \]
Figure 1 sums up the effect of gemination on each one of the temporal parameters examined. It shows the mean durations for each measurement across speakers, repetitions, places of articulation and positions. Vowel durations are pooled across all obstruents (stops and fricatives). Release duration values are presented separately for voiceless and for voiced stops, so as to highlight the differences in gemination effect for these two series of stops.
With the exception of VOT duration for voiceless stops, all the other temporal parameters are significantly affected by gemination in all positions. Consonant duration (and closure duration for stops) is the most robust correlate that distinguishes singletons from geminates; the latter being systematically longer than the former. A specific question raised in this study was to determine whether these durational differences between singletons and geminates would be maintained in absolute initial position for voiceless stops. Results, based on the EPG measurements of tongue-to-palate contact over time for the two subjects, show that these durational differences were robustly maintained for these segments in this position. Figures 2 and 3 illustrate these durational differences.

Figure 2. Durational differences, based on EPG, between initial singleton and geminate voiceless stops for the two subjects RA and HA.

Figure 3. An illustration of closure duration differences obtained using EPG data. The figure shows closure duration for the voiceless stops in /tili/ ‘ewe’ (left) and /ttili/ ‘have’ (right).
Characteristics other than closure duration also distinguished geminates from singletons, but less consistently. Release duration was significantly affected by the presence or absence of gemination only for voiced stops. No such significant differences were observed between the two series of voiceless stops. Similar findings were observed for Moroccan Arabic (Zeroual 2006) and Bengali (Mikuteit and Reetz, ms). Like Tashlihíyt Berber, in these languages, gemination has an effect on the release duration of voiced stops, but not for their voiceless counterparts. In Cypriot Greek, Arvaniti and Tserdanelis (2001) and Muller (2003) found that the release duration of voiceless stops is significantly affected by the presence of gemination; geminates having a longer aspiration duration than singletons (the Cypriot inventory does not include voiced stops). According to them, this acoustic property is present in order to enhance the differences between the two phonemic categories. In Tashlihíyt Berber, this interpretation is valid for voiced stops only. The occurrence of these differences is probably a consequence of the devoicing which affects geminate stops, so that the more devoiced a segment the longer its release duration. Figure 4 illustrates such a relationship between devoicing and release duration; the form containing the devoiced /dd/ clearly exhibits a longer release duration. The fact that longer release is produced in voiceless singletons than in voiced singletons, and in voiceless geminates than in voiced geminates provides additional evidence that differences in release duration between voiced singleton stops and geminates are probably a consequence of the devoicing which affects the longer stops.

![Figure 4. Waveforms and spectrograms of two realisations of an intervocalic voiced geminate stop /dd/ in [tiddi]. The figure on the left illustrates the realisation of a partially devoiced /dd/.

Preceding vowel duration was also found to be significantly affected by gemination; vowels being significantly shorter before geminates. The interaction between preceding vowel duration and gemination has been reported in many languages (33% of the 24 languages presented in Table 2, see also Maddieson 1985). This shortening is generally explained by syllable structure differences between singletons and geminates: the vowel is longer in an open syllable (V.CV)⁶ and shorter in a closed syllable (VC.CV). This explanation can probably account for the shortening observed in intervocalic position, where the first part of the geminate closes the syllable. Unless the final timing slot is considered to be extrasyllabic (see Vaux, forthcoming), this explanation cannot account for the shortening observed in absolute final position, since the vowel here is in a closed syllable for both singleton and geminate environments, but still shorter in the latter. Another plausible explanation would be to argue, along with Malécot (1968, 1970), that vowel shortening is due to the human tendency to anticipate relatively great efforts and to delay lesser ones, so that the more energy required by the consonant, the shorter the vowel (see also Ouakrim 1994 for Tashlihíyt Berber). These two interpretations are tested through the comparison of vowel duration in forms displaying the same syllable structure (i.e. VC.CVC), where CC is either a lexical geminate or a two-consonant cluster. These forms are presented in (3).
These items were read 5 times by 5 Tashlhiyt Berber native speakers, each form being embedded in the following carrier sentence: *inna jas ... jat twalt* ‘he told him ... once’. Measurement of the vowel durations show that /i/ is significantly shorter in the geminate context compared to the cluster context \(F(1, 198) = 22.573, p<.0001\). These durational differences are shown in figure 5.

