# Frequency Analysis of Arabic Vowels in Connected Speech

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## 1. Introduction[1]

Talking about vowel descriptions within the framework of the Cardinal Vowels, the American researcher G. Oscar Russell stated that 'phoneticians are thinking in terms of acoustic fact, and using physiological fantasy to express the idea'[2]. This comment has since proved to be true for the largely impressionistic quadriliteral representations of vowel systems of the world's languages. And Arabic is by no means an exception.

Any general description of  Arabic vowels tends to start with the famous vowel 'triangle' of the 'fundamental' vowels, as they were first called by W. Gairdner (1925), the pioneer of modern Arabic phonetics and the first to place the Arabic vowels within the Cardinal Vowel diagram.

This more or less reflected the physical positions indicated by mediaeval Arabic philologists like al-Sibawayh – the *nom de plume* of Abu Bishr Amr b. Uthman b. Qanbar (d. late 8th c.) – and Ibn Jinni (*floruit* 10th c.)[3] in that both descriptions are *perception*-based and closely related to tongue positions. Indeed, Arabic scholars, like modern Western ones, distinguished between, to use the terms of J. Cantineau (1960 : 879ff.),  *aperture minima* (back and front, i.e. velar and palatal), and *aperture maxima* (/a/). This is summarized by Mitchell as follows : 'the vowel system of Classical Arabic/Modern Standard Arabic is a simple one of three vowel units or phonemes – open, close front, close back – with a superposed short/long distinction applicable to all three' (1993 : 138). The same author also clearly related the vowels of the classical language to the Cardinal Vowels, i.e. the set of reference vowels devised by Daniel Jones.

Any investigation of the sounds of 'Arabic' throws up many tendentious issues related to the existence of a normative variety alongside local dialects (many of them mutually unintelligible), a phenomenon known as *diglossia*. The terminology used by early

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[1] For typographical reasons, Arabic names and terms will be rendered in untransliterated form, i.e. without diacritics.
[2] quoted in P. Ladefoged 1993 : 197.
[3] For Sibawayh, see e.g. A. al-Nassir 1993; G. Troupeau 1989. For Ibn Jinni, see the excellent study by M. Bakallah 1982.

modern phoneticians for the normative speech variety confused the issue even more, with Gairdner using the terms Classical Arabic (CA) and Literary Arabic, whereas Cantineau referred to *ancien arabe* (whose vowels he lumped together with *ancien sémitique*). The most common term used to denote the modern descendant of Classical Arabic (the language of the Qur´an) is 'Modern Standard Arabic (MSA)'.[4] This may be associated with Ferguson's 'High style' (1959) or al-`Badawi's` (1975) *fusha al-turath*, i.e. 'heritage *fusha* (pure speech)'. Belkaid (1984), for her part, preferred to call the highest formal register 'Classical Arabic as it is realized today', proposing a Modern Literary Arabic 'in opposition to Classical Literary Arabic and dialectal Arabic'.

Far from referring to the existence of a 'received' acrolectal pronunciation, the above terms above all reflect a normative use of the grammar and lexis in very formal contexts, and are thus primarily rooted in a *grammar*- rather than a *speech* (or pronunciation)-based approach.

In terms of pronunciation, it seems that within this context it is difficult to commit oneself to anything more than 'careful speech', implying the pronunciation of Classical Arabic phonemes, and the avoidance of dialectal variants (e.g. /q/ → ///, /g/ ; /d$^f$/ - /z$^f$/ ; /T/→/s/, /t/ ; /D/→/z/, /d/) and 'unclassical' vowel phonemes like /e/ and /o/. The phonological and phonemic variations have on the whole received far less attention.[5] Matters are further complicated by the existence of a *supraformal* register of Qur´anic recitation (*tajwid, qira`a*), which is perceived by Western scholars and Arabic-speakers alike to reflect the Classical Arabic sounds most closely.This pronunciation, within which any dialectal influence is eschewed, is wholly restricted to liturgical uses and is the subject of rigorous training as well as of a distinct theological discipline in accordance with historical precepts.[6] It is this style which the most recent authority on Arabic phonetics, T. Mitchell (1990-3), referred to as 'High Classical Pronunciation' (HCP) or 'Classical Arabic Reading Style' (CARS), though it should be added that he, himself, blurred the issue by using 'the Classical language', 'High Classical Style', 'CARS', and CA/MSA interchangeably to denote this acrolectal speech variety.

