A PHONETIC STUDY OF GEMINATION IN LEBANESE ARABIC

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ABSTRACT

This paper reports on phonetic and phonological patterns of gemination in Lebanese Arabic (LA) and on the temporal relationship between geminate consonants and vowel length. While previous studies have generally used controlled data only, the present study investigates the effect of style on absolute and proportional durations by eliciting data from both word-lists and spontaneous speech.

Five females from Beirut were recorded reading target word-lists containing medial singleton and geminate consonants preceded by long and short vowels and engaging in naturalistic conversations. Acoustic and auditory analyses of medial consonants and of preceding and following vowels were made. Results from word-lists show separate distributions for singleton and geminate consonants and for short and long vowels. Medial consonants and preceding vowels show proportional rather than absolute temporal compensation. In spontaneous speech, the distributions for singleton and geminate consonants and for target short and long vowels show considerable overlap. Moreover, target long vowels and geminate consonants overlap in duration with singleton targets in word-list style, but proportional durations still contribute to the percept of phonological length.

Keywords: Gemination; Lebanese Arabic; temporal relations; duration; speech style.

1. INTRODUCTION

Gemination is a phonological property of LA. All 27 consonants in LA can be geminated. Vowel length is also phonemic, and both long and short vowels occur before geminate consonants [20, 21]. Word medial consonants can therefore occur in the trochaic contexts[1]:

Table 1: Gemination in medial contexts in LA.

CV**C**V(C)	CV**CC**V(C)	C**VV**CV(C)	C**VVCC**V(C)
/ˈtˤabaʔ/	/ˈtˤabbaʔ/	/ˈtˤaabaʔ/	/ˈtˤaabbe/
'dish'	*'he persuaded'*	*'he matched'*	*'she is bending over'*

The phonetic realization of the geminate contrast and the temporal relationship between medial consonants and their surrounding vowels has been the subject of many cross-linguistic and cross-dialectal studies (e.g. [1, 3, 4, 6, 8-11, 15, 16, 18, 23, 24]). The general consensus is that duration plays a major role in distinguishing singleton and geminate consonants in languages, but that other articulatory and acoustic cues contribute to the perceptual effect of gemination. These include the duration and spectral characteristics of the preceding vowel and the manner of articulation of the medial consonant. Non-temporal characteristics such as a more centralized vowel, more frequently lenited/fricated stops, and lower burst amplitude in singleton contexts suggest a tense/lax distinction that is thought to enhance the perceptual distance between singletons and geminates.

This study contributes to the literature on gemination by providing a detailed examination of LA. There are few phonetic studies of LA [7, 9, 20, 21, 22], and none on the acoustic patterns of consonant and vowel length in the colloquial variety. While consonant gemination in LA is very frequent and plays an important morpho-syntactic role in the language, little is known about the phonetic realization of singleton and geminate targets in this dialect or about the role played by the preceding vowel. The same is true regarding phonemic vowel length. LA has a rich inventory of vowels [13] compared with the traditional three-way distinction in Standard Arabic, with short and long vowels being qualitatively and quantitatively different. Moreover, the long open vowel is often raised in many LA accents due to a process known as Imala [20]. Imala refers to the realization of /aa/ as [eː] in the neighborhood of and /i/ vowel (e.g. /ʒaamiʕ/ as [ʒeːmiʕ] 'mosque'), but in LA it can occur without the presence of an /i/. Both these factors may in some contexts deflect attention from the durational contrast due to the loss of minimal pair distinction that would normally be achieved through vowel length (e.g. /sabaʔ/ 'race' *vs* /saabaʔ/ 'he raced' is now [sabaʔ] *vs* [seːbaʔ]).

The study also examines the effect of style on absolute and proportional durations of target short and long consonants. Arvaniti [3, 4] compared the effect of fast speech rate on singleton and geminate consonant duration in Cypriot Greek and found that there was still no overlap between singleton and geminate targets despite the fact that both targets shortened. In both styles, however, the informants read utterances from a scripted text. To my knowledge, no previous study has investigated the extent to which duration still plays a role in consonant gemination and phonemic vowel length in spontaneous speech.

