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An Acoustic Study of the Production of Iraqi Arabic Vowels

**ABSTRACT**

The present study describes the Mosuli Iraqi Arabic (henceforth MIA) pure vowels acoustically in terms of two parameters: vowel quality and vowel quantity. Two measurements are made: first, measuring the three formants F1, F2 and F3, and second, measuring vowel duration. The MIA pure vowels /i, iː, a, aː, u, uː, eː, oː/ are analysed acoustically using 14 monosyllabic CVC and two disyllabic (CVCCVC) words. These words are read in a carrier phrase by 15 native speakers of MIA (three times each) obtaining 720 tokens. The effect of the voicing of the following consonant on vowel duration is also investigated. The results show that the qualitative differences between the MIA long vowels and their short counterparts, especially on the F2 dimension, are of greater importance than the quantitative differences. It is also found that vowels before voiced consonants are longer than those before voiceless ones.

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1. Introduction

The study of the physics of the speech signal is an important part of phonetics. Ladefoged (2006:6) and Ladefoged and Johnson (2011:6-7) give four motives for the desire to describe speech sounds acoustically: First, acoustic description is useful to explain the confusion that occurs between speech sounds. Second, speech sounds are better described by their acoustic structure instead of their articulatory movements. Third, acoustic phonetics helps to perceive how speech sounds are synthesised and recognized by computers. Fourth, the most effective way of studying speech data is achieved by analysing a permanent recording since x-rays or photographs are difficult to get in order to know what the speaker is doing during his speech.

Arabic is one of the Semitic languages. It is considered the second most spoken language in regard to the number of speakers (Alotaibi and Husain, 2009; Alotaibi and Husain, 2010; Almisreb, Abidin and Tahir, 2015). The number of speakers of Arabic is approximated to be more than 250 million people (Sabir and Al-Saeed, 2014). In addition to the standard variety used nowadays, viz. Modern Standard Arabic (henceforth MSA), there are different dialects used in Arabic societies. MSA comprises 36 phonemes: six pure vowels, two diphthongs and 28 consonants. There are three short vowels and their corresponding longer versions: /i, i:, a, a:, u, u:/ (Alotaibi and Husain, 2010). Western scholars did not pay attention to the Arabic language till the commencement of the 19th century (Al-Ani, 1970:17; Alotaibi and Husain, 2010). Saadah (2011) and Saber and Al-Saeed (2014) among other researchers share the same view that Arabic is much less researched in comparison to other languages such as English.

There are some studies conducted on MSA vowels in addition to some Arabic dialects. The first acoustic study conducted on MSA vowels was by Al-Ani (1970). Al-Ani recorded vowels in isolation as well as in minimal pairs and sentences, but the description of vowel formants and duration depended on the recordings made of isolated vowels produced by Al-Ani himself. Al-Ani (1970) found almost no difference in quality between the high vowels /i:/ and /u:/ and their short counterparts. However, higher F1 and F2 differences were found between the vowel /a:/ and its short counterpart /a/. The quantity differences between long vowels and their short counterparts were much greater than their quality differences.

Belkaid (1984, cited in Ahmed, 2008) investigated the production of MSA vowels in the CV and CVC environments. He found significant differences between long and short vowels. Alghamdi (1998) conducted an acoustic analysis study of MSA vowels. He aimed to examine whether the six Arabic pure vowels are realised in the same way when uttered by speakers of different Arabic dialects. He studied these vowels in three different dialects: Saudi, Sudanese and Egyptian. The duration and the formant frequencies of vowels were measured using monosyllabic CVC words. The duration of the syllable containing the vowel was also measured. Newman and Verhoeven (2002) conducted a formant analysis
of Classical Arabic (henceforth CA) vowels in connected speech. The study was based on Qur'anic recitation by one of the most respected Arabic Qur'an readers. The aim of the study was to prove whether vowels in CA were to be regarded references like the cardinal vowels and thus can be used as a device for comparison when studying other varieties of Arabic. In addition, an acoustic analysis of the same vowels in connected colloquial Egyptian Arabic was conducted. Saadah (2011) studied the acoustic characteristics of MSA vowels produced by Palestinian speakers. Palestinian vowels were described according to their formant structure and duration using CVC monosyllabic words embedded in a carrier phrase.