![Figure 5. Vowel durations in VCC context (where CC = geminate or consonant cluster)](image)

The vowel shortening observed in Tashlhiyt Berber can not be considered a consequence of syllable structure differences, the vowel /i/ being in a closed syllable both for [ik.kid] and [ik.tid], but significantly shorter in the geminate environment. This shortening is interpreted, along with Malécot, as a consequence of the “tense” articulation that characterises geminate segments, so that the stronger the consonant, the shorter the preceding vowel. From an impressionistic point of view, geminate vs. non-geminate opposition is, in effect, often associated with supplementary features characterising a “tense” or “strong” articulation Jakobson et al. (1952) and Jessen (1998), for example, define geminates with the feature \[tense\], and Kohler (1984) proposes the feature \[fortis\] to characterise this opposition (see also Catford 1977, Ladefoged and Maddieson 1996).

The non-temporal differences observed in this study between singletons and geminates also correspond to the ones described in literature as being related to a “tense” articulation. Geminate stops are for instance produced with a higher RMS amplitude, compared to their singleton cognates. As is shown in figure 6, at the exception of one subject (AQ), the four other speakers were found to produce geminates with a higher release amplitude.
Figure 6. Effect of gemination on release RMS amplitude for initial and intervocalic voiceless stops.

Geminates were also systematically produced with complete closure, while their singleton counterparts were sometimes lenited and produced with noise leakage. The amount of incomplete seals varies according to the voiced/voiceless nature of singleton stops as well as to their place of articulation. Voiced singletons are more frequently realised with incomplete closure than their voiceless counterparts. Among the voiced stops, the tendency for incomplete closure is much higher for velars than for dentals. These findings support the contentions in literature that voiced singleton stops are weaker than their voiceless counterparts, and that velars are weaker than dentals (Foley 1977, Lavoie 1996, Ohala 2002). One last manifestation of the tense vs. non-tense articulation is related to the presence or absence of stops release. Geminates are systematically produced with a clearly identifiable noise burst, while singletons are sometimes burst-less. The absence of release, which results from a weaker manifestation of a stop (see Stevens and Keyser 1989), was observed mainly for voiced stops in final position, due also to the positional weakness characteristic of a coda compared to onset. For geminates, however, release was systematically maintained even in this position. This is unsurprising from a perceptual point of view, since for the perception of the primary correlate (i.e. duration), both starting and end points of this period need to be discernible.

2.4. Lexical geminates: representation and behaviour

The phonetic investigation shows that geminates and singletons are phonetically implemented by different correlates and supports the view that this contrast is not limited to the duration of the target segments. These articulatory and acoustic attributes can be characterised in three ways. Duration can be considered to be the primary correlate since the opposition expressed with it is produced in every context in which the contrast occurs, even for voiceless stops after pause. Differences observed in release duration, which were limited to voiced stops, can be considered to be concomitant correlates, since they occur only as a consequence of the devoicing which affects these segments due to their longer duration. Vowel shortening and higher RMS amplitude, interpreted as manifestations of a “tense” articulation, can be considered to be secondary correlates, since they are either contextually limited (vowel shortening) or present some variability across subjects (release amplitude). Vowel shortening is contextually limited since this correlate is present only when the geminate is preceded by a vowel. This correlate can not be implemented in initial position, nor in the numerous Tashlhiyt Berber cases where a word is composed of only one geminate obstruent (e.g. [kk] ‘cross’, [gg*] ‘wash’, [[§]] ‘eat’, etc.).

According to Enhancement Theory, developed by K.N. Stevens and his colleagues (Stevens, Keyser and Kawasaki 1986, Stevens and Keyser 1989, Keyser and Stevens 2006), a
distinctive feature is never used by itself to contrast lexical items, rather a supplementary enhancing feature is conveyed to phonetically increase the salience of the distinctive feature. This is the case, for instance, for the feature [+rounded] which is introduced to enhance the difference between back vowels and front vowels (Stevens, Keyser and Kawasaki 1986). This feature has the effect of increasing the auditory difference between front and back vowels by increasing their difference in second formant (F2) frequency. Data from Tashlhiyt Berber provide a further example showing that not only feature contrasts, but skeleton-based contrasts between simple and geminate speech sounds can be enhanced in the same way. The secondary correlates, interpreted as manifestations of the feature [tense], serve to enhance the primary correlate by contributing additional acoustic properties which increase the perceptual distance between singletons and geminates. In addition to being more variable than the primary correlate, these enhancing correlates display another property: they can take on distinctive function in cases where the primary correlate is not perceptually recoverable. This is, for instance, the case for voiceless stops after pause, where duration differences between singletons and geminates is not detectable by listeners.