The first acoustic study of Arabic vowels, which was also the first and hitherto only full-blown phonetic study of Arabic sounds, was that by S. al-Ani (1970). Afterwards, Arabic vowels were the subject of acoustic research by Ghazeli (1979), Belkaid (1984), and Abou Haidar (1994), with F. Mitleb (1984), Aloua (1991), and Lahlou (1981-82) concentrating on vowel length. An examination of these studies reveals the following.

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[4] Cf. D. Newman in this volume.
[5] Notable exceptions being H. Kästner 1980; T. Mitchell 1990-3. H. Abd-el-Jawad 1987 ; M. Sallam 1980.
[6] For a discussion, see *Encyclopaedia of Islam*, s.vv. "`kiraa`" (R. Paret), "`tadjwid`" (F. M. Denny); Abu Bakr 1974.

Firstly, nearly all profess to render the values of what is, irrespective of the labels used, essentially Modern Standard Arabic, *as spoken by* respondents from various dialectal areas, with Iraqi by al-Ani (eight respondents, with additional data gathered from two Jordanian speakers) and Tunisian for Belkaid, whereas Ghazeli included a number of informants (12) from six different Arab countries (Algeria, Tunisia, Libya, Egypt, Jordan, and Iraq) with the inclusion of dialectal segments in the corpus (without however providing an indication as to the proportion of non-MSA entries, nor of the values of the individual speakers). Abou Haidar, too, produced a comparative study, involving 8 informants from as many different linguistic backgrounds (Qatar, Lebanon, Saudi Arabia, Tunisia, Syria, Sudan, United Arab Emirates, and Jordan).

The second thing all these studies, bar one, have in common is that the data are based on spectrogram readings (though al-Ani did for some sounds also rely on X-rays). Abou Haidar was the only one who availed himself of modern DSP methods.

Thirdly, one should comment on the discrepancies in the segments investigated. While al-Ani only gives exact values for /i,u,a/ and only ranges and deviations for allophones, Ghazeli focused exclusively on /i,iˇ,u,uˇ/, with Belkaid excluding vowels in pharyngealized contexts. Abou Haidar was the only one to provide values of the allophone of /a,aˇ/ next to pharyngealized consonants, /q/ and /r/ (/A,Aˇ/).

When it comes to the data corpus, one must remark on both the relatively small sample sizes and variation in approach by the researchers. Al-Ani used vowels in isolation and an unspecified number of CV sequences, minimal pairs and short phrases (though he does put the total number of spectrograms at 2000, which also includes phrases and sentences used for the purposes of investigating syllable and stress patterns), whereas Belkaid relied on 70 words (50 of three syllables and 20 of two), with vowels in CV and CVC contexts, examining a total of 110 long vowels and 50 short vowels. Abou Haidar's findings were based on 232 monosyllabic words (CVC).

The aims of the studies also varied greatly. While Al-Ani's is exclusively descriptive, Ghazeli set out challenging the traditional 'Cantineauesque' phonological analysis of Arabic vowels, and posited that the existence of more open varieties of the close vowels /I, U/ is linked to syllable type. Belkaid aimed to test the results arrived at by al-Ani and Ghazeli, with additional attention to the effect or stress and syllable type on the quality of the vowels. Abou Haidar examined the Modern Standard Arabic vowel system in a broader perspective, postulating a cross-dialectal *structural stability* in perception.

All the aforementioned studies relied on recordings made in laboratory conditions, which sometimes leads to rather unrealistic results, with al-Ani, for instance, reporting long vowels of *exactly* twice the length as the short varieties (300ms vs 600ms).

In view of the small research corpuses and the limitations mentioned, the studies should first and foremost be considered preliminary investigations. Yet, they do provide a good starting point for comparison.

In the current article, the authors intend to fill a gap within the study of the phonetics of Arabic by presenting an acoustic investigation of the vowels of Arabic in connected speech, which, remarkably enough, has never received any attention before. The speech variety that will be investigated is the Qur´anic recitation style. This decision was based on the abovementioned prestige and perception of purity of this variety. Furthermore, for comparative purposes, we have excluded vowels in pharyngealized contexts – i.e. next to pharyngealized ('emphatic') consonants - since these are subject to coarticulation (Bonnot 1977 ; *idem* 1979 ; Zawaydeh 1997 ; Boff 1983 ; Norlin 1987), and need to be examined separately. Suffice it to say, that these allophones display an increase in F1 and a lowering of F2 in comparison with their non-pharyngealized counterparts. To provide additional insights, we have also conducted an acoustic analysis of the relevant connected-speech vowels of colloquial Egyptian Arabic (Cairo), which dialect has been chosen for the prestige it enjoys within the Arab world.

