ACOUSTIC ANALYSIS OF THE SYRIAN ARABIC VOWEL SYSTEM

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ABSTRACT

This paper describes the vowel system of Damascus Arabic in Syria, from now onwards referred to as Syrian Arabic (SA). We examine the acoustic correlates of SA short/long vowel contrasts, and investigate the status of mid vowels in SA. The goal is to expand on the auditory description of the SA vowel system performed by Cowell [8]. The full set of vowel categories proposed by Cowell were produced in a neutral /hVd/ context by fifteen SA speakers. Quantitative analysis of vowel duration and formant measurements confirms that the vowel system of Syrian Arabic includes the main /i(ː)/, /a(ː)/, and /u(ː)/ short/long vowel contrasts and supports the phonemic status of mid-long vowels /eː/ and /oː/. However, the phonemic status of the mid short vowels [e] and [o] and of schwa was not supported and they are analysed as allophonic variants of their high counterparts /i/ and /u/, respectively.

Keywords: Arabic, vowel quantity, vowel quality, duration, formants

1. INTRODUCTION

Arabic is a Semitic language, which is spoken in twenty-five countries in the Middle East and North Africa. The standard variety of Arabic coexists in a diglossic context with colloquial dialectal varieties. Standard Arabic is used in formal contexts such as education and broadcasting, whereas the dialects are used in daily and informal communication [25].

The following sections review the main findings of prior studies of vowels in Arabic in general, and in the SA dialect in particular. Arabic vowels have in general received less attention in the phonetic literature than Arabic consonants, with the exception of much work on the effects of pharyngealised consonants on neighbouring vowels. Since our goal here is to establish the size of the contrastive vocalic inventory in SA, work on pharyngealised vowels is not included in the following discussion.

1.1. Vowel quality

Standard Arabic has a simple three vowel quality system, consisting of the most frequent vowels in the world's languages /i(ː)/, /u(ː)/, and /a(ː)/, together with short/long distinctions [13, 18, 20]. A few researchers have argued that Arabic short vowels differ from their long counterparts in quality as well as quantity [22, 6]. Watson [25] describes the /iː/ and /uː/ articulation as being closer, and the /aː/ articulation fronter, than their short counterparts.

The vowel systems of the different spoken Arabic dialects are not identical to that of the Standard Arabic nor to each other. Due to linguistic or extra-linguistic factors, some dialects have additional vowels and some have the same inventory but with different spectral and temporal manifestations. For example, Jordanian, SA and rural Palestinian Arabic are all reported to have mid long vowels /eː/ and /oː/, and in addition SA and rural Palestinian Arabic are reported to have mid short vowels /e/ and /o/ [6, 8, 23]. Syrian, Moroccan and Sudanese Arabic have all been reported to have a schwa vowel [2, 6].

Arabic dialectal mid long vowels are generally assumed to have emerged as a result of coalescence of vowel-glide sequences, as found in Standard Arabic, such as bajt~beːt 'home' and nawm~noːm 'sleeping' [26].

1.2. Vowel quantity

Length is contrastive in Arabic vowels and consonants [15, 21]. The duration of long vowels has been found to be twice as long as their short counterparts, in spontaneous speech as well as in a word list task, in Lebanese Arabic [15, 16].

Phonemic vowel length is affected by linguistic factors such as stress, focus, and voicing of the preceding and the following consonants, and by extra linguistic factors such as speech rate. In Jordanian Arabic [14], durational differences between long and short vowels were found to be significantly larger in stressed syllables than in unstressed syllables, to increase also under focus; a similar effect is found in Lebanese Arabic [7].

In contrast, Allatif's study [3] of three speakers from Mayadin in eastern Syria showed that rapid speech reduced the duration of short vowels by 20% but of long vowels also by 19%. Similarly, although

it is reported cross-linguistically that vowels are longer before voiced consonants than before voiceless ones [9, 19], Mitleb [18] examined the productions of Arabic minimal pairs of eight Jordanian speakers and found that voicing of the following segment did not have any effect on vowel duration. A similar lack of effect of voicing on the preceding vowel was found for Saudi Arabic speakers by Flege [12].

These results suggest that Arabic speakers do not exhibit a significant voicing effect on a preceding vowel, which could be taken to support the view that Arabic is primarily a quantitative language, which relies extensively on the duration of segments to preserve phonological contrasts. If Arabic relies on duration to form phonemic contrasts, native speakers might aim to maintain the duration of vowels regardless of the voicing of following consonants.