2. METHODOLOGY

Five females from Beirut aged between 23 and 39 were audio recorded in a quiet room reading a word-list with randomized target short and long vowels and consonants in disyllables with medial VCV, VVCV, VCCV and VVCCV structure (Table 2). The recordings were made digitally at a 44.1 KHz 16-bit sampling rate using an Edirol R9 solid-state recorder with a Sony microphone.

Designing near-minimal sets for the four syllable types was challenging due to the low frequency of occurrence of target words with medial VVCCV structure. Some of the words with this structure were rejected by the subjects, which yielded fewer tokens for this context compared with the other three. The vowel before (V1) and after (V2) the target consonant in each case was /a/ or /aa/, though these were sometimes realized differently by the speakers due to Imala. All Lebanese consonants were elicited in their singleton and geminate form, but this paper presents results for stops, nasals, and liquids: /b, t, d, k, m, n, l, r/. In order to obtain spontaneous speech, the subjects were then asked to recall two incidents that brought about the happiest and the saddest or scariest moments of their lives (following the Labovian sociolinguistic interview technique [19]). Each of the stories lasted about 5 minutes.

With the exception of the medial VV1CCV2 structure, three tokens per person for each of the target consonants in each of the syllable types were extracted from the word-lists for auditory and acoustic analysis (Table 2). Durational measurements (in ms) of V1, the medial C or CC target and V2 were made using PRAAT version 4.4.16 [5]. Measurements of medial stops included the closure duration as well as the release burst and VOT with no attempt to separate them in this case since the main aim was to examine overall consonant durations over various manners of articulation and to compare these with the durations of the preceding and following vowels.

Table 2: Target words for each of the syllable types and each of the consonants examined. There were no tokens of /t/ with a medial VV1CCV2 structure.

	V1CV2	V1CCV2	VV1CV2	VV1CCV2
b	ʔabadˤ sabaʔ ʔabadˤ	ʔabbadˤ sabbaʔ ʔabbadˤ	ʔaabidˤ seebaʔ ʔaabidˤ	ʔaabbe seebbe ʔeebbe
t	katab ʔatal fatal	kattab ʔattal fattal	keetib ʔaatil feetil	______ ______ ______
d	ʕadad badal ʒadal	ʕaddad baddal ʒaddal	ʕaadid beedal ʒeedal	ʕaadde seedde ʒeedde
k	ħakam sakat sakan	ħakkam sakkat sakkan	ħaakam seekit seekin	ħaakke seekke ______
m	ʕamal samaʕ ħamal	ʕammal sammaʕ ħammal	ʕaamil seemaħ ħaamil	ʕaamme seemme dˤaamme
n	bana sˤanaʕ ʔanaʕ	banna sˤannaʕ ʔannaʕ	beene sˤaaniʕ ʔaaniʕ	meenne ħaanne ______
l	ʕalam malak ʔalab	ʕallam mallak ʔallab	ʕaalam maalik ʔaalib	ʔaalle meelle feelle
r	baram barad harab	barram barrad harrab	baarim beerid heerib	maarra ʒeerra ______

Comparable targets with stops, liquids and nasals were extracted from the spontaneous interactions. The frequency of occurrence of each consonant and syllable type was, as expected, variable. The most commonly occurring pattern was the medial V1CCV2(C) syllable type and the most commonly occurring consonants were nasals and laterals. Future research is needed to establish whether these are indeed the most frequent consonants and syllable type in LA. Only two occurrences of disyllables with a medial VV1CCV2 structure occurred in the spontaneous speech corpus, which confirms the low frequency occurrence of target words with long vowels and consonants. A total of 443 word-list and 216 spontaneous speech tokens were analyzed.