In this paper, an attempt will be made to examine whether acoustic evidence supports the common *perceptual* thesis that there is a High Classical pronunciation style which coexists with formal Modern Standard Arabic and is inured to local influences, and, concomitantly, to test the validity of the implied corollary that the vowels in CARS are to be considered references (like cardinal vowels), i.e. extremes within the Arabic vowel system, and can thus be used as a tool for comparison.

## 2. Data

For the acoustic analysis, vowels were taken from a section of Qur´an recitation. There are various styles of recitation, ranging from very slow (tartil) to medium-pace (tadwir), and fast (hadr), whereas there are usually melodic embellishments, resulting in chanting. It stands to reason that only the slow non-musical variety is suitable for the purposes of the acoustic processing of sound segments. The reader used in the course of our research is one of the most respected across the Arab-Muslim world in terms of purity and clarity of classical orthoepy, i.e. shaykh Muhammad Sadiq al-Minshawi. The corpus consisted of audio-tape recordings of the entire Qur´an (20 tapes, published by Abu Hamza Recordings, Cairo, [1994]).

In this corpus, all the vowels of approximately 30 minutes of recitation were segmented manually on the basis of visual information in a broadband spectrogram and auditory assessment. These vowels were analysed acoustically by means of PRAAT (Boersma & Weenink) with standard analysis parameters suitable for a male voice. The total number

of observations is 400, approximately equally distributed along the different vowel categories.

The average formant values for the short and long vowels were subsequently calculated and plotted on an acoustic vowel chart which is illustrated in figure 1 :

*Figure 1 : Acoustic characteristics of the Qur´an vowels.*
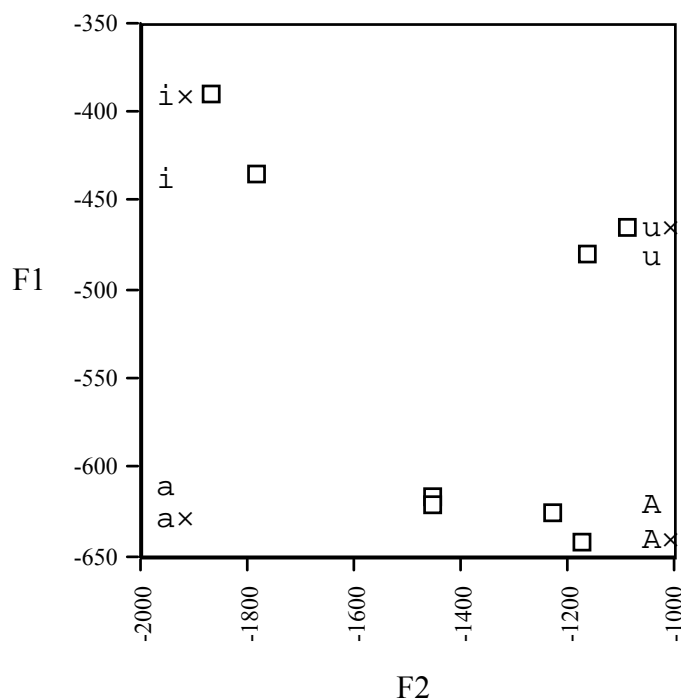


In figure 1 it can be seen that the short vowels are positioned somewhat more central than their long counterparts : this trend is more outspoken for the high vowels. Statistical analysis of these differences indicates that the observed differences are not significant

Besides the Qur´an recitation vowels, we also analysed the vowels of an Arabic translation of the 'North Wind and the Sun' passage. This passage was read by a speaker of the Egyptian variety of Arabic (Cairo) and recorded in high quality conditions. The vowels in this passage were subsequently segmented and analysed acoustically with the same analysis conditions as the Qur´an vowels. The average values of these measurements are illustrated in figure 2 :

*Figure 2 : Acoustic characteristics of the Cairene vowels.*
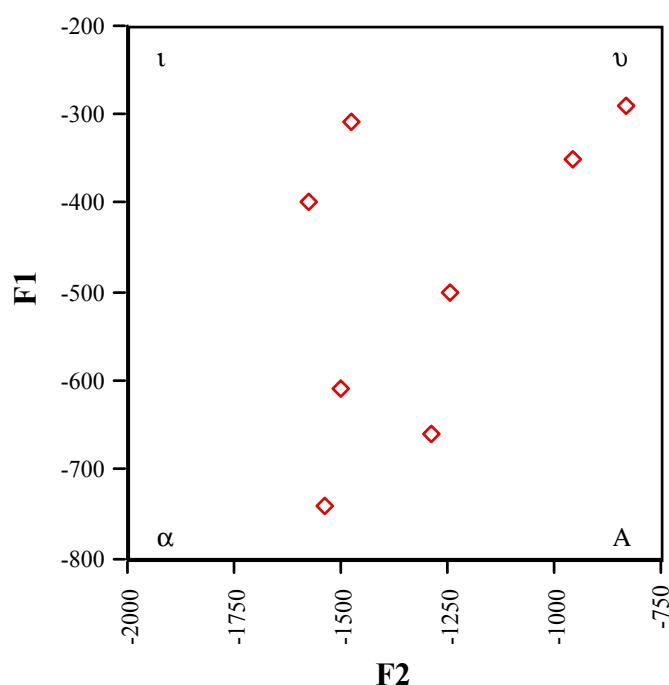