Assuming a tight relationship between phonetic and phonological representations (see, for example, Pierrehumbert 1990, Keating 1990), and assuming that this closeness should be reflected in linguistic theory, the phonetic characteristics of Tashlhiyt Berber geminates are better captured by a structural treatment of these segments as two timing units associated to one melodic slot as in (4). This structural difference is reflected in the observed acoustic and articulatory differences in consonant duration:

(4)  
   \[ \begin{array}{c} 
   \text{a. } X \\
   \text{k} \\
   \text{b. } X \\
   \text{k} 
   \end{array} \]

Phonetic durations are assigned to these representations, allowing for segment-inherent and language-specific durations (see Clements 1986). For example, in Tashlhiyt Berber, geminate stops are more than twice as long than their singleton counterparts, whereas geminate fricatives are somewhat less than twice as long. In Turkish, geminate stops are about three times longer than their singleton counterparts, whereas in Bengali they are less than twice as long (Lahiri and Hankamer 1988). These durations are then adjusted for other factors which may lengthen the duration of these segments (e.g. the widely observed phenomenon of initial and final prosodic lengthening). The enhancing feature [tense], which may also contribute to a certain amount of duration added to geminates, is assigned to this representation through a phonetic implementation rule, as shown in (5).

(5) Phonetic implementation rule assigning the feature [tense]  
   \[ \begin{array}{c} 
   X \\
   \text{k} \\
   [+ \text{tense}] 
   \end{array} \]

The phonological representation in (5) largely solves some problems raised by the properties of geminate consonants. A particular aspect of these segments is that they behave in some respects as if they were two segments, and in others as if they were one, an aspect generally referred to in literature as “geminate ambiguity” or “geminate ambivalence” (Kenstowicz 1970). This representation accounts for the ambiguous behaviour of geminate consonants in the following way: the representation of the geminate is identical to the representation of a single segment in that both are comprised of only one feature bundle. The representation of
the geminate is also identical to the representation of two adjacent segments in that both are composed of two prosodic slots. Rules that require a feature representation mostly affect the quality of the segment, hence affecting geminates and singletons alike, while rules requiring a sequence representation generally affect the quantity of segments, hence affecting geminates and two-consonant sequences alike (Kenstowicz 1994).

Evidence suggesting that Tashlhiyt Berber geminates behave like single segments comes from a palatalization process. In Tashlhiyt Berber, velars may be realised as palatals before the front vowel /i/ (see Ridouane 1999). This palatalization affects singletons and geminates alike.

(6) Tashlhiyt Berber Palatalization

The similar patterning of singletons and geminates vis-à-vis the process of palatalization is accounted for straightforwardly in the CV framework. Rule (6) is expressed on the melodic tier where velar stops, be they singletons or geminates, are defined with the same feature bundle. As is demonstrated in (7), the process affects any velar stop immediately preceding the vowel /i/, regardless of whether this segment is singly or doubly linked.

(7) a. X X X X b. X X X X X X
   k i k^j i k i k^j i

While geminates behave as single segments for some processes, they also pattern like consonant clusters for others. A clear example comes from the way these segments are syllabified (see Dell and Elmedlaoui 1997). In Tashlhiyt Berber, a geminate consonant, unlike its singleton counterpart, can belong to two syllables at once, and behaves in this respect as a sequence of two consonants. Consider the following examples in (8) and their syllabic parsing given in (9).

(8) a. b i l a d “now”
   b. b a s s a d “today”
   c. h a l k a r “here is the bus’

(9) a. [b i l a d]
In (9b), the first half of the geminate is the coda of the first syllable, the second half being the onset of the following syllable. The syllable structure of this form is identical to that of (9c) but different from that of (9a). One main argument in favour of this syllable parsing in drawn from versification. In Tashlhiyt Berber poetry, all the lines of a piece often share the same meter. This meter is characterised by a succession of a definite number of metrical syllables, which are either light or heavy (Jouad 1983, 1986). A heavy syllable is one that has a coda consonant, while a light syllable lacks a coda consonant. Following the works of Jouad (1983, 1986) and Dell and Elmedlaoui (2002), it will be shown below that a Tashlhiyt Berber geminate patterns with a sequence of two segments (i.e. [as.sad] syllabified like [hal.kar]).