3. RESULTS

3.1. Word-list results

Figures 1 and 2 show absolute and proportional means and distributions for V1, C, and V2 in short and long targets for all speakers and all consonant contexts. Table 3 lists the means and standard deviations for the above targets and the ratios of C to CC in short and long vowel contexts.

In V1CV2 contexts, V2 durations are the longest. There is considerable overlap between V1 and C (Fig. 1), although the difference between the two distributions is statistically significant ($t(119)= 2.80$, $p < .005$). This effect is due to the very short tap durations for /r/ medial consonants, ranging between 12 and 27ms (when the tap measurements are taken out there is no statistical significance between the two distributions for V1 and C).

In V1CCV2 contexts, the medial consonant has the longest duration, and there is little overlap between the distributions for V1 and CC. The overlap appears due to the short trill measurements for /r/. The absolute vowel durations preceding the geminate consonant are not significantly different from those found for vowels preceding singleton consonants in V1CV2 contexts ($F(3, 439)= 562.94$; $p = .95$). However, when we examine the proportional durations as a function of the VCV sequence (Fig. 2), it is clear that V1 in V1CCV2 contexts contributes a smaller proportion of the overall duration compared with V1 in V1CV2 contexts. This suggests overall temporal compensation between vowels and consonants at the proportional rather than the absolute level.

In VV1CV2 contexts, VV1 has the longest duration (as expected) with very little overlap between the distributions for VV1 and C. The distributions for C duration in V1CV2 and VV1CV2 are significantly different despite the considerable overlap ($F(3, 439)= 382.18$; $p = .041$). Interestingly, the mean duration for C in VV1CV2 contexts is longer than in V1CV2 contexts. However, proportional durations (Fig. 2) still show a smaller percentage for C in V1CV2 than in VV1CV2 contexts, suggesting overall temporal compensation between vowels and consonants when the vowel is long.

Finally, in VV1CCV2 contexts, the target long vowel and consonant are relatively shorter than their long counterparts in VV1CV2 and V1CCV2 contexts (For V: $F(3, 439)= 562.94$, $p < .0001$; for C: $F(3, 439)= 382.18$, $p < .0001$). However, they are still longer than phonologically short V1 and C in V1CV2 contexts, though this is only significant for V1 ($p < .0001$). There is a great degree of overlap between the distributions for VV1 and CC in the VV1CCV2 context, although the difference between the two distributions is statistically significant ($t(84) = -2.23$, $p < .05$). This is again mainly due to the short tap durations for medial /r/.

Figure 1: Mean duration (white squares) and distribution (black bars) for vowels and consonants in word-list tokens with medial V1CV2, V1CCV2, VV1CV2, and VV1CCV2 structure.

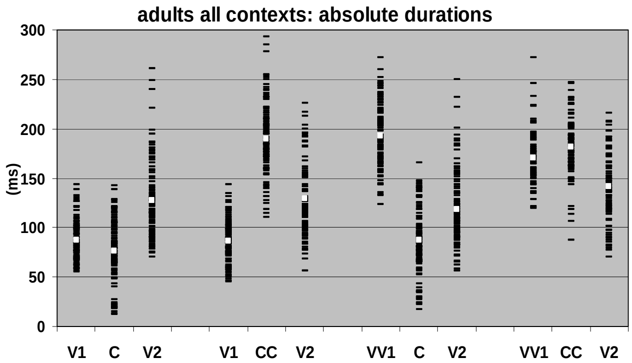

Figure 2: Mean proportional duration (white squares) and distribution (black bars) for vowels and consonants in word-list tokens with V1CV2, V1CCV2, VV1CV2, and VV1CCV2 structure.