1.3. Syrian Arabic vowel system

As part of a comprehensive descriptive grammar of SA, based on auditory analysis of one male Damascene speaker, Cowell classified the speaker's vocalic productions into five long and five short vowels and a schwa, i.e. SA vowel system includes the fundamental short/long vowels of MSA as well as mid long vowels and their short counterparts.

The long high /iː/ and /uː/ are said to have more or less the same quality as /i/ and /u/, though the latter short vowels are said to be slightly lower and tense [8]. The quality of the schwa is described as depending, to a large extent, on that of neighbouring sounds. The schwa is the only sound that has no long counterpart; and it never occurs word finally, which suggest that the schwa has an underlying form, which can be one of the other short vowels. One could argue that, due to coarticulation effects, short vowels tend to centralise and surface in the form of a schwa because short (lax) vowels are affected by the surrounding context more easily than long (tense) vowels [22]. Gairdner [13] describes the Arabic schwa as a 'vague vowel' which can replace short vowels in rapid speech.

As for the mid short vowels /e/ and /o/, they almost never bear stress and occur rarely in open syllables unless word final. The low short vowel /a/ is described as slightly raised and retracted English /a/. The long vowel /aː/ varies regionally as having higher and more forward values, such as /ʒweːmiʕ/ 'mosques', in Coastal regions than in Damascus.

In a study of the variety of SA spoken in Mayadin, Allatif and Abry [4] found that both quantity and quality distinguish /a aː/ and /u uː/, with a greater role for quantity in the /a aː/ distinction and a greater role for quality in the /u uː/ distinction. Unexpectedly, only quality was claimed to play a role in the /i iː/ distinction. Their conclusion was that a contrast shift from quantity to quality is in progress. These results prompted us to analyse the acoustic correlates of the SA vowel system as spoken in Damascus, to determine the natures of quantitative and qualitative differences between long and short vowels, and to determine the status of the mid vowels and of schwa in Syrian Arabic.

2. METHODS

Fifteen Damascene participants were recorded (10M/5F); their average age was 23.5 (males) and 30.6 years (females). Recordings took place in 2009 in Damascus, in a quiet computer room at the Asia Institute for Languages, using a Marantz PMD660 Solid State Recorder and a Shure SM10A unidirectional head-worn dynamic microphone. Audio files were recorded at 44.1 Khz 16 bit as .wav files on a compact flash TM memory card.

Materials were designed to elicit all of Cowell's suggested SA vowel categories, as in Table 1 below. Each SA vowel was produced in /hVd/ context, embedded in a carrier phrase /ktoːb ___ marteːn/ "Write ___ twice". In total the SA dataset comprises 3 repetitions × 11 vowels × 15 speakers = 495 items.

Table 1: SA long/short vowels in /hVd/ context. The table shows the similar to target words which were presented to the participants at the same time as the main /hVd/ stimuli.

SA vowel	Target word	Similar to target	Arabic word	English gloss
/iː/	/hiːd/	/fiːd/	فيد	do sth useful!
/eː/	/heːd/	/zeːd/	زيد	proper name
/aː/	/haːd/	/haːd/	هاد	this one
/oː/	/hoːd/	/xoːd/	خود	Take!
/uː/	/huːd/	/huːd/	هود	prophet name
/i/	/hɪd/	/hɪdd/	هِد	destroy!
/e/	/hed/	/naːhed/	ناهد	proper name
/a/	/had/	/hadd/	هَد	he destroyed
/o/	/hod/	/hidhod/	هدهد	hoopoe
/u/	/hud/	/huda/	هدى	proper name
/ə/	/hədne/	/hədne/	هدنة	a truce

It was difficult to find real monosyllabic /hVd/ words in SA for all target vowels, so some nonsense words were used. To ensure correct production of the target vowels, a real monosyllabic /CVC/ word, which had the same target vowel as the one in the nonsense /hVd/ context, was presented alongside the nonsense word. The speakers were asked to produce the target nonsense word with the same vowel as in the real word beside it.

Analysis was performed using a Praat script to extract vowel duration and midpoint F1 and F2 measurements; the start and end of each vowel was labelled by hand in textgrid files.

Two types of derived variables were calculated from the raw measurements. Vowel duration was normalised over the duration of the phrase /ktoːb ___ marteːn/ for each vowel as in (1):

(1) Normalised vowel duration =
('vowel dur'/'phrase dur') * 100

Formant frequency measurements were normalised using the LOBANOV procedure, implemented in an online software package NORM [24]. LOBANOV has been found to succeed in preserving relevant phonemic and sociolinguistic variation while minimising anatomical variation [1, 11].