In the lines given in (10), the pattern is HLHLLHLHL. The meter is thus composed of 9 syllables where the first, third, sixth and eighth must be heavy and the others must be light. (10a) is the first line (and refrain) of a song by a Tashlhiyt Berber musical group called Iznzarn. (10b) is the first line of a text, well known in the area of Agadir and its suburbs, that modifies Iznzarn’s original song while keeping the same metrical pattern. The same text is given in Table 5, broken into nine boxes corresponding each to a metrical syllable.

(10) a. ʔassad izri wa ʔassad izri ‘today is gone, oh today is gone’
    b. halkar izri wa halkar izri ‘the bus is gone, oh the bus is gone’

Table 5. The text in (10) broken into 9 boxes corresponding each to a metrical syllable.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>a. ʔas</td>
<td>sa</td>
<td>diz</td>
<td>ri</td>
<td>wa ʔas</td>
<td>sa</td>
<td>diz</td>
<td>ri</td>
<td></td>
</tr>
<tr>
<td>b. hal</td>
<td>ka</td>
<td>riz</td>
<td>ri</td>
<td>wa hal</td>
<td>ka</td>
<td>riz</td>
<td>ri</td>
<td></td>
</tr>
</tbody>
</table>

What is worthy of notice here are the syllables in lines 1a. and 1b. In the original text, the syllable has a CVC structure, the coda being the first half of the geminate (i.e. ʔas). As is required by the parsing of this verse, in the modified text, the first syllable is also heavy (i.e. hal). The first syllable of the modified text can not contain a light syllable, otherwise the text would no longer be viewed by Tashlhiyt Berber speakers as a succession of well-formed lines with the same metrical pattern, and can no longer be song in accordance with this parse.

---

Submission to Papers in Laboratory Phonology X: Variation, Detail and Representation
3. Experiment 2: Underlying vs. derived geminates
In Tashlhiyt Berber, surface geminates may arise from three different sources. Tautomorphemic lexical geminates, represented underlyingly as single melodic units associated with two timing slots, are given in the lexicon. Heteromorphemic geminates may arise either by concatenation of two identical consonants at a word boundary or by total assimilation. Concatenated geminates are represented underlyingly as two timing slots each associated with a melodic unit. According to McCarthy (1986), these “fake” geminates can be identical to lexical geminates in surface representation, as a result of “Tier Conflation”. Assimilated geminates, which arise from the spread of one segment onto the other, are also represented as two timing units associated with a single melodic unit (Hayes 1986a). If these analyses are correct, all three types of geminates, no matter what their underlying representations, will all be identical at the surface level, all being represented as one melodic unit linked to two timing slots. In this second experiment, the three types of geminates are compared so as to determine whether or not they display the same acoustic correlates. Specifically, it questions the autosegmental approach which predicts that the outputs of external sandhi assimilation will fall into categories already established for lexical contrasts. Number of studies, specifically within the gestural overlap model, have in effect cast doubt on this traditional assumption of categorical phonological modifications at word boundaries (Browman and Goldstein 1990, Nolan 1992).

An aspect examined in the light of these instrumentally measurable phonetic properties is related to the behaviour of lexical and derived geminates. As is largely established in literature (see Kenstowicz 1994), lexical and assimilated geminates usually behave differently from concatenated geminates vis-à-vis certain phonological processes. The former are, for example, universally unaltered by spirantization, while the latter can be. If inalterability is attributed to phonetic considerations, as is advocated by different authors (Churma 1988, Kirchner 2001), one should then explain why lexical and assimilated geminates pattern together and behave differently from concatenated geminates.

3.1. Speech material and method
The speech material analysed in this second production study is listed in Table 6. It consists of 36 sentences (containing 12 of each type of geminates).

Table 6. List of the three types of geminates examined.

