Durational cues for gemination in Lebanese Arabic

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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. Six males and six females from Beirut were recorded reading target word-lists containing disyllables with medial singleton and geminate consonants preceded by long and short vowels. Acoustic and auditory analyses of medial consonants and of preceding and following vowels were conducted. Results show separate durational distributions for singleton and geminate consonants and for short and long vowels in word-list style. There was no evidence for the temporal compensation between medial consonants and preceding vowels that is normally reported in the literature and that is linked to the perceptual enhancement of gemination and the syllabic structure of medial geminates. Instead, the intrinsic length of medial consonants was the main driver of preceding vowel length. In terms of manner of articulation, fricatives were the longest consonants and liquids the shortest, but the ratio of singleton to geminate was highest for liquids, which may compensate for the lack of phonetic length and help maintain the salience of the geminate contrast for this category of sounds. There were no differences between males and females in the realisation of contrastive length in consonants and vowels; their durational patterns were on the whole very similar apart from slight differences in singleton to geminate ratios and final syllable lengthening, which was more evident in males then females.

INTRODUCTION

Gemination is a productive phonological feature in LA. All 27 LA consonants (Table 1) can be geminated. Vowel length is also phonemic, and both long and short vowels occur before geminate consonants (Nasr, 1960; 1966; Ham, 2001). Word medial consonants can therefore occur in the following trochaic contexts: CVCV(C); CVVCV(C); CVCCV(C); CVVCCV (Table 1). A 5th syllable structure with an iambic pattern and a following long vowel is also possible (CVCCVVC), e.g. /mallaáak/ 'property owner'. Gemination is not only restricted to medial position but can also occur in final position (e.g. /ʕam/ 'to be' *versus* /ʕamm/ 'uncle'; /ʕaam/ 'he floated' *versus* /ʕaamm/ 'public'). In initial position, gemination is the result of vowel syncope and assimilation between the definite article /al/ and following coronal sounds (Standard Arabic /al/+/suuq/ 'the market' > /assuuq/ > [ssuuʔ] in LA). Finally, Gemination plays a role in lexical (e.g. /ˈħakam/ 'he ruled' *vs* /ˈħakkam/ 'he treated') as well as morpho-syntactic patterning in LA (e.g. /dafaʕ/ 'he paid' *vs* /daffaʕ/ 'he made someone pay').

The phonetic realisation 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. Al-Tamimi, F., 2004; Arvaniti, 1999; 2001; Blevins, 2004; Ghalib, 1984; Ham, 2001; Hassan, 2002; 2003; Ladd & Scobbie, 2002; Lahiri, 1988; Local & Simpson, 1999; Payne, 2005; Ridouane, 2007). The general consensus is that duration plays a major role in distinguishing singleton and geminate consonants in many languages, but that other articulatory and acoustic cues may contribute to the perceptual effect of gemination. These include the duration and spectral characteristics of the preceding and/or following vowels, the manner of articulation of the geminate consonant, and long-term domain changes affecting the realisation of the whole word or utterance. Non-temporal characteristics such as a more centralised and a more open preceding vowel, lax phonation, and darker consonantal resonance in singleton contexts suggest a tense/lax distinction that

is thought to enhance the perceptual distance between singletons and geminates (e.g. Local & Simpson, 1988; 1999; Payne, 2005; 2006).

Table 1: Consonant inventory of LA

	Bilabial	Labio-dental	Dental-alveolar	Post-alveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	(p) b		t d tˤ dˤ			k (g)	(q)		ʔ
Nasal	m n		n						
Trill			r						
Tap or flap			ɾ						
Fricative		f (v)	s z sˤ zˤ	ʃ ʒ		x ɣ	(χ) (ʁ)	ħ ʕ	h
Approximant	w (labial-velar)				j				
Lateral approximant			l lˤ						

Notes: /p/, /v/, and /g/ occur in loan words; /q/ is used in a small set of Standard lexical items and is a dialectal variant of /ʔ/ for the Druze community in Lebanon. /χ/ and /ʁ/ are in free variation with /x/ and /ɣ/.

Table 2: Gemination in medial contexts in LA

CVCV(C)	CVCCV(C)	CVVCV(C)	CVVCCV(C)
/ˈʕalam/	/ˈʕallam/	/ˈʕaalam/	/ˈʔaalle/
‘flag’	‘he taught’	‘world’	‘becoming sparse’

This study contributes to the literature on gemination by providing a detailed examination of LA. There are few phonetic studies of LA (Chahal, 2001; Ham, 2001; Nasr, 1960; 1966; Obrecht, 1968), 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 role in grammar of the language, little is known about the phonetic realisation 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 (Khattab, 2007) compared with the traditional three-way distinction in Standard Arabic, with short and long vowels being qualitatively and quantitatively different (Table 3). Moreover, the long open vowel is often raised in many LA accents due to a process known as Imala (Nasr, 1966). Imala refers to the realization of /aa/ as [eː] in the neighbourhood of an /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 vocalic durational contrast due to the loss of minimal pair distinction that would normally be achieved through vowel length (e.g. /saba?/ ‘race’ *vs* /saaba?/ ‘he raced’ is now [saba?] *vs* [seːba?]).