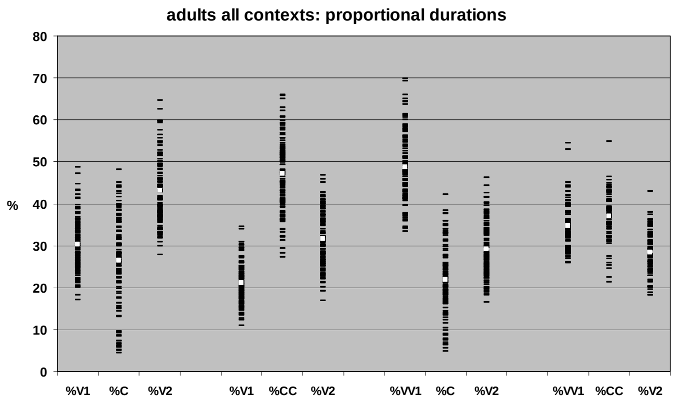

Table 3 shows that the ratio of C to CC is smaller in long VV1 than in short V1 contexts. This is due to C duration being longer in VV1CV2 than V1CV2 contexts and CC duration being shorter in VV1CCV2 than V1CCV2 contexts. While the latter is expected due to the long preceding VV1, it is not clear why C in VV1CV2 contexts was on average longer than in V1CV2 ones.

Table 3: Mean duration (in ms) and standard deviations (in brackets) for vowels and consonants in word-list tokens with medial V1CV2, V1CCV2, VV1CV2 and VV1CCV2 structure.

V1CV2			**V1CCV2**		
V1	C	V2	V1	CC	V2
88 (20)	76 (30)	127 (40)	86 (21)	190 (35)	130 (38)
Ratio of C to CC = 1 to 2.50					
VV1CV2			**VV1CCV2**		
VV1	C	V2	VV1	CC	V2
193 (31)	87 (33)	118 (37)	170 (27)	182 (31)	141 (36)
Ratio of C to CC = 1 to 2.09					

Table 4 shows results for each of the consonant categories separately. It can be seen that the shortest consonants are taps and trills followed by the lateral and alveolar nasal, and the longest consonants are the voiceless stops. In terms of singleton to geminate ratio (Table 5), the order is reversed, with the shortest durational difference occurring between voiceless stops, while liquids and the alveolar nasal show the greatest difference in duration between singleton and geminate targets.

Table 4: Mean duration (in ms) and standard deviations (in brackets) for each of the consonants examined in singleton and geminate targets.

	C		**CC**	
	VCV	**VVCV**	**VCCV**	**VVCCV**
b	76.9 (9)	89 (8)	188 (27)	196 (23)
t	106 (9)	132 (16)	227 (29)	
d	78 (13)	89 (17)	191 (20)	195 (24)
k	119 (12)	133 (9)	225 (22)	216 (23)
m	83 (10)	85 (8)	188 (33)	182 (23)
n	63 (14)	69 (8)	186 (24)	168 (34)
l	65 (13)	69 (9)	170 (25)	172 (16)
r	20 (4)	32 (9)	147 (25)	135 (21)
All Cs	**76 (30)**	**87 (33)**	**190 (35)**	**182 (31)**

Table 5: Ratio of short to long consonants

	Ratio of C to CC in short V contexts	**Ratio of C to CC in long VV contexts**
b	1 : 2.48	1 : 2.21
t	1 : 2.14	----
d	1 : 2.45	1 : 2.19
k	1 : 1.89	1 : 1.63
m	1 : 2.26	1 : 2.13
n	1 : 2.97	1 : 2.44
l	1 : 2.63	1 : 2.48
r	1 : 7.50	1 : 4.27
Mean	**1 : 2.50**	**1 : 2.09**

3.2. Spontaneous speech

The absolute temporal measurements for V(V)1, C(C) and V2 were significantly shorter in the spontaneous interactions compared with the word-list data, but the general temporal relations between V1 and C in spontaneous speech are comparable to those found in word-lists. Figures 3 and 4 show absolute and proportional means and distributions for V1, C, and V2 for three of the four consonant contexts examined in word-lists (due to the lack of occurrence of words with medial VV1CCV2 structure in the spontaneous data). Table 6 lists the means and standard deviations for the above targets and the ratio of C to CC in short vowel contexts.