## 3. Discussion

The data from this study are compared with those of other researchers in figure 3 (for numeric values cf. appendix 1). Figure 3 reveals that both /i/ and /i:/ in our data are considerably lower and more central than the values established by other researchers, with for /i:/ an *average* F2 spread of approximately 300Hz, i.e. the difference between the lowest value found and ours, whereas it is interesting to note that the second-lowest F2 is that of Cairo Arabic (see appendix 1, figure 3), whose F1 value is close to Belkaid's, al-Ani's, and Abou Haidar's findings. The F1 of CARS /i:/ exceeds the values found by other researchers, and is 60 Hz than the highest value, i.e. that of Abou Haidar's United Arab Emirates (UAE) speaker. It should be pointed out that al-Ani's values in the table are those of the vowels *in isolation*, which largely explains the deviation from the others. For /i/, it appears that the CARS values are close to Ghazeli's and Abou Haidar's, (average value for all eight speakers), with the values of the Syrian, Sudanese, and UAE Arabic speakers coming closest, but markedly higher than the findings of Belkaid and al-Ani. The Cairene /i/ and /i:/ in connected speech are even more centralized, with F1 of /i:/ being within a hair's breadth of the values found by al-Ani, Ghazeli, Belkaid, and Abou Haidar.

*Figure 3 : Comparison of the acoustic vowel data of the various reports on the subject.*
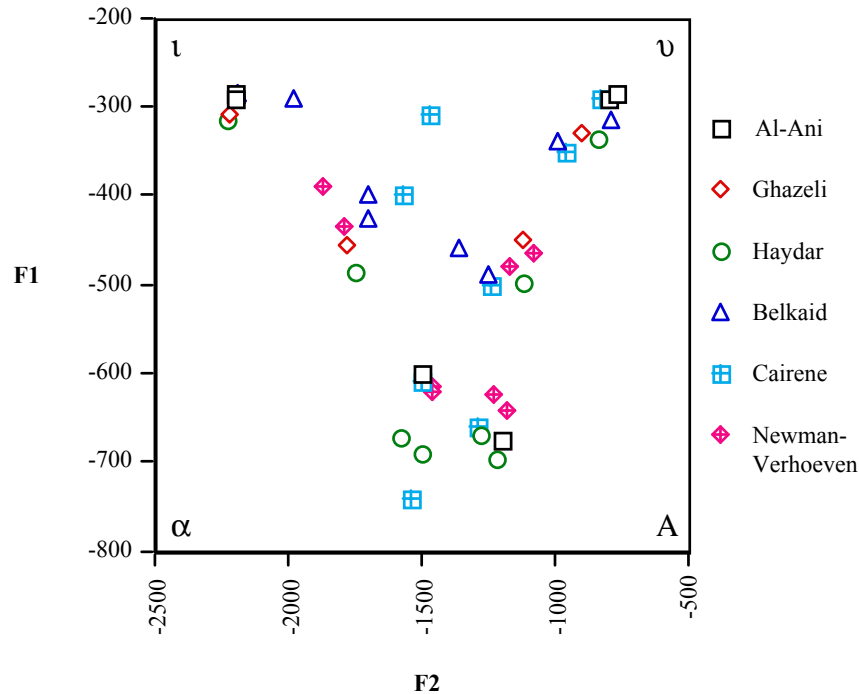


A somewhat similar picture emerges with regard to /u/ and /u:/, with our values being by far the highest for both F1 and F2, resulting in a highly central and lowered position. Of particular note is the rather high F2 value for /u:/ , with only the UAE speaker coming close. Interestingly enough, the F1 value for /u/ falls well within the expected range. The values for vowels in Cairene connected speech are strikingly higher and more back than the Qur´an recitation vowels, and thus closer to the findings related to the vowels in unconnected speech of earlier researchers.