3. RESULTS

Figure 1 presents mean normalised vowel durations for the SA vowels across all participants. As predicted, it shows that the mean duration of the long vowels is almost double that of their short cognates. Additionally, the duration of the schwa which does not have a long counterpart is produced shorter than the other short vowels.

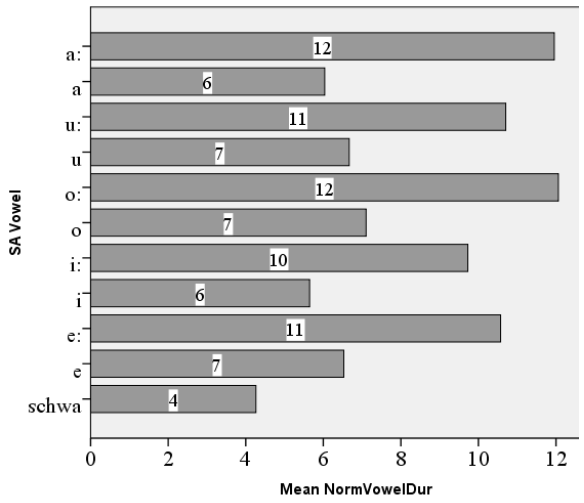

Figure 1: mean normalised vowel duration of the SA vowels across all SA participants.

The overall V to VV ratio was calculated for the normalised vowel duration and it showed that the duration of SA long vowels is approximately one and a half times longer than SA short vowels (1:1.63). This finding matches the ratio found for Lebanese Arabic (1:1.58) [15].

A linear mixed model with 'normalised vowel duration' as dependent variable, 'vowel' and 'sex' as fixed effects and 'participant' as a random effect revealed a significant main effect for 'vowel' [F(11,509)=107, p<.000] but no 'vowel'*'sex' interaction [F(11,509)=1.397, p=.170].

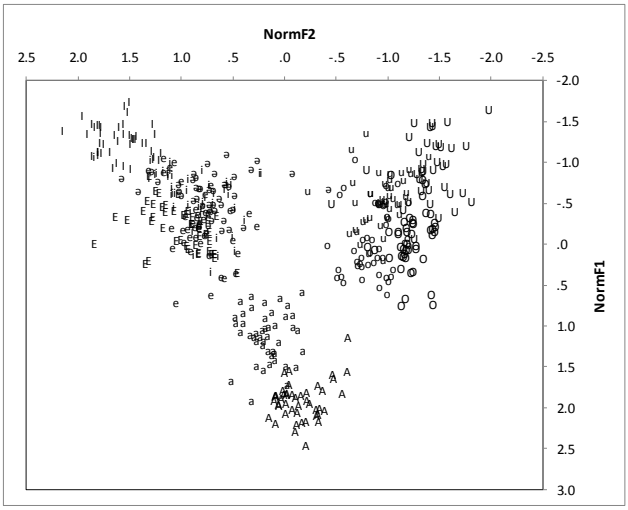

Figure 2: Normalised F1 and F2 values of the SA vowels across all SA participants (CAPITAL letters represent long vowels, and small letters represent short vowels).

Figure 2 presents a scatter plot of the normalised F1 and F2 values for the SA vowels across all participants. Apart from a few schwa and /i/ tokens from the female speakers, the chart shows that the central area of the vowel space is almost empty and not occupied by any vowel, which leads us to question the status of the central schwa vowel in SA. The vowel space of SA appears to have the same triangular shape as that reported for Standard Arabic [21], with the addition of some additional centralised mid vowel categories.

Figure 2 shows that there is a clear separation in the vowel space between SA long vowels /iː aː uː/ and their short cognates /i a u/. However, there is no clear separation in the vowel space between SA mid-long vowels /eː oː/ and their short cognates /e o/. Additionally, there is a great overlap in the mid-high area, particularly among the short vowels /i e ə/ and between /u o/. The overlap between these categories in the vowel space as well as in duration suggests that the difference between these categories might be phonetic rather than phonological.

Two linear mixed models were conducted with 'F1' and 'F2' as dependent variables, respectively, (and the same fixed/random factors as for duration). The results showed a significant main effect of 'vowel' on 'F1' [F (11,509)=395.9, p<.000] and 'F2' [F(11,509)=708.5, p<.000]. There was no 'vowel'*'sex' interaction for 'F2' [F(11,509)=1.433, p=.154] but there was a significant 'vowel'*'sex' interaction for 'F1' [F(11,509)=2.162, p=.015].