Looking at absolute durations first, all three sounds (V1, C, and V2) are predictable shorter in spontaneous speech than in the word-list style (For V1: $F(1, 655)= 296.20$, $p < .0001$; for C: $F(1, 655)= 152.41$, $p < .0001$; For V2: $F(1, 655)= 92.95$, $p < .0001$). The durations for the geminate consonants in spontaneous speech are closer to those of the singleton targets in the word-lists. Moreover, the ratio of C to CC in short vowel contexts is considerably lower than what was found in the word-list style, especially when considering that most of the spontaneous tokens consisted of nasals and laterals. This greater overlap between C and CC was noted during the auditory analyses as well, with 35% of the target long consonants being auditorily identified as having only short or medium length. The same was true of target long vowels in CVV1CV2 contexts, with 50% being identified as short or medium. V2, on the other hand, showed variation the most due to its occurrence in utterance-medial or final pre-pausal position. Moreover, while in the word-lists V2 was only longer than V1 and C in short vowel and consonant contexts (V1CV2), it was the longest in all three contexts examined in spontaneous speech.

In terms of proportional durations, while there is a lot more overlap between V1 and CC in V1CCV2 contexts and between VV1 and C in VV1CV2 contexts, the general temporal relations between V1 and C in spontaneous speech are similar to those found in word-lists. That is, they have comparable proportional durations whereby V1 and C overlap in CV1CV2 ($t(68) = 1.65$ $p = .104$) contexts while CC is proportionally longer than V1 in V1CCV2 ($t(112) = -11.24$ $p < .0001$)

and V1 is proportionally longer than C in VV1CV2 contexts ($t(41) = 5.17$ $p < .0001$).

Figure 3: Mean duration (white squares) and distribution (black bars) for vowels and consonants extracted from spontaneous speech in medial V1CV2, VV1CV2, and VV1CV2 contexts.

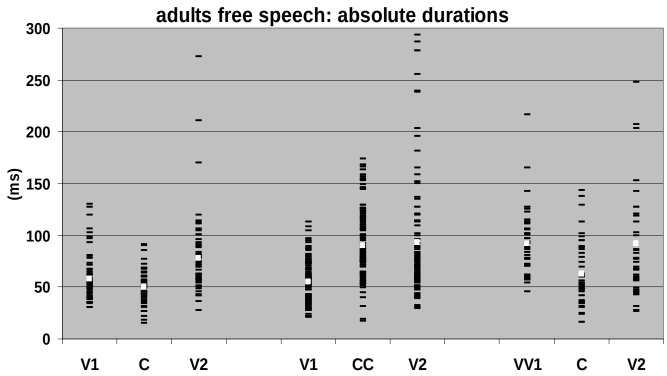

Figure 4: Proportional duration (white squares) and distribution (black bars) for vowels and consonants extracted from spontaneous speech in medial V1CV2, VV1CV2, and VV1CV2 contexts.

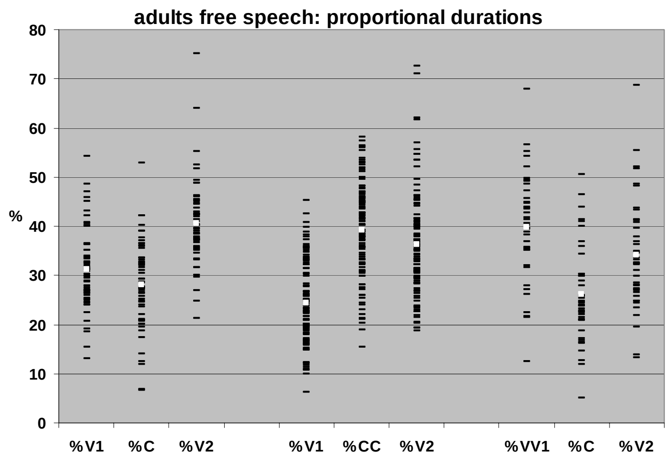

Table 6: Mean duration (in ms) and standard deviations (in brackets) for vowels and consonants in medial V1CV2, VV1CV2, and VV1CV2 contexts in spontaneous speech.