There are few studies conducted on vowels in other Arabic dialects. An experimental study of vowel duration in Iraqi spoken Arabic was conducted by Hassan (1981). One of the aims of the study was to investigate the intrinsic vowel duration with which the present study is concerned. It also studied the effect of voicing of the following consonants on vowel duration. Ahmed (2008) conducted an acoustic investigation of the quality and quantity of the eight Libyan Arabic vowels. These vowels were presented in two CVC monosyllabic words embedded in a carrier phrase. The acoustic measurements made were F1, F2 and vowel duration. Almbark (2012) conducted an acoustic analysis study of the Syrian Arabic vowels. The Syrian vowels were put in monosyllabic /hVd/ context embedded in a carrier phrase. The acoustic measurements made were F1, F2 and vowel duration.

Having reviewed the acoustic studies found on Arabic vowels, it is evident that Arabic vowels have received little attention as far as experimental studies are concerned. Little research has been conducted to examine Arabic vowels experimentally. The present study attempts to contribute to the literature on Arabic vowels by providing an acoustic description of MIA vowels which, to the best of the researchers’ knowledge, has not received such description. These vowels will be described acoustically in terms of vowel quality and vowel quantity; i.e. vowel formant structure and vowel duration, respectively.

2. Aims of the Study
The main aim of the study is to present an acoustic description of MIA vowels as spoken by Mosuli Iraqi speakers. This aim is achieved by investigating the following:

1. The formants structure of MIA vowels and measuring their frequency, i.e. vowel quality.
2. MIA intrinsic vowel duration, i.e. vowel quantity.
3. The difference between MIA vowels and other Arabic dialects.
4. The effect of voicing of the following consonants on MIA vowel duration.

3. Method:
A test is conducted in order to obtain vowel formant frequencies and vowel duration. The details are presented below.
3.1. Data Collection:

The words used in the study were sixteen meaningful words. Each MIA vowel was represented in monosyllabic CVC words except the vowel /i/ which was put in disyllabic (CVCCVC) words due to the difficulty of finding monosyllabic words for this vowel. The syllable containing the short vowel /i/ in the disyllabic words was the unstressed one to avoid the effect of stress on vowel duration. Two words were selected for each vowel; one word ended with a voiced consonant, while the other terminated in a voiceless consonant. The choice of voiced and voiceless contexts after the vowels was of two folds: first, it was difficult to choose one context over the other since prevocalic consonant voicing effect has been reported in different studies (see for example Hassan, 1981; Ahmed, 2008 and Kasim, 2018), second, to investigate the effect of voicing on vowel duration. The two words used for each vowel were minimal pairs, except the ones including the vowel /u/. It was difficult to find minimal pairs for all the words used in the study. Choosing monosyllabic words instead of multisyllabic words was to avoid the effect of stress and the number of syllables on vowel duration. Nearly all the words used in the study were dialectal words except the word /dub/ which was produced in the standard variety since it was difficult to find a monosyllabic dialectal word for the short vowel /u/. Some of the test words can be used both in the standard variety and the dialect. The consonants preceding and following the target vowels were either stops or fricatives since they provide clear boundaries on the spectrogram. Nasals and liquids were avoided in the vicinity of the target vowels due to the difficulty of segmentation. Avoiding nasals, liquids, pharyngeal, pharyngealised (emphatic) consonants, geminated consonants and the uvulars /x/ and /ɣ/ limited the choice of the test words. Some studies showed that these consonants affected the formant frequencies of vowels and their duration. Nonsense words were not used in this study since they tend to have longer duration than the real words (Ahmed, 2008:106). The test words are presented in Table (1).