Table 3: Vowel inventory of LA (symbols are impressionistic as there are no acoustic studies of LA vowels)

	LA inventory	Examples	Gloss
High-front	iː ɪ	tiːn mɪn	'figs' 'from'
Mid-high front	eː e	beːb binte	'door' 'my daughter'
Mid-low front	æː æ	xæːdɪm kælb	'servant' 'dog'
Central mid-open	*aː* *a*	tˁ*aː*be bɑtˁː	'ball' 'ducks'
High-back	uː ʊ	ħuːt ħʊr	'whale' 'free'
Mid-high back	oː o	hoːne ʔakalo	'here' 'they ate'
Diphthongs	æɪ æʊ	næːɪ ; zæɪ ʔæʊ	'flute'; 'outfit' 'or'

METHODOLOGY

Twenty subjects (10 males and 10 females) with no reported history of speech and language therapy and aged between 18 and 40 were recruited from Beirut. The subjects were audio-recorded in a quiet room reading a word-list with randomized target short and long vowels and consonants in trochaic disyllables with medial V_1CV_2, VV_1CV_2, V_1CCV_2 and VV_1CCV_2 structure (Table 4) interspersed with fillers. The disyllables consisted of minimal or near-minimal sets. Due to the long list of target words, no carrier sentence was used in the elicitation technique in order not to induce boredom and because the emphasis was on eliciting enough examples of all the consonants of LA. All subjects were university-educated and were born and bred in Lebanon. At the time of recording, half of them had lived in Beirut for most their lives while the other half had studied there for at least two years, but no other criteria were used to control for their dialectal background. All subjects were also exposed to English and in some cases French due to the multilingual nature of Lebanon. The recordings were made digitally in mono, 16-bit, 44.1 KHz sampling rate, using an Edirol R9 solid-state recorder with a SONY MS957 Uni-Directional Stereo Electret Condenser microphone. The recording sessions took place in a quiet room either in an office or in the subjects' homes. Although the words were presented in the written format using the Standard Arabic script, the spelling and diacritics, where needed, followed the informal LA pronunciation. Subjects were instructed to produce the written words as if they were speaking them in their own variety in an informal style and normal rate. All but one male subject had no problem doing that, so a new subject was recruited. This study reports on preliminary results for 12 of the subjects (six males and six females).

Designing near-minimal sets for the four syllable types was challenging due to the low frequency of occurrence of target words with medial VV_1CCV_2 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 target vowel before (V_1) and after (V_2) the medial consonant in each case was /a/ or /aa/, though these were sometimes realized differently by the speakers due to Imala. All LA consonants were elicited in their singleton and geminate form, but this paper presents results for the following fricatives, nasals, liquids, and approximants: /f, s, z, ʃ, ʒ, x, ɣ, ħ, h, m, n, l, ɾ, w, *j[1], ʕ[2]/.

[1] /j/ was not included in the analysis due to the insufficient number of tokens from all required syllable structures

[2] Acoustic analyses revealed that LA /ʕ/ was realised as an approximant rather than a fricative so it was included in that category.

With the exception of the medial VV_1CCV_2 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 4). Durational measurements (in ms) of $V(V)_1$, medial C(C), and V_2 were made using PRAAT version 5.0.0 (Boersma & Weenink, 2007). The data were labelled semi-automatically and measured using a specifically designed script and checked by hand (example in Figure 1). For V_1 the beginning was determined in accordance with the rise in amplitude and appearance of formant structure, and the end in accordance with the drop in amplitude and disappearance or abrupt change in the formant structure. The boundaries for medial fricatives were determined according to the first and last visible and audible friction, including any period of silence which sometimes preceded the start of the following vowel. Nasals, laterals, and approximants (including the voiced pharyngeal fricative) were mainly identified through the drop in amplitude and beginning/end of transitions in the surrounding vowels, coupled with absence of higher formants for approximants and /ʕ/. Taps and trills were delimited from the drop in amplitude and/or cessation of formants in the preceding vowel (but not formant shadows) to the rise in amplitude after the last vertical striation indicating tongue contact and start of formants in the following vowel. Where taps and/or trills were realised as approximants, the labelling followed the same procedure as for laterals and approximants. For the V_2, the beginning boundary was in accordance with the ending part of the preceding consonant. The ending was marked in accordance with any intensity variation observed on the spectrogram and/or the waveform. Where V_2 was in final position and the last part was voiceless and low in amplitude, the end boundary as placed before the start of formant shadows/end of voicing and a hypothetical consonant was labeled to represent the last portion. A total of 2391 word-list tokens were analyzed.

Statistical analyses were carried out using a MANOVA with 5 factors: consonant length (single, geminate), vowel length (short, long), consonant type (fricative, nasal, rhotic, lateral, approximant), sex of speaker (male, female), and number of speakers (12). The dependent variables were the duration of each of V_1, C, and V_2, and the proportional durations.