V1CV2			V1CCV2			VV1CV2		
V1	C	V2	V1	CC	V2	VV1	C	V2
58 (24)	50 (16)	78 (40)	55 (20)	91 (34)	93 (71)	92 (32)	62 (31)	92 (82)
Ratio of C to CC = 1 to 1.82								

4. DISCUSSION

This study presented data from absolute and proportional durations of vowels and consonants in medial V1CV2, V1CCV2, VV1CV2, and VV1CCVV2 structures in word-list and spontaneous speech in LA. In the word-list style, medial V1CV2 shows a symmetrical temporal pattern whereby V2 is the longest when V1 and C are short, C is longest when it is geminated, and V1 is longest when it is a phonologically long vowel. Stops were in general longer than nasals and laterals, but the ratio of C to CC was shortest in the stops and longest in nasals and laterals. The duration of geminate consonants in this study is generally comparable to what has been found for Jordanian [1], Iraqi [10], Berber [24], and Malayalam [18]. However, it is much shorter than what has been found for other languages such as Greek [4], Swedish [10], and Finnish [14].

Temporal compensation takes place at the proportional rather than the absolute level in that the absolute duration for V1 does not shorten in V1CCV2 as opposed to V1CV2 but it is proportionally shorter before a geminate than a singleton consonant. The same is true of singleton consonants following short and long vowels; that is, singleton consonants are proportionally shorter following long than short vowels although their absolute duration does not differ in the two contexts. This suggests that temporal compensation affects consonants as well as vowels, and that the percept of phonological length is mainly achieved through the proportional durations for each of the short or long targets and their surrounding sounds.

In spontaneous speech there were very few tokens with a medial VV1CCV2 syllable pattern, which suggests a low frequency of occurrence of this structure in LA. The consonants and vowels in the other three contexts were significantly shorter in spontaneous speech compared with the word-list data. Arvaniti [3] found that in fast speech, geminate targets never shortened enough to the extent they overlapped with singletons spoken at a normal rate. By contrast, this study found that this does occur in spontaneous speech. Singleton and geminate targets overlapped in duration both in word-list and spontaneous speech styles, but to a much greater degree in the latter style. Moreover, geminates in spontaneous speech were occasionally realized as singletons from an auditory and acoustic perspective. This is not surprising when considering the fact that listeners make use of non-phonetic cues such as the semantic, syntactic, and lexical context to retrieve the intended target by the speaker. The results therefore suggest that even when duration is a strong temporal cue for categorical distinction, overlap can take place between the different phonological categories when redundancy allows [17]. More data are needed to examine the extent to which speakers normally reduce the temporal difference between singleton and geminate targets in natural speech and what effect this has on the targets that are available for children acquiring languages with geminates. Preliminary results [12] show that singletons and geminates in child-directed speech have comparable durations and exhibit the same degree of overlap observed in adult-directed speech. This suggests that the durational contrasts between short and long targets may not be amplified by Lebanese mothers in order to aid the acquisition of this phonological feature.

More work is currently underway to look at more data and to examine other potential temporal and non-temporal cues to gemination in Arabic including the quality of the preceding vowel, the amplitude of the medial consonant, consonant closure duration, VOT, and burst duration for stops. Preliminary results show that both singleton and geminate medial consonants exhibit weak or incomplete closures in Lebanese Arabic, not just singletons as reported elsewhere (e.g. [18, 24]).

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[1] A fifth context which was not investigated here is CV**CCVV**(C) with an iambic stress pattern (e.g. /tˤabˈbaal/ ‘drummer’).