<table>
<thead>
<tr>
<th>Lexical</th>
<th>Assimilated*</th>
<th>Concatenated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voiceless dental stop</td>
<td>Innajas matta  t̪id</td>
<td>Innajas attasit</td>
</tr>
<tr>
<td></td>
<td>Innajas tattuy daw</td>
<td>Innajas attawit</td>
</tr>
<tr>
<td>Voiced dental stop</td>
<td>Innajas addal ns</td>
<td>Innajas adda yaf</td>
</tr>
<tr>
<td></td>
<td>Innajas addag ns</td>
<td>Innajas addis zr̪a</td>
</tr>
<tr>
<td>Voiceless velar stop</td>
<td>Innajas takka nu</td>
<td>innajas akkasna</td>
</tr>
<tr>
<td></td>
<td>Innajas akka jas</td>
<td>innajas akka su</td>
</tr>
<tr>
<td>Voiced velar stop</td>
<td>Innajas aggu nu</td>
<td>innajas aggis ga</td>
</tr>
<tr>
<td></td>
<td>Innajas aggas u̱n̪</td>
<td>innajas aggim dr̪n</td>
</tr>
<tr>
<td>Voiceless dental fricative</td>
<td>Innajas assas  t̪id</td>
<td>Innajas assis gnu</td>
</tr>
<tr>
<td></td>
<td>Innajas tassast ad</td>
<td>Innajas assal flu</td>
</tr>
<tr>
<td>Voiced dental fricative</td>
<td>Innajas azzan inu</td>
<td>Innajas azza fту</td>
</tr>
<tr>
<td></td>
<td>Innajas azzar inu</td>
<td>Innajas azza sli</td>
</tr>
</tbody>
</table>
The same type of obstruents as in experiment 1 were examined: voiced and voiceless dental stops and fricatives /tt, dd, ss, zz/ as well as voiced and voiceless velar stops /kk, gg/. The same contexts for the three types of geminates were provided. Specifically, each sentence is composed of six syllables, with geminates belonging to the fourth and fifth syllable (the first half being the coda of the 4th syllable and the second half the onset of the 5th syllable). Additionally, all geminate types were preceded by the same vowel /a/. Each sentence was read 5 times by 5 Tashlhiyt Berber native speakers. Five parameters, those affected by gemination in experiment 1, were measured: duration of the preceding vowel (V1d), closure duration (Cld), consonant duration for fricatives (Frd), release duration (Rld), and RMS amplitude of the burst.

3.2. Results

Figure 7 sums up the effect of the different types of geminates on each one of the temporal parameters examined. It shows the mean durations for each measurement across speakers, places and manners of articulation. Closure duration and consonant duration for fricatives are pooled together (Cnd).

Results show that the three types of geminates are produced with virtually the same consonant durations (closure duration for stops). The ANOVA analysis performed on this parameter showed that there are no significant differences between lexical, assimilated and concatenated geminates \( [F(2, 45) = .711, p=.4966] \). As is the case for consonant duration, all three types of geminate stops are also produced with virtually the same release durations. The ANOVA analysis showed no significant differences between these three series \( [F (2,12) = 1.388, p=.2870] \), for voiceless stops, and \( [F (2,12) = .227, p=.8001] \) for their voiced counterparts.

These results, showing that all three types of geminates display the same durational values (closure duration + release duration for stops) were also obtained by Lahiri and Hankamer (1988) on Bengali. However, contrary to what was found in this language, significant differences are observed in the preceding vowel durations between the three types of geminates in Tashlhiyt Berber. Figure 8, which reports the durational values for these vowels, shows that /a/ is significantly shorter before lexical and assimilated geminates than before concatenated geminates. A Fisher’s PLSD post hoc test (Table 7) shows significant differences between lexical and assimilated geminates on the one hand and concatenated geminates on the other hand.
Table 7. Post-hoc test for preceding vowel duration differences.

<table>
<thead>
<tr>
<th></th>
<th>Mean difference</th>
<th>Critical difference</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexical, concatenated</td>
<td>14.50</td>
<td>8.46</td>
<td>.0012</td>
</tr>
<tr>
<td>Lexical, assimilated</td>
<td>1.10</td>
<td>8.46</td>
<td>.7946</td>
</tr>
<tr>
<td>Concatenated, assimilated</td>
<td>15.60</td>
<td>8.46</td>
<td>.0006</td>
</tr>
</tbody>
</table>

Another important difference between lexical and assimilated geminates on the one hand and concatenated geminates on the other hand concerns the RMS amplitude of the burst. Results, illustrated in figure 9, show that the former are produced with a higher burst energy, compared to the latter. A Fisher’s PLSD post hoc test showing these significant differences is reported in Table 8.