Table 4: Target words for each of the syllable types and each of the consonants examined. Dashed lines signify that there were no tokens for that particular syllable structure

	V_1CV_2	V_1CCV_2	VV_1CV_2	VV_1CCV_2		V_1CV_2	V_1CCV_2	VV_1CV_2	VV_1CCV_2
f	tˤafa kafal dafaʕ	tˤaffa kaffal daffaʕ	tˤaafe keefil deefaʕ	ħaaffe xeeffe _____	h	sahar rahan bahar	sahhar sahhal ʔahhal	seehir raahib neehib	_____ _____ _____
s	ħasab ɣasal masal	ħassaa ɣassal massal	ħaasab ɣeesil meesik	ħaasse _____ _____	m	ʕamal samaʕ ħamal	ʕammal sammaʕ ħammal	ʕaamil seemaħ ħaamil	ʕaamme seemme dˤaamme
z	kazab nazaʕ nazaf	kazzab nazzal ʕazzab	keezib neezil ʕaazib	keezze heezze ʕaazze	n	bana sˤanaʕ ʔanaʕ	banna sˤannaʕ ʔannaʕ	beene sˤaniʕ ʔaniʕ	meenne ħaanne _____
ʃ	naʃar kaʃaf ʔaʃar	naʃʃar kaʃʃaf ʔaʃʃar	neeʃir keeʃif ʕaaʃar	neeʃʃe keeʃʃe ɣaaʃʃe	l	ʕalam malak ʔalab	ʕallam mallak ʔallab	ʕaalam meelik ʔaalib	ʔaalle meelle feelle
ʒ	haʒar ʕaʒan faʒar	haʒʒar ʔaʒʒar faʒʒar	heeʒar ʕaaʒin feeʒir	dˤaaʒʒe _____ _____	r	baram barad harab	barram barrad harrab	baarim beerid heerib	maarra ʒeerra _____
x	ʔaxad saxan faxat	ʔaxxar raxxa faxxat	ʔeexir reexe feexit	ʃeexxa neexxa _____	w	sawa ʔawe kawa	sawwa ʔawwa kawwa	seewe raawe keewe	_____ _____ _____
ɣ	ʃaɣal laɣam	ʃaɣaal laɣɣam	ʃeeɣil leeɣim	_____ _____	ʕ	ʔaʕad kiʕe	ʔaʕʕad kaʕʕa	ʔaaʕid keeʕe	_____ _____

	naɣam	naɣɣam	reeɣim	_____		wiʕe	waʕʕa	weeʕe	_____
ħ	saħab	saħħab	seeħib	_____					
	laħam	laħħan	leeħim	_____					
	saħar	waħħad	waaħad	_____					