Further examination of the data showed that this is due to males displaying significantly lower realisations of /o u ə eː oː/.

3.1. Analysis of mid-high short vowels overlap

The results of Bonferroni post hoc tests showed that /i e ə/ are not different from each other in terms of duration. However, /ə/ is significantly shorter than the mid vowel /e/ ($p<.000$). In terms of height F1, SA /i ə/ are significantly higher than /e/ ($p<.000$). The three vowels do not differ from each other in their F2 values.

The degree of overlap of SA short vowels in the mid-high area was measured in terms of Euclidean distance (ED), a measure used in sociolinguistic research to investigate cases of merger, to evaluate the separation of any two vowel categories in the vowel space. ED is calculated as in (2) [10]:

$$(2)\ \text{DISTANCE} = \sqrt{((\text{F1 vowel1} - \text{F1 vowel2})^2 + (\text{F2 vowel1} - \text{F2 vowel2})^2)}$$

In order to have a comparable measure to the mid-high vowels, the ED of short vowels in the mid-low area /e a/ and /o a/ were also calculated. A linear mixed model was used to compare the ED of mid-high (/i e/, /i ə/, /e ə/, and /o u/) and mid-low (/e a/ and /o a/) vowel contrasts. 'ED' was the dependent variable, with 'vowel contrast' and 'sex' as fixed effects and 'participant' as a random effect. The results showed a main effect of 'vowel contrast' on ED [$F(29,1290)=190$, $p<.000$], which indicates that the ED between the mid-low short vowels are significantly greater than the ED between the mid-high short vowels.

The results of a Bonferroni post hoc test show no significant differences in ED between the three (/i e/, /i ə/, /e ə/) vowel contrasts ($p = 1$). This suggests that the three SA vowels /i e ə/ are equally close to each other and may represent a single vowel quality. Additionally, the ED of these vowel contrasts was significantly different ($p <.000$) from the ED of the mid-low vowel contrast /e a/.

As for the SA short mid-high back vowels /u o/, Bonferroni post hoc tests showed no significant difference between /u o/ in terms of duration ($p = 1$) or F2 ($p = 1$). However, the two vowels were significantly different from each other in terms of F1 ($p < .000$), with the mid vowel /o/ significantly lower than /u/. Additionally, /i e/ and /u o/ were not significantly different from each other in terms of the ED ($p = 1$). However, the ED between /u o/ was significantly less ($p < .000$) than the ED between the mid-low vowels /o a/, which suggests that /u o/ may form a single vowel category as well.

4. CONCLUSIONS

Contrary to expectations, the SA short/long vowel contrasts were found to differ not only in terms of duration but also in terms of F1 and F2, i.e. in quantity and quality. Even though a qualitative difference has been found in production, the role of this difference in the phonemic distinctions among these vowels cannot be determined without examining the effect of vowel quality alternations on the perception of short/long vowels.

As for the SA short vowels, they showed great quantitative and qualitative overlap, in particular among the mid-high vowels. The acoustic differences between mid and high short vowels are small and mainly on one dimension only, i.e. namely height/F1, which leads us to question the phonemic status of the short mid vowels in SA. In the case of the long mid vowels, it can be argued that these derive from historical vowel-glide sequences, as found in Standard Arabic /aj aw/, but the source of mid short vowels is less clear since the mid short vowels do not carry any morphological functions (cf. [26]). We suggest therefore that the SA mid short vowels /e o ə/ should be interpreted as phonetic variants of SA high short vowels /i u/. Similarly, the status of SA schwa can be interpreted as a phonetic variant which can surface in the place of any other SA short vowel.

To summarise, the results of acoustic analysis of the SA vowel system indicate that SA has five long vowels (/iː/, /eː/, /aː/, /oː/, /uː/), three of which have short contrasts (/i/, /a/, /u/). Based on the results of this study, Figure 3 presents suggested phonological categories (black) and (non-pharyngealised) allophonic phonetic categories (grey) for SA vowels.

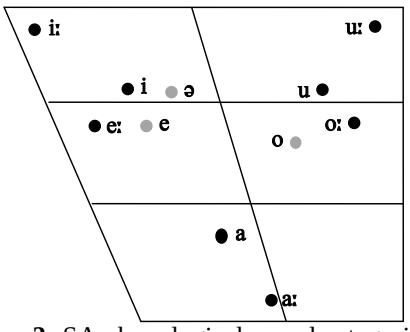

Figure 3: SA phonological vowel categories in black and allophonic categories in grey based on the present study.

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