Table 8. Post-hoc test for RMS amplitude differences.

<table>
<thead>
<tr>
<th></th>
<th>Standard deviation</th>
<th>Critical error</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexical, concatenated</td>
<td>.110</td>
<td>.106</td>
<td>.0429</td>
</tr>
<tr>
<td>Lexical, assimilated</td>
<td>.001</td>
<td>.106</td>
<td>.9780</td>
</tr>
<tr>
<td>Assimilated, concatenated</td>
<td>.112</td>
<td>.106</td>
<td>.0006</td>
</tr>
</tbody>
</table>

3.3. Derived geminates: representation and behaviour

The acoustic investigation shows that phonologically derived geminates display the same temporal values as lexical geminates, all being produced with virtually the same consonant durations (closure duration for stops). This supports the assignment of the same timing representation to these three types of geminates (i.e. two timing slots). However, compared to underlying geminates, a major difference has been observed between assimilated and
concatenated geminates. While assimilated geminates, like lexical ones, shorten the preceding vowel and are produced with higher RMS amplitude, concatenated geminates do not. In other words, assimilated geminates, being phonetically implemented with additional enhancing correlates, manifest the same characteristics as “true” geminates. This finding, which shows that post-lexical geminates arising from total assimilation are categorically identical to underlying geminates, has also been observed in Sardinian (Ladd and Scobbie 1999). It provides additional evidence that external sandhi assimilation is correctly accounted for within the autosegmental model, in which feature spreading and delinking give rise to multiply-linked structures that are identical to underlying geminates. This model is also sufficient for concatenated geminates, provided they are represented at the surface level as two timing slots each associated with a melodic position. The phonetic implementation rule whereby doubly linked segments are assigned the feature [+tense] will not apply to this consonant sequence since the structural description of this rule implies that the melodic tier be linked to two timing positions. Clearly, the mere fact of having adjacent identical segments is not sufficient in itself to manifest the expected phonetic characteristics of a “true” geminate.

Interestingly, in terms of phonological behaviour, lexical and assimilated geminates also pattern together as opposed to concatenated geminates. In a variety of Tashlihyt Berber (the Haha variety spoken in the High Atlas area, henceforth HTB), the former are not affected by spirantization, while the latter is. In other words, lexical and assimilated geminates display what is known in literature as Geminate Inalterability, while concatenated geminates do not. Let us illustrate this property through the examination of the morphophonemic alternation between singleton spirants and geminate stops displayed in (11).

\[(11)\]

\[
\begin{array}{lll}
\text{Imperative Form} & \text{Intensive Form} \\
\text{a.} & \text{ftu} & \text{fttu} & \text{‘to walk’} \\
& \gamma \nu & \gamma \nu \nu & \text{‘to sew’} \\
& rz & rzza & \text{‘to break’} \\
\text{b.} & xrz & kkrz & \text{‘to plow’} \\
& \gamma n & \gamma \gamma n & \text{‘to sleep’} \\
& \eta \beta u & \eta \beta \beta u & \text{‘to hide’} \\
\end{array}
\]

The main questions raised by these data concern the representation of the singleton/geminate alternations (11a and 11b), and the spirant/stop alternations (11b). Concerning the singleton/geminate alternation, Dell and Elmedlaoui (1989) developed a set of rules accounting for this phenomenon, and concluded that the geminates in alternating forms should be derived from non-geminate consonants. Concerning the geminate stop/singleton spirant alternation, one must decide in some principled way whether the underlying segment is a stop or a spirant. There appears to be strong evidence for positing underlying single stops and deriving the spirants from these segments. This solution, supported by concepts of markedness and implicational universals, is observationally adequate. The spirantization rule is a synchronic obligatory one; recent Arabic loan words occurring with phonetic non-geminate stops are realised with spirants in HTB, as is shown in (12).

\[(12)\]

\[
\begin{array}{lll}
\text{Moroccan Arabic} & \text{HTB} \\
\text{lkas} & \text{lxas} & \text{‘glass’} \\
\eta \text{km} & \text{hxm} & \text{‘govern’} \\
\text{ltkta} & \text{lxta} & \text{‘cloth’} \\
\text{lgzzar} & \text{aqzzar} & \text{‘butcher’} \\
\end{array}
\]
The only stable rule under these conditions is a spirantization context-free rule, whereby non-dental singleton stops are spirantized. HTB geminate stops resist the application of this rule:

(13) Singleton spirantization and geminate blockage in HTB

<table>
<thead>
<tr>
<th>Language</th>
<th>Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>/baba/</td>
<td>‘father’</td>
</tr>
<tr>
<td></td>
<td>/akal/</td>
<td>‘land’</td>
</tr>
<tr>
<td></td>
<td>/gawr/</td>
<td>‘sit down’</td>
</tr>
<tr>
<td>b.</td>
<td>/tibbit/</td>
<td>‘breast’</td>
</tr>
<tr>
<td></td>
<td>/tawkka/</td>
<td>‘worm’</td>
</tr>
<tr>
<td></td>
<td>/aggas/</td>
<td>‘injury’</td>
</tr>
</tbody>
</table>

Why do geminate stops resist the application of spirantization (13b), though it applies to their singleton counterparts (13a)? In other words, why does spirantization fail to turn the geminate bb’s into geminate ββ’s? This inalterability of geminates is a universal characteristic observed in different unrelated languages (e.g. Tiberian Hebrew, Tigrinya. See Kirchner (2001) for a review). Different proposals have been posited to account for it (e.g. Hayes’ (1986) Linking Constraint, Schein and Steraide’s (1986) Uniform Applicability Condition). In a criticism of these proposals as mere notional machinery restating observational facts instead of predicting significant generalisations, Churma (1988) argues that recognising a distinction between “weakening” and “strengthening” rules will allow for a theory which has significantly greater predictive power (see also Foley 1977, Elmedlaoui 1993). In particular, he argues that it is the inherent “strength” of geminate consonants that prevents a weakening process like spirantization from affecting them. Churma (1988), along with Foley (1977) and Hooper (1976), place geminate consonants at the bottom rung of the sonority hierarchy, i.e. at the top rank of the inherent segmental strength. A slightly different account of geminate strength has been proposed by Elmedlaoui (1993) who sees in gemination rather a positional and metrical or moraic property, and places geminates at the top rank of positional strength. Besides these phonological hypotheses on geminate tenseness or « strength » (Hooper 1976, Foley 1977, Churma 1988, Elmedlaoui 1993), this property is established in this work on a phonetic ground. In addition to their extra duration, lexical geminates are shown to display characteristics of a strong articulation, the manifestations of which are mainly related to the shortening of the preceding vowel, the higher RMS amplitude of the burst, the systematic absence of noise leakage during closure, and the systematic presence of stop releases.

Assimilated geminates, like lexical geminates, are also shown to display the same tenseness characteristics. Interestingly, this type of geminates also resist the application of this weakening process, as is shown in (14).

(14) Spirantization Blockage in assimilated geminates

<table>
<thead>
<tr>
<th>Language</th>
<th>Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>/rad-k-awin/</td>
<td>rakk awin (*raxx awin) ‘they will take you’</td>
</tr>
<tr>
<td></td>
<td>/rad-gis gaβ/</td>
<td>raggis  yaβ (*  γαγγ  γαβ ) ‘I will put in it’</td>
</tr>
</tbody>
</table>

Concatenated geminates, on the other hand, are affected by spirantization as data in (15) demonstrate. The weakening observed here is due to the failure of the concatenated segments to surface with the same enhancing correlates as true geminates, and thus display characteristics of a tense segment. In other words, concatenated geminates are not “strong” enough to resist the application of this weakening process.
(15) Spirantization of concatenated geminates

```
/jufak kiyyi/  jufax xiyyi  ‘it is better for you’
/imrg gma/    imrγ γma    ‘my brother was ashamed’
```

As Churma observed, aside from degemination, no non-assimilatory weakening process may affect strong consonants (see also Foley 1973). A parallel may be made between this observation and a rather unexpected property displayed by enhancing correlates. Based on numerous examples drawn from different languages, Keyser and Stevens (2006) observed that while the basic correlates are, in certain contexts, subject to weakening or obliteration, enhancement correlates are far more robust and are apparently never weakened or obliterated. In Tashlhiyt Berber, the enhancing correlates of geminate stops, those responsible for the strength displayed by these segments, also resist the application of weakening rules. In other words, once introduced to reinforce existing contrasts between two sounds, the enhancing correlates tend to survive, and may eventually supplant the basic correlate which they originally served to enhance.