The open central /a/ and /a:/ are by far the most stable, with our values approaching those of al-Ani's vowels in isolation ! It is interesting to note that this stability can be observed for almost all speakers of previous studies, with the notable exception of F2 values, with spreads of 500Hz and 300 Hz for /a/ and /a:/, respectively. The Cairene vowels again are closer to the positions of the vowels of earlier researchers.

However, the area in which our findings most clearly diverge from those of other researchers is that of length. While length is *phonemic* in MSA as in most other varieties of Arabic (R. Nasr 1960 ; F. Mitleb 1984) – our data reveal that within the acrolectal Qur´anic recitation style the *acoustic* difference between the short and long varieties is **not** statistically significant.

## 4. Conclusion

Although ours is a preliminary study and further research is clearly required, it would seem that the findings do not confirm the existence of a High Classical Style as an acoustically 'purer' variety of Modern Standard Arabic. Indeed, the evidence does not support the long-held perception-based view that, contrary to MSA, the High Classical Style is somehow less 'tainted' by regional speech varieties. Rather, our data of the vowels in High Classical Style – at least in connected speech – would seem to corroborate the existence of a cross-dialectal structural stability of Arabic vowels at the top end of the style continuum. Finally, as the HCS vowels are hardly at acoustic extremes, their use as a reference tool is as limited as those of other varieties of Arabic.

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**Appendix 1**

*Comparative list of vowel frequencies (Hz). Values in bold are the highest in range, those underscored the lowest, blanks indicate absence of data.*

|  | ĭ | | i | | ŭ | | u | | ă | | a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** |
| **Al-Ani** | <u>285</u> | 2200 | <u>290</u> | **2200** | <u>285</u> | <u>775</u> | <u>290</u> | <u>800</u> | 675 | <u>1200</u> | 600 | 1500 |
| **Ghazeli** | 310 | 2225 | 455 | 1780 | 330 | 900 | 450 | 1125 | | | | |
| **Belkaid** | <u>285</u> | 2195 | 355 | 1830 | 310 | 790 | 340 | 995 | <u>425</u> | 1720 | <u>400</u> | **1640** |
| **Haidar** | 315 | **2230** | **485** | <u>1750</u> | 335 | 835 | 500 | 1120 | **690** | **1500** | 675 | 1585 |
| **Newman-Verhoeven** | **390** | <u>1725</u> | 440 | 1770 | **470** | **1120** | **480** | **1170** | 620 | 1455 | 616 | <u>1460</u> |
| **Spread** | 105 | 525 | 195 | 450 | 195 | 345 | 190 | 370 | 275 | 300 | 275 | 180 |

*List of vowel frequencies (Hz) in Abou Haidar (1994). Values in bold are the highest in range, those underscored the lowest.*

|  | ĭ | | i | | ŭ | | u | | ă | | a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** |
| Qatari | 310 | 1990 | 500 | 1400 | <u>310</u> | 830 | 490 | <u>1005</u> | 621 | <u>1280</u> | <u>620</u> | 1540 |
| Lebanon | <u>280</u> | 2010 | 490 | <u>1530</u> | 330 | 795 | 475 | 1060 | 610 | 1430 | 640 | <u>1390</u> |
| Saudi | 305 | 2530 | 540 | 1830 | 375 | 930 | 540 | 1190 | 730 | 1540 | 695 | 1590 |
| Tunisia | 315 | 2275 | 510 | 1690 | 360 | 830 | 540 | 1135 | <u>610</u> | **1780** | 650 | 1590 |
| Syria | 330 | 2465 | 415 | **2135** | 320 | <u>620</u> | <u>430</u> | 1200 | 710 | 1560 | 700 | **1680** |
| Sudan | 325 | 2220 | 420 | 2000 | **380** | 900 | 455 | 1040 | 730 | 1500 | 660 | 1600 |
| UAE | **335** | 2065 | 460 | 1720 | 350 | **990** | 475 | 1075 | 730 | 1380 | 640 | 1660 |
| Jordan | 320 | 2295 | 565 | 1720 | 260 | 795 | **580** | **1240** | <u>770</u> | 1521 | **780** | 1620 |
| Spread | 50 | 470 | 150 | 600 | 70 | 350 | 150 | 240 | 150 | 500 | 150 | 300 |

*List of vowel frequencies (Hz) in Cairene.*

|  | ĭ | | i | | ŭ | | u | | ă | | a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** | **F1** | **F2** |
| Cairene | 290 | 1940 | 375 | 1575 | 290 | 830 | 360 | 912 | 610 | 1500 | 683 | 1435 |