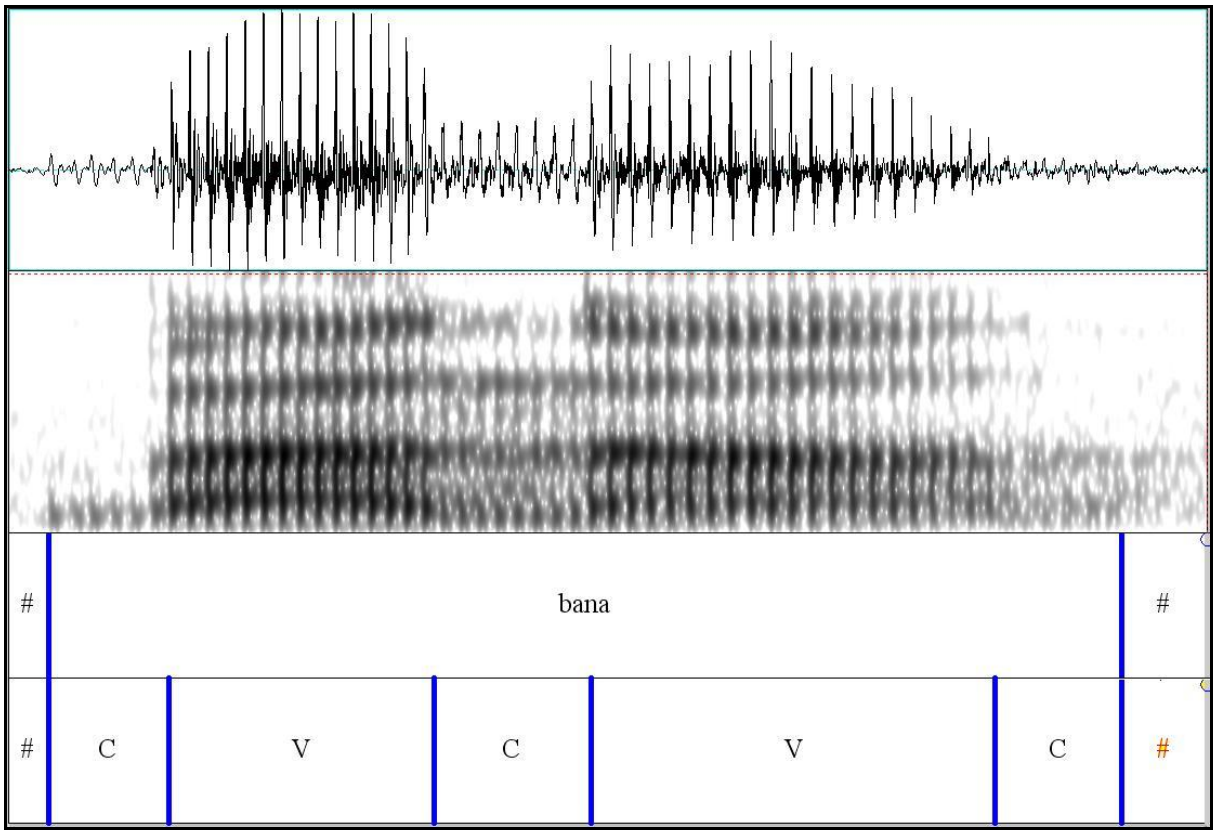

Figure 1: An illustration of data labelling showing the word /bana/ 'he built' as produced by one of the male speakers and realized as [banah].

RESULTS

Absolute and proportional durations

Figures 2 and 3 show absolute and proportional means and standard deviations for V_1, C, and V_2 durations in short and long targets for all subjects and in all consonantal contexts. Table 5 lists the means and standard deviations for the above targets and the ratios of C to CC in short and long vowel contexts. As can be seen from Figure 2 and 3 below, there was no significant difference between the durational results for males and females (neither for the absolute duration: $F(3, 2391)= 1.35$; $p=0.257$; nor for the proportional duration: $F(3, 2391)= 0.02$; $p=0.997$) apart from more V_2 lengthening by males (on the 4 syllable structures; $p<0.001$). The findings that are discussed in the remainder of this section therefore apply to both groups unless specified.

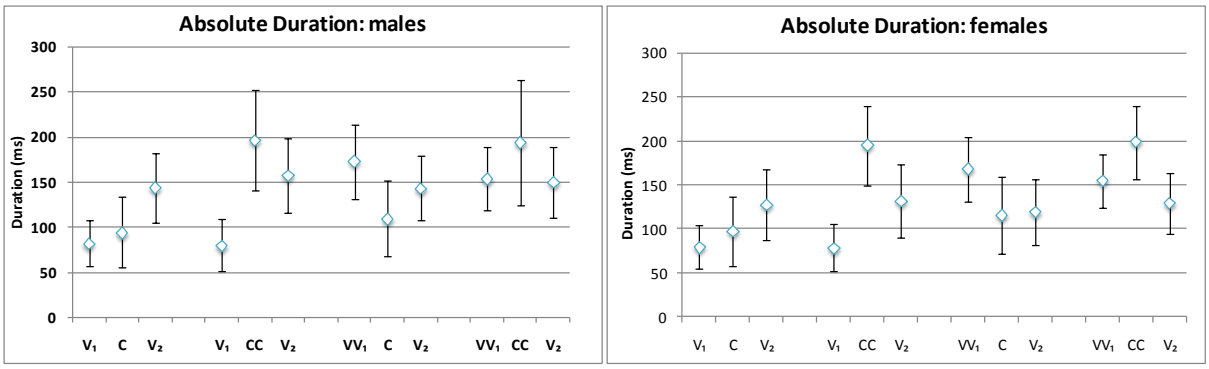

Figure 2: Mean duration (white squares) and standard deviation (black bars) for vowels and consonants in medial V_1CV_2, V_1CCV_2, VV_1CV_2, and VV_1CCV_2 contexts for males (left) and females (right).

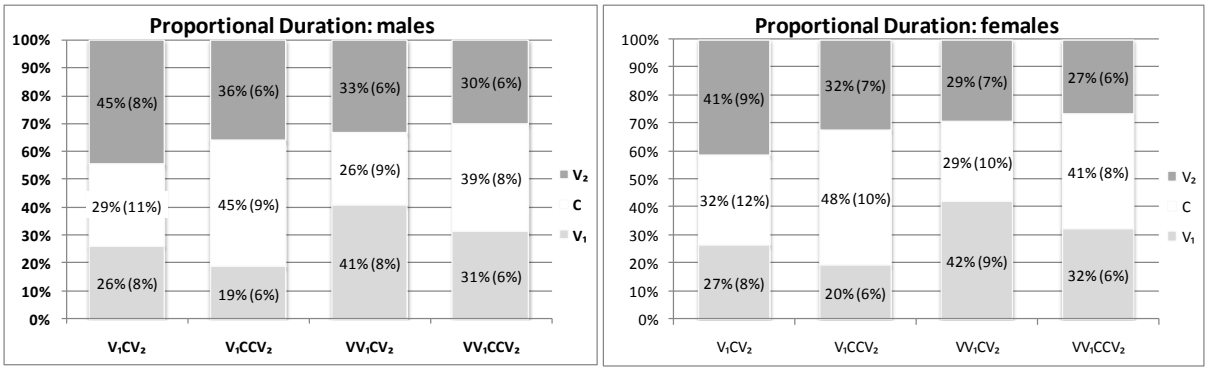

Figure 3: Mean proportional duration for vowels and consonants in medial V_1CV_2, V_1CCV_2, VV_1CV_2, and VV_1CCV_2 contexts for males (left) and females (right).