![Table 1 The data used in the test.](image)

The test words were embedded in the carrier phrase /quːl...?arbaʕ mar'raːt/ "say ...... four times". Saying the words in a carrier phrase can achieve a close approximation to natural speech. The test words embedded in the phrase were followed by a glottal stop which was followed by a
vowel. The glottal stop provides a clear boundary and it prevents forming consonant clusters with the final consonant of the test words which would affect vowel duration. The carrier phrase is neutral in terms of the grammatical category, stress and meaning. It helps to analyse vowels. It is not syntactically sensitive to the grammatical category of the inserted word. In addition, the test words inserted in the phrase do not receive stress since the stress is on the word /ʔarbaʕ/ in the carrier phrase.

3.2. Subjects:

The subjects of the study were eighteen native speakers of MIA: eleven males and seven females. All of them were educated and their ages ranged from 18 to 29 years. None of them reported any speech disorders. All the subjects were monolinguals. The subjects were asked to fill a language questionnaire (see Appendix 1) before starting the recording to make sure that they met the selection criteria concerning age, education and being monolingual native speakers of MIA.

3.3. Procedure:

The test words were printed in Arabic on flash cards (8cmx11cm) using simplified Arabic with a font size of 80. The printed words were presented to the subjects who were asked to familiarize themselves with the test words. They pronounced these words several times before recording to avoid any pronunciation mistakes. The subjects were asked to pronounce the word /dub/ (bear) as used in the standard variety and not as in the dialect. The subjects were asked to insert the test words in the carrier phrase /qu:l ..... ?arbaʕ mar-ra:t/ "say ...... four times". The subjects were asked to pronounce the carrier phrase in a normal speaking conversation, and not to make pauses between the words. The test words were randomised and presented again to each subject. There were three trials of recording for each subject. Three males were excluded from the study. The reason behind excluding them was that one of them made pauses between the words in the phrase. The second subject had a very low speech rate which might affect the average vowel duration. The third subject produced very fast speech which was difficult to be segmented and analysed on the spectrogram. So, the total number of subjects was 15: eight males and seven females. The number of vowels recorded was 720 (16 words x 3 trails x 15 subjects). Each subject was tested individually in the language laboratory of the College of Education for Social Sciences, University of Mosul.

3.4. Equipment:

In order to record the test data, a desk microphone was connected to a laptop. Praat (Boersma and Weenink, 2017) version 6.0.33 was used for recording and analysing the data. The recordings were saved as WAV files.

3.5. Acoustic Measurements:

There were two types of acoustic measurements made: first, taking the frequency values of the first three formants F1, F2 and F3, and second, specifying vowel duration. Formant frequency measurements of F1, F2 and F3 were taken for the target vowels at the vowel midpoint (see Figure1).
Figure 1. The selected area shown by the arrow indicates the vowel midpoint for measuring the first three formants for the vowel /e:/ in the word /be:dʒ/. Vowel duration was measured at the vowel’s steady-state from the onset of energy of F1, F2 and sometimes F3 to the offset of energy of F1, F2 and sometimes F3. Since F1 and F2 sometimes do not appear clearly on the spectrogram, F3 is made use of with one of the first two formants to specify vowel duration (see Figure 2).

Figure 2. The selected area in the middle of the figure indicates the steady state for measuring duration of the vowel /i:/ in the word /dʒi:t/. The consonants preceding and following the vowels in the test words were either fricatives or stops (see 3.1). They provided a clear boundary to the beginning and the end of the target vowel. When the vowel was preceded by a stop, the onset of the vowel was marked by the end of the noiselessness of the stop and the beginning of the first vertical striation indicating voicing on the wide band spectrogram (see Figure 3). The onset of the vowel preceded by a fricative, on the other hand, was marked by the end of the noise for the fricative and the beginning of the first vertical striation of the vowel (see Figure 4). The offset of the vowel followed by a
fricative was marked by the beginning of the noise of the fricative (see Figure 3), whereas it was marked by the beginning of the closure of the stop when the vowel was followed by a stop (see Figure 4). The following spectrograms illustrate each case.

Figure 3. A spectrogram of the vowel /i:/ preceded by a stop and followed by a fricative (see selected area in the middle) in the word /beːʃ/.

Figure 4. A spectrogram of the vowel /a/ preceded by a fricative and followed by a stop (see selected area in the middle) in the word /ʃak/.