### 4. Conclusion

In Tashlhiyt Berber, the primary correlate distinguishing singletons from geminates is duration, even for voiceless stops after pause. This primary correlate is enhanced by additional acoustic attributes (such as vowel shortening, higher RMS amplitude, etc.), interpreted as manifestations of a tense articulation. These enhancing correlates are present in order to increase the perceptual distance between the two phonemic categories, and may take on a distinctive function if the primary correlate is not perceptually recoverable. The acoustic and articulatory characteristics of geminates are captured within CV phonology by a structural representation of these segments as two timing units associated to one melodic slot, and for an interpretation of that representation according to which the relevant timing measure is the duration of the consonant (and of closure duration for stops). Such a representation, as shown by data drawn from a palatalization process and syllabification, correctly accounts for the dual behaviour of geminates. The comparison between lexical and phonologically derived geminates shows that they all display the same temporal values which supports the assignment of the same timing representation to these three types of geminates. However, a major difference between assimilated and concatenated has been observed. While assimilated geminates, like underlying ones, are enhanced by additional acoustic attributes, concatenated geminates are not. Interestingly, in terms of behaviour, lexical and assimilated geminates also pattern together as opposed to concatenated geminates. The former are, for example, unaltered by spirantization while the latter is. In order to account for the distinct behaviour of these segments, a distinction was made between “true” and “fake” geminates. True geminates, including lexical and assimilated geminates, are phonetically implemented by the feature [tense] which accounts for the “strength” displayed by these segments. Following Churma (1988), I argue that it is the tenseness of these geminate stops that prevents any weakening process (such as spirantization) from affecting them.
Notes

1 Here is the signification of the symbols used in Table 2. ‘+’ means that the parameter is significantly affected by gemination though there is some variability (depending either on speakers, contexts or type of consonants). ‘++’ means that the parameter is highly significant. ‘-‘ means that the parameter is not significantly affected by the presence of gemination. The empty cells indicate that the corresponding parameter has not been investigated.

2 These words were not embedded in a carrier sentence so as to ensure that initial and final obstruents were indeed produced in utterance initial and final positions.

3 A detail presentation of the criteria used to extract these acoustic parameters is spelled out in Ridouane (forthcoming).

4 A question that comes immediately in mind in view of these results is whether isolated words beginning with voiceless stops can be identified as to length category. If Tashlihiyt Berber native speakers cannot recover the length contrast in this position, this will not be due to phonological cum phonetic neutralization (as is the case, for instance, for initial geminate (or tense) stops in Korean, see Han 1996), but simply due to the primary correlate not being implementable after pause.

5 In addition to durational differences, figure 3 shows that geminate stops are produced with a larger linguapalatal contact than singletons.

6 Periods indicate syllable boundaries.

7 Other examples are presented in Dell and Elmedlaoui (1997) and Galand (1997).

8 Scansion operates regardless of morphological or syntactic boundaries, as is the case in Tashlihiyt Berber poetic scansion in general (see Jouad 1983).

9 Assimilated geminates arise from total assimilation of the preverb final consonant in /ad/ to the following obstruents (e.g. [attasit] from /ad tasit/ “to take”).

References


Brownman, C.P. and Glodstein, L 1990 Tiers in articulatory phonology, with some implications for casual speech. In J. Kingston and M.E. Beckman (eds.), Papers in

Churma, D 1988  *On 'on geminates'*. Ms., Suny-Buffalo.


Han, J-I 1996  *The phonetics and phonology of “tense” and “plain” consonants in Korean*. Ph.D. Dissertation, Cornell University.


Local, J. and Simpson, A 1999 Phonetic implementation of geminates in Malayalam nouns. Proceedings of the 14th International Congress of Phonetic Sciences 1, 595-598


Miller, A 1987 Phonetic characteristics of Levantine Arabic geminates with differing morpheme and syllable structures. Ohio State Papers from the Linguistics Laboratory 36,120-140.


Ouakrim, O 1994 Un paramètre acoustique distinguant la gémination de la tension consonantique. Études et Documents Berbères 11, 197-203.


Ridouane, R 1999 *La spirantisation dans un parler berbère du Maroc (parler chleuh de Haha).* Diplôme d’Etudes Approfondies, Université Paris 3.