Table 5: Mean duration (in ms) and standard deviations (in brackets) for vowels and consonants in medial V_1CV_2, V_1CCV_2, VV_1CV_2, and VV_1CCV_2 contexts for males (left) and females (right).

Males						**Females**					
V_1CV_2			**V_1CCV_2**			**V_1CV_2**			**V_1CCV_2**		
V_1	**C**	**V_2**	**V_1**	**CC**	**V_2**	**V_1**	**C**	**V_2**	**V_1**	**CC**	**V_2**
82 (25)	94 (39)	144 (39)	80 (28)	196 (56)	157 (41)	80 (25)	98 (39)	127 (40)	79 (27)	195 (45)	132 (42)
Ratio of C to CC = 1 to 2.08						**Ratio of C to CC = 1 to 1.99**					
All subjects ratio of C to CC = 1 to 2.04											
VV_1CV_2			**VV_1CCV_2**			**VV_1CV_2**			**VV_1CCV_2**		
VV_1	**C**	**V_2**	**VV_1**	**CC**	**V_2**	**VV_1**	**C**	**V_2**	**VV_1**	**CC**	**V_2**
173 (41)	110 (41)	143 (36)	153 (35)	193 (69)	150 (39)	168 (37)	116 (44)	119 (38)	155 (30)	199 (42)	129 (35)
Ratio of C to CC = 1 to 1.75						**Ratio of C to CC = 1 to 1.72**					
All subjects ratio of C to CC = 1 to 1.74											

Looking at consonant duration first, geminate CC is predictably longer than C regardless of syllable shape and the distributions for C and CC are non-overlapping in short V_1 contexts while they show minor overlap when preceded by long VV_1. The ratio of C to CC is around 1 to 2 when preceded by a short vowel and 1 to 1.7 when preceded by a long vowel (Table 5). This is due to CC duration being shorter in VV_1CCV_2 than V_1CCV_2 contexts and C duration being longer in VV_1CV_2 than V_1CV_2 contexts. While the former is expected due to the long preceding VV_1, it is not clear why C in VV_1CV_2 contexts was on average longer than in V_1CV_2.

Vowel length behaves in a similar way in that the distributions for V_1 and VV_1 are exclusive in both short and long C contexts, and the ratio of V_1 to VV_1 tends to be comparable to that of C to CC (Table 6). In Absolute durational terms, however, V_1 tends to be shorter than C and VV_1 shorter than CC, especially in VV_1CCV_2 contexts. V_2 duration tends to interact not only with the phonetic length of the other segments (Table 5) but also with the rhythm of the second syllable which varies as a function of phonological consonant length (Local & Simpson, 1988). For instance, V_2 is longest in V_1CCV_2 contexts (not V_1CV_2), where V_1 is short and the relative rhythmic quantities of the two syllables are equal, and shortest in VV_1CV_2 where VV_1 is long and the relative rhythmic quantities of the two syllables are long-short. V_2 for females was significantly shorter for females than for males (on the 4 syllable structures; $p<0.001$), which may be due to differences in word-list style reading between the two groups.

Table 6: Ratio of V_1 to VV_1 in singleton and geminate contexts for males and females.

Ratio of V_1 to VV_1			
Males		**Females**	
C contexts	**CC contexts**	**C contexts**	**CC contexts**
1 to 2.11	**1 to 1.91**	**1 to 2.1**	**1 to 1.96**

Looking at each disyllabic shape in more detail (Figure 2), there is considerable overlap between short V_1 and C in V_1CV_2 contexts, although the difference between the two distributions is statistically significant for females ($p<0.05$). In V_1CCV_2 contexts, the medial consonant has the longest duration, and there is little overlap between the distributions for V_1 and CC. The absolute vowel durations preceding the geminate consonant are not significantly different from those found for vowels preceding singleton consonants in V_1CV_2 contexts ($p=1$). However, when we examine the proportional durations as a function of the V-C-V sequence (Figure 3), it is clear that V_1 (and V_2) in V_1CCV_2 contexts contribute a smaller proportion of the overall duration compared with these vowels in V_1CV_2 contexts. Note that this is due to the length of the medial CC, not V_1 shortening. In fact, V_1 and V_2 have comparable lengths in V_1CV_2 and V_1CCV_2 contexts, so any percept of shorter vowels in V_1CCV_2 is purely due to the near-doubling of consonant length.