4. Results:

The results of the description of vowel formant frequencies and vowel duration are presented below.

4.1. Vowel Formant Frequency Analysis:

The two words representing each MIA vowel are embedded within a phrase. The average formant frequency value for each vowel is obtained from these two words. The values are rounded to the nearest one as shown in Table (2).
Table (2) Formant frequency mean values of MIA vowels in the CVC words embedded in the phrase (numbers refer to Hz).

<table>
<thead>
<tr>
<th>MIA vowels</th>
<th>/i/</th>
<th>/i:/</th>
<th>/a/</th>
<th>/a:/</th>
<th>/u/</th>
<th>/u:/</th>
<th>/e:/</th>
<th>/o:/</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>387</td>
<td>354</td>
<td>578</td>
<td>726</td>
<td>453</td>
<td>409</td>
<td>495</td>
<td>583</td>
</tr>
<tr>
<td>Difference</td>
<td>33</td>
<td>148</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>1942</td>
<td>2169</td>
<td>1765</td>
<td>1437</td>
<td>1337</td>
<td>1235</td>
<td>2047</td>
<td>1115</td>
</tr>
<tr>
<td>Difference</td>
<td>227</td>
<td>328</td>
<td>102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>2684</td>
<td>2809</td>
<td>2592</td>
<td>2676</td>
<td>2669</td>
<td>2615</td>
<td>2671</td>
<td>2633</td>
</tr>
</tbody>
</table>

As presented in Table (2), the short vowels /i/ and /u/ have higher F1 values than their long counterparts /i:/ and /u:/ successively, while the short vowel /a/ has a lower F1 value than its long counterpart /a:/.

Concerning F2 values, the short vowel /i/ has a lower F2 value than its long counterpart, while the two vowels /u/ and /a/ have higher F2 values than their long counterpart /u:/ and /a:/ respectively. The two dialectal vowels /e:/ and /o:/ have higher F1 values than the high vowels /i:/ and /u:/ and their short counterparts. When compared with the low vowel /a:/ and its short counterpart /a/, the vowel /e:/ has a lower F1 value. The vowel /o:/, on the other hand, has a lower F1 value than /a:/, but a higher F1 value than the short vowel /a/. The vowel /e:/ has a higher F2 value than all other MIA vowels except the vowel /i:/ which has a higher F2 value than /e:/.
The vowel /o:/ has a lower F2 value than all other vowels. As for the F3 values, they are important in the acoustic analysis, but they are not utilised in the comparison of long vowels and their short counterparts.

The F2 differences between long vowels and their short counterparts are higher than the F1 differences. The F1 difference is 33 Hz between /i/ and /i:/, 148 Hz between /a/ and /a:/ and 44 Hz between /u/ and /u:/.
The F2 difference is 227 Hz between /i/ and /i:/, 328 Hz between /a/ and /a:/ and 102 Hz between /u/ and /u:/.

4.2. Vowel Duration Analysis:

The mean duration values of MIA vowels embedded in the phrase are shown in Table (3). The mean duration value for each vowel is obtained from the two words representing each vowel. These values are rounded to the nearest one.

Table (3) The mean duration values in milliseconds (ms) of MIA vowels embedded in the phrase, their difference and ratio.

<table>
<thead>
<tr>
<th>MIA vowels</th>
<th>/i/</th>
<th>/i:/</th>
<th>/a/</th>
<th>/a:/</th>
<th>/u/</th>
<th>/u:/</th>
<th>/e:/</th>
<th>/o:/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>51</td>
<td>112</td>
<td>76</td>
<td>144</td>
<td>76</td>
<td>139</td>
<td>150</td>
<td>142</td>
</tr>
<tr>
<td>Difference</td>
<td>61</td>
<td>68</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td>2.2</td>
<td>1.9</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The shortest duration for the short vowels is found in the high front vowel /i/ being 51 ms. The two short vowels /a/ and /u/ have the same duration being 76 ms. As for the long vowels, the shortest duration is found in the high front vowel /i:/ being 112 ms, while the longest duration is found in the dialectal vowel /o:/ being 150 ms.