In VV_1CV_2 contexts, VV_1 has the longest duration with very little overlap between the distributions for VV_1 and C. The distributions for C duration in V_1CV_2 and VV_1CV_2 are significantly different for females only despite the considerable overlap ($p<0.01$). Proportional durations (Figure 3) show a smaller percentage for C in V_1CV_2 than in VV_1CV_2 contexts, but this is once again due to the longer VV_1 in the latter context, not temporal compensation affecting consonant length.

Finally, in VV_1CCV_2 contexts, the target long vowel is significantly shorter (slight difference for males, $p=0.051$, no significant difference for females) than its long counterpart in VV_1CV_2 while the geminate consonant varies between being slightly shorter than in V_1CCV_2 contexts for the males data but slightly longer for the females. While both VV_1 and CC in VV_1CCV_2 are still longer than phonologically short V_1 and C in V_1CV_2 contexts (for both males and females; $p<0.001$), VV_1 certainly exhibits more shortening than CC. There is a considerable degree of overlap between the distributions for VV_1 and CC in the VV_1CCV_2 context, although the difference between the two distributions is statistically significant (for both males and females; $p<0.001$), with CC being longer than VV_1. This may be due to gemination shifting some of the rhythmic weight to the second syllable and vowel length being shared between the first and second vowel.

Gemination and manner of articulation

Figure 4 shows durational results for each of the consonant categories separately. In short C contexts ($V1CV_2$ and $VV1CV_2$), the shortest consonants are taps followed by laterals, nasals, and approximants, with the fricatives being the longest ($p<0.001$). In long CC contexts, the order is more or less the same although approximants are shorter than nasals in the male data ($p<0.001$) and trills tend to be of similar length to laterals and approximants in the female data ($p=1$). Approximants were

difficult to measure due to their acoustic similarity to their surrounding vowels leading to formant transitions continuing into the consonants and only a slight amplitude drop compared with the other consonants, which may have led to their relatively shorter length in geminate contexts. Some trills were realised as approximants in the female data, which may have contributed to their longer length.

When looking at the ratio between singleton to geminate consonants (Table 7), however, it is the shortest consonants that produce the highest ratio, with liquids and nasals showing the greatest difference in duration between singleton and geminate targets while the shortest durational difference was found between singleton and geminate fricatives. The ratio of C to CC in short vowel contexts was relatively higher for males than for females (Table 7). This was due to short female Cs being slightly longer than male Cs, and some female CCs being slightly shorter than their male counterparts. There was no significant difference between the ratio of C to CC by males and females in long vowel contexts.

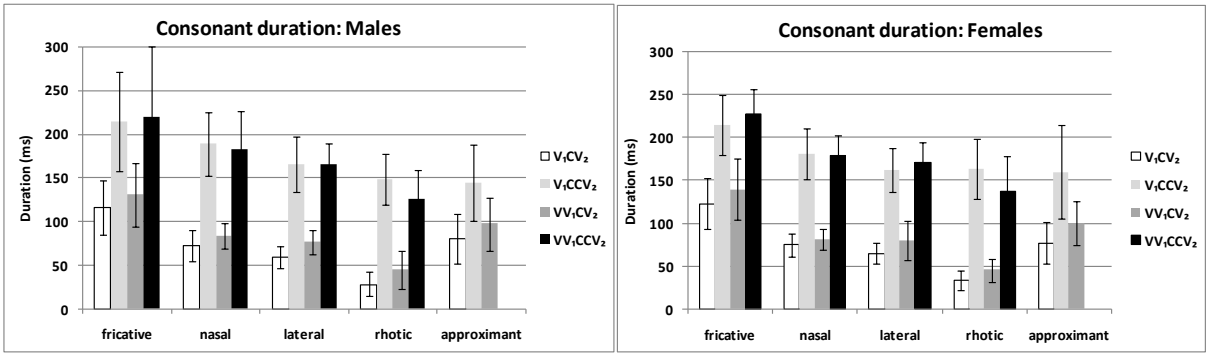

Figure 4: Mean duration (in ms) and standard deviations for each of the consonant categories in singleton and geminate targets for males (left) and females (right).

Table 7: Ratio of C to CC in each of the consonant categories. Note that overall mean ratios are higher than in Table 5 due to the inclusion of rhotics.

	Ratio of C to CC in short V contexts		**Ratio of C to CC in long VV contexts**	
	Males	**Females**	**Males**	**Females**
fricatives	1 : 1.85	1 : 1.75	1 : 1.69	1 : 1.63
nasals	1 : 2.55	1 : 2.42	1 : 2.19	1 : 2.21
laterals	1 : 2.79	1 : 2.51	1 : 2.17	1 : 2.14
rhotics	1 : 5.22	1 : 4.89	1 : 2.82	1 : 3.02
approximants	1 : 1.81	1 : 1.97	--	--
Mean	**1 : 2.88**	**1 : 2.71**	**1 : 2.22**	**1 : 2.25**