The duration differences between the MIA vowels and their short counterparts are lower than their F2 differences. Concerning F1 differences they are lower than the duration differences except the F1 difference between /a/ and /a:/ being 148 Hz which is higher than their duration difference being 68 ms. As presented in Table (3), the quantity difference is 61 ms between /i/ and /i:/, 68 ms between /a/ and /a:/ and 63 ms between /u/ and /u:/.

The long vowel /i:/ is more than twice as long as its short counterpart /i/, while the long vowels /a:/ and /u:/ are almost twice as long as their short counterparts /a/ and /u/ respectively (see the ratios of the duration of long vowels to their short counterparts in Table (3)). The ratios of these vowels are rounded to the nearest two.

5. Discussion:

The results of the description of MIA vowel formant frequency and vowel duration within the phrase are discussed below.

5.1. Vowel Formant Frequency (Vowel Quality):

The two long vowels /i:/ and /u:/ are produced with higher tongue body position than their short counterparts /i/ and /u/ successively as is evident from their lower F1 values compared to those of /i/ and /u/ (see Table 2). The long vowel /a:/, on the other hand, is lower than its short counterpart /a/ due to its higher F1 value (726 Hz) than that of /a/ (578 Hz). The high F2 differences between long vowels and their short counterparts denote that there is a qualitative difference among MIA vowels and their short counterparts. The long vowel /i:/ is more to the front in the vowel space than its short counterpart /i/. This is clear from the higher F2 value of /i:/ than that of /i/. On the contrary, the two long vowels /a:/ and /u:/ are more retracted than their short counterparts /a/ and /u/ respectively since /a:/ and /u:/ have lower F2 values than their short counterparts.

As for the dialectal vowels, the vowel /e:/ has a higher F1 value than the vowel /i:/ and /u:/ and their short counterparts, but a lower F1 value than the vowel /a:/ and its short counterpart. This means that the vowel /e:/ is produced lower than the high vowels /i:/ and /u:/ and their short counterparts and higher than the vowel /a:/ and its short counterpart. The vowel /o:/ is produced with lower tongue body position than the vowels /i:/ and /u:/ and their short counterparts due to its higher F1 value. When compared with the vowel /a:/ and its short counterpart /a/, the vowel /o:/ is produced higher than the vowel /a:/, but lower than /a/. This is clear-cut from the higher F1 value of /o:/ being (583) Hz than that of /a/ being (578) Hz (see Table 2). Concerning F2 values of the two vowels /e:/ and /o:/, the vowel /e:/ has a higher F2 value than all other vowels except the vowel /i:/ which indicates that it is more to the front than all other vowels except the vowel /i:/ which is more front than /e:/.
retracted than all other vowels due to its lower F2 value (1115 Hz) due to the effect of lip rounding (Fry, 1979:79). The MIA vowels are plotted on a formant chart (see Figure 5). The two triangles in the chart highlight quality difference between MIA long vowels and their short counterparts. One of the advantages of having a formant chart of a language is its use for pedagogical purposes. The chart of MIA vowels can be utilised in teaching English vowels. Ladefoged and Johnson (2011:224) state that the vowels of the students’ first language can be used as “reference points” to be compared with the vowels of the language taught.

![Formant Chart](image)

**Figure 5.** A formant chart showing the frequency of the first formant on the ordinate (the vertical axis) plotted against the second formant on the abscissa (the horizontal axis) for the eight MIA vowels (the chart is reproduced from Ladefoged, 2006).

5.2. **Vowel Duration (Vowel Quantity):**

The ratio of the long vowel /i:/ to that of /i/ is higher than that found between the other two vowels /u:/ and /a:/ and their short counterparts (see Table 3). This can be attributed to the production of the short vowel /i/ in disyllabic words while the vowel /i:/ is produced in monosyllabic words (see Table 1). It is known that the increase of the number of syllables lowers vowel duration (Ladefoged, 2001:73).