Figures 5 and 6 show the durational results for V_1 and V_2 in each of the syllable shapes. Starting with V_1, the general pattern for separate distributions for V1 in short and long targets is maintained for all categories, with the longest first vowels found in VV_1CV_2 structures and the shortest in V_1CCV_2, with the exception of fricatives and approximants where V_1 was shortest in V_1CV_2 (Figure 5). Rhotics were preceded by the longest vowels and fricatives by the shortest vowels, which shows an interaction between $V(V)_1$ and C(C) whereby intrinsic consonant length triggers a shorter preceding vowel. This type of temporal compensation is related to manner of articulation and is independent of the phonological length of the medial consonant or its preceding vowel. Moving on to V_2, the tendency for this vowel to be longest in V_1CCV_2 contexts and shortest in VV_1CV_2 still applies when one looks at the individual consonant categories with a couple of exceptions (Figure 6).

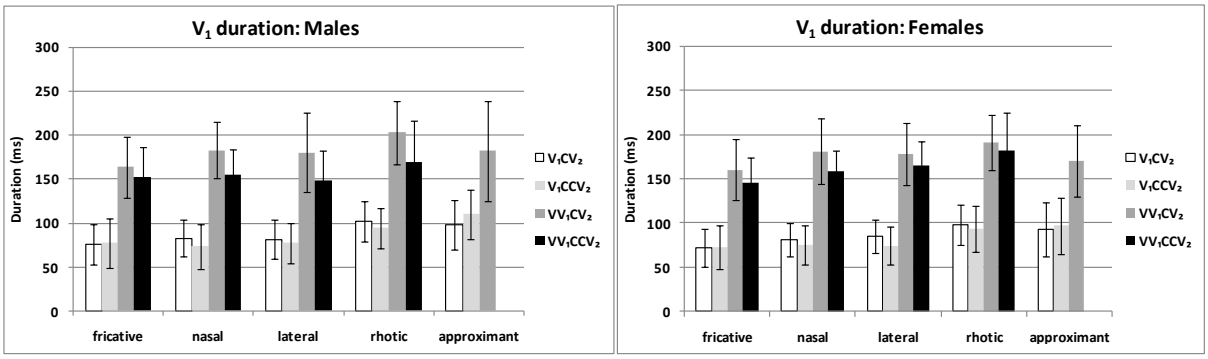

Figure 5: Mean duration (in ms) and standard deviations for V_1 in each of the syllable shapes for males (left) and females (right).

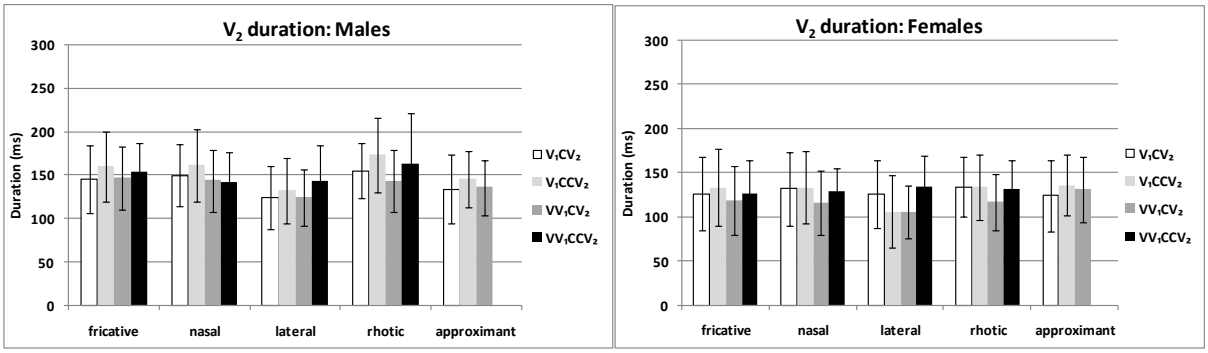

Figure 6: Mean duration (in ms) and standard deviations for V_2 in each of the syllable shapes for males (left) and females (right).

DISCUSSION

This study presented data from absolute and proportional durations of vowels and consonants in medial V_1CV_2, V_1CCV_2, VV_1CV_2, and VV_1CCV2 structures in word-list style in LA. Duration emerged as a robust cue for the distinction between singleton and geminate consonants in LA as well as phonologically short and long vowels in all four syllable structures and for all consonant types that were examined. These results support findings from other studies which highlight the importance of duration as consistent cue to gemination (e.g. Lahiri & Hankamer, 1988; Esposito & Di Benedetto, 1999). The duration of geminate consonants in this study is generally comparable to what has been found for Jordanian (e.g. Al-Tammi, 2004), Iraqi (e.g. Hassan, 2002), Berber (e.g. Ridouane, 2007), Cypriot Greek (e.g. Arvaniti, 1999) and Malayalam (e.g. Local & Simpson, 1999), whereby the geminate consonant is around twice as long as its singleton counterpart. This ratio is considerably smaller than what has been found for languages such as Swedish (e.g. Hassan, 2002), Italian (e.g. Payne, 2005) and Finnish (Kunnari, Nakai & Vihman, 2001), whereby the geminate consonant tends to be around three times as long as its singleton counterpart. Long vowels in this study were also approximately twice as long as short vowels and the distributions for short and long showed no overlap despite the fact that the distinction between the two categories is heading towards more than just duration due to Imala (cf. Abramson & Ren, 1990). However, the results should be treated with care because the only pair looked at here was for the open front vowels /a/ and /aa/, and different results might have been obtained for /i ɪ/, /u ʊ/ and in spontaneous speech.

Local & Simpson (1988) suggested that disyllables with medial geminates and non-geminates exhibit different rhythmic patterns whereby the presence of medial geminates evenly distributes the weight of the syllables on either side whereas a trochaic disyllable with a singleton consonant has longer rhythm for the first syllable. The vocalic results from this study support this suggestion. The disyllabic shapes that were examined exhibit temporal and rhythmic patterns whereby V_1 is longest

when it is a phonologically long vowel and C is short, rendering the first syllable rhythmically longer than the second; V_2 is longest when V_1 is short and C is geminated and shortest when V_1 is long and C is a singleton, rendering the second syllable rhythmically short. Further evidence for rhythmic balance in geminate contexts comes from VV_1 and CC length in VV_1CCV_2 contexts, whereby VV_1 shortens more in relation to its length in VV_1CV_2 than CC shortens in relation to its length in V_1CCV_2. In fact, CC is slightly longer in VV_1CCV_2 than V_1CCV_2 in the female results, though the difference is not significant.

Fricatives were in general longer than nasals and laterals, but the ratio of C to CC was shortest in the fricatives and longest in nasals and laterals. While there is a suggestion that sonorant geminates might be more difficult to distinguish from singletons than obstruent geminates due to their acoustic similarity to the surrounding vowels (Kahawara, 2008), the high ratio of singleton to geminate duration for sonorants might enhance their acoustic salience and help maintain the perception of phonological length. This was evident for nasals and laterals in this study. These consonants are frequent in LA and their productive gemination attested in many languages (e.g. Blevins, 2005; Local & Simpson, 1988; 1999; Payne, 2005; 2006). Approximants, however, were indeed difficult to elicit and segment. /j/ was difficult to elicit due to the lack of sufficient targets with a V_1CV_2 or VV_1CCV_2 structure and there were no /w/ tokens with a VV_1CCV_2 structure. The boundary between medial /w/ and surrounding vowels was hard to establish due to low drops in amplitude and continuing formants.

Despite the occasional tendency for preceding vowels to be shorter before geminate than singleton consonants, there was no evidence for vowel or consonant temporal compensation as a function of phonological length in this study (Arvaniti & Tserdanelis, 2000; Delattre, 1971; but cf. Al-Tamimi, F., 2004 and Hassan, 2003). The absolute duration for V_1 did not shorten in V_1CCV_2 compared with V_1CV_2, nor was C shorter in VV_1CV_2 than V_1CV_2. From a phonological point of view, these results provide no evidence for V_1 being in a open syllable in $V_1.CV_2$ as opposed to $V_1C.CV_2$, which is also used as an explanation for longer V_1 in V_1CV_2, or for durational balancing to maintain the rhythm structure of the word (e.g. Esposito and Di Benedetto 1999; Lehiste, 1971). Instead, phonologically long consonants or vowels doubled in length, which led the surrounding sounds to be proportionally shorter. This suggests that the percept of vowel shortening before a geminate consonant may be achieved through the proportional rather than the absolute duration of this target. Temporal compensation was, however, evident when intrinsic consonant length was looked at. That is, vowels tended to be shorter when preceding intrinsically long consonants such as fricatives and longer when preceding short consonants such as taps and approximants.

More work is currently underway to look at more speakers and to examine non-temporal and long domain cues to gemination in Arabic including the resonance, phonation, and intensity of the consonant and surrounding vowels. While durational differences reported here provide some insight into the syllable affiliation of medial consonants in singleton and geminate contexts, it is important to look at the potential role of V-to-V co-articulation effects (following Öhman, 1966) and vowel dynamics (Al-Tamimi, J., 2007) in revealing long-domain gemination effects. Moreover, since in Arabic the term gemination translates as ‘tashdiid’, meaning ‘strengthening’ or ‘enforcement’ (Al-Tamimi, F., 2004), this suggests a fortis type of articulation. It is therefore important to investigate whether geminate consonants in LA might involve more than just lengthening. Data from stops is also available and is currently being analysed for differences in consonant closure duration, VOT, and burst amplitude for stops in singleton and geminate contexts. And while the results presented here were obtained through the word-list elicitation technique, analysis of spontaneous speech is currently underway in order to find out to what extent speakers reduce the temporal difference between singleton and geminate targets in natural speech and what role non-temporal cues play in maintaining the phonological distinction in case of temporal overlap. For the time being though, geminate consonants in LA do appear to be long consonants.

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