5.3. **MIA Vowels and Other Arabic Dialects:**

Compared with the vowels of other Arabic dialects, (see Appendix 2) the F1 difference between the MIA vowel /i:/ and its short counterpart
/i/ is lower than that between the corresponding Tunisian (Belkaid,1984), Saudi (Alghamdi,1998), Sudanese (Alghamdi,1998), Egyptian (Alghamdi,1998), Cairene (Newman and Verhoeven,2002), Qur’anic (Newman and Verhoeven,2002) and the Libyan (Ahmed,2008) vowels /i:/ and /i/. The MIA vowels /u:/ and /u/ exhibit a higher F1 difference than the Tunisian, the Sudanese, Qur’anic and the Libyan vowels /u:/ and /u/, but a lower F1 difference than the Saudi and Egyptian vowels. As for the MIA vowels /a:/ and its short counterpart /a/, they show a higher F1 difference than the Tunisian, the Saudi, the Sudanese, the Egyptian, Cairene, the Qur’anic, and Libyan vowels. As for the F2 differences, the MIA vowels /i:/ and /i/ show a lower F2 difference than the Tunisian, the Saudi, the Egyptian, the Cairene and Libyan vowels, but they show a higher F2 difference than the Sudanese and Qur’anic vowels. The F2 difference between the MIA vowels /u:/ and its short counterpart /u/ is lower than that between the corresponding Tunisian, Saudi, Sudanese, Egyptian and Libyan vowels, while they exhibit a higher F2 difference than the Cairene and Qur’anic vowels. As for the two MIA vowels /a:/ and /a/, they show a higher F2 difference than the Tunisian, Saudi, Sudanese, Egyptian, Cairene, Qur’anic, and Libyan vowels.

The quantity differences of the present study are compared with those of other studies (see Appendix 3). The quantity difference between the MIA vowels /i:/ and /i/ is higher than it between the Iraqi vowels /i:/ and /i/ studies by Hassan (1981), but it is lower than that between the corresponding Saudi, Sudanese, Egyptian (Alghamdi,1998), Libyan (Ahmed,2008) and Palestinian (Saadah,2011) vowels. The same thing can be said for the MIA vowels /u:/ and /a:/ and their short counterparts except that the quantity difference between the MIA vowel /a:/ and /a/ is lower than the Iraqi vowels /a:/ and /a/ studied by Hassan (1981).

5.4. Prevocalic Consonant Voicing Effect on Vowel Duration:

Each of the MIA eight vowels was embedded in a pair of words in which it was followed by either a voiced or a voiceless consonant (see Table 1). The aim was to investigate the effect of prevocalic consonant voicing on vowel duration. The result shows that vowels before voiced consonant are longer than those before voiceless consonants. The mean duration values of the vowels before the two types of consonants are presented in Table (4).

<table>
<thead>
<tr>
<th>MIA vowels</th>
<th>/i/</th>
<th>/i:/</th>
<th>/a/</th>
<th>/a:/</th>
<th>/u/</th>
<th>/u:/</th>
<th>/e:/</th>
<th>/o:/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before voiced consonants</td>
<td>58</td>
<td>118</td>
<td>81</td>
<td>152</td>
<td>81</td>
<td>144</td>
<td>158</td>
<td>157</td>
</tr>
<tr>
<td>Before voiceless consonants</td>
<td>44</td>
<td>105</td>
<td>70</td>
<td>136</td>
<td>71</td>
<td>134</td>
<td>142</td>
<td>126</td>
</tr>
<tr>
<td>Difference</td>
<td>14</td>
<td>13</td>
<td>11</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>31</td>
</tr>
</tbody>
</table>

6. Conclusion:

This study presented an acoustic description of MIA vowels with regard to their formant structure (quality) and vowel duration (quantity). The MIA vowels were analysed using 14 CVC monosyllabic and 2 disyllabic words, which were embedded in a carrier phrase. The results showed that MIA vowels exhibited F1 and F2 differences similar to other Arabic vowels. F2 differences between the MIA long vowels and their short counterparts, however, were higher than their F1 differences. In addition, although MIA vowels showed quantity differences, these differences were lower than the quality differences especially regarding F2 differences. It was also found that vowels before voiced consonants were longer than those before voiceless consonants; a finding that is similar to many other studies.

7. Acknowledgements:

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References:


