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A Dialectal Acoustic Comparison of Vowels in Jordanian Arabic: Madani Dialect vs Fallaħi Dialect

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***Abstract*—This study investigates the acoustic correlates of long and short vowel contrast for two dialects spoken in the northern part of Jordan. More specifically, it describes the vowels uttered in a connected speech by the Urban Speakers (referred to as 'Madani Dialect,' henceforth 'MD') and Rural Speakers (referred to as 'Fallaħ Dialect,' henceforth 'FD'). Three males and two females from each region uttered 40 words. The vowel inventory for both dialects consists of three short vowels, /i, a,u/, and five long vowels, /i: a: u: e: o:/. Phonetically speaking, vowels can be best analyzed by measuring their acoustic properties rather than describing their articulatory configurations (Ladefoged, 2003). As such, analyzing formant frequencies is the most common method to examine the characteristics of vowel systems of any language or variety. The F1, F2, and duration are the acoustic parameters that were measured, analyzed, and compared with previous studies when necessary. The results revealed that females have higher formants than males, duration is a cue for vowel identity, and length is phonemic. Also, the vowels of the Madani and Fallaħi dialects were found to have relatively shorter durations than their Arabic counterparts by Egyptian, Palestinian, Saudi, and Sudanese.**

***Index Terms*—Madani dialect, Fallaħi dialect, vowel quantity, vowel quality, vocalic space**

I. Introduction

Many studies on vowel production in Classical Arabic and Modern Standard Arabic (henceforth, MSA) (Newman & Verhoeven, 2002; Salameh, 2014), as well as Arabic varieties (Al-Ani, 1970; Abou Haidar, 1994; Alghamdi, 1998; Almbark, 2010; Al-Tamimi & Barkat-Defradas, 2003; Kalaldeh, 2018), have been conducted. The spoken Arabic dialects have different vowel systems, whether in the number of vowels or the spectral manifestations. For example, it has been reported that Jordanian and Palestinian Arabic have mid-long vowels /e:/ and /o:/, emerging from the monopolization process of vowel-glide sequence, as found in /bajt/ 'home' and /mwat/ 'death' in Modern Standard Arabic (Youssef, 2010). Moreover, other dialects, such as Moroccan and Sudanese Arabic, have been proven to have schwa in their vowel inventory (Abou Haidar, 1994; Al-Tamimi, 2007; Kalakdeh, 2018). The following section will present a brief overview of the results of some acoustic studies on Classical Arabic and Arabic varieties.

1. Previous Studies on the Vowels of Arabic dialects

Al-Ani (1970) conducted an acoustic analysis of Arabic vowels produced by Iraqi informants using X-rays and spectrographs. He recorded vowels in isolation without being in contexts, suggesting that consonants may affect the formants' steady state. Unsurprisingly, he found that the vowels' duration was twice as long as the ones uttered in contexts. Another limitation is that the analysis of the results was descriptive. Another study dealt with Arabic vowels; Abou Haidar (1994) performed an acoustic analysis for eight dialects (Qatari, Lebanese, Syrian, Jordanian, Sudanese, Tunisian, Saudi, and Emirati) using one informant from each dialect. He reported that there are wide variations in formant values across these dialects. However, the results revealed that the Jordanian dialect has the highest formant values while Qatari's formant values are the lowest. Although Abo Hiader is the only one who utilized DSP methods; However, his results were somehow unreliable and could not be overgeneralized since he recorded one participant from each variety.

In the same pursuit, Alghamdi (1998) investigated the acoustic cues for six vowels /a, i, u, a:, i:, u:/ produced by 15 speakers from Saudi Arabia, Sudan, and Egypt. The speakers uttered six CVC long and short syllables in isolation. The short vowel words were nonsense (sis-sus-sas). He measured duration, frequencies, amplitudes, and bandwidths using linear predictive coding spectrum tables. His study revealed that the duration of long vowels is twice as long as their counterparts. Moreover, he claimed that vowel quality is the determiner of differences between dialects, as vowel quantity is similar in these dialects. In addition, Newman and Verhoeven (2002) attempt to make a cardinal vowel space as a reference for Arabic varieties in their study. They performed an acoustic analysis for Arabic vowels in connected speech. Accordingly, they recorded the recitation of Quranic verses and Colloquial Egyptian Arabic in non-pharyngealized contexts, claiming that the Quranic verses represent a prestigious and pure Classical Arabic language. The results of this study show that no acoustic extremes were detected in the Classical Arabic vowels, and the short-long vowel duration

opposition was not statistically significant. For comparison purposes, Table 1 displays data for short and long vowels' first two formants as spoken in some Arabic varieties (taken from Newman & Verhoeven, 2002).

TABLE 1
F1 AND F2 FOR SHORT AND LONG VOWELS IN SOME ARABIC VARIETIES

	/i:/		/i/		/u:/		/u/		/a:/		/a/	
	F1	F2	F1	F2	F1	F2	F1	F2			F1	F2
Al-Ani/Iraqi	285	2200	290	2200	285	775	290	800	675	1200	600	1500
Ghazali/mixed[1]	310	2225	455	1780	330	900	450	1125				
Belkaid/Tunisian	285	2195	355	1830	310	790	340	995	425	1720	400	1640
Haidar/mixed[2]	315	2230	485	1750	335	835	500	1120	690	1500	675	1585
Newman-Verhoven/ Quranic	390	1725	440	1770	470	1120	480	1170	620	1455	616	1460
Newman-Verhoven/ Cairene	290	1940	375	1575	290	830	360	912	610	1500	683	1435

It would be difficult to make comparisons for F1, F2, and duration across Arabic vowel studies due to the different methods of recording and collecting data (speaking rate, speaking style, etc). Thus, comparing the acoustic results of this study with previous studies would be available when relevant and necessary.

2. Vowel Quantity

It is widely assumed that Arabic is a quantity language and that lengths in Arabic vowels are phonemic and contrastive (Ryding, 2005; Cowell, 1964). Unlike English, which uses the lax-tense mechanism to distinguish vowel duration, Modern Standard Arabic and its varieties utilize a short-long mechanism, forming minimal pairs, for example, /ʤam**a**l/ 'a camel' and /ʤam**a:**l/ 'beauty.' Moreover, a study by Jong and Zawaydeh (2002) found that Jordanian Arabic has longer significant durational differences in stressed syllables than in unstressed syllables.

3. Vowel Quality

The standard vowel inventory of Modern Standard Arabic consists of six vowels, described as short-long distinctions (/i/-/i:/, /u/-/u:/, /a/-/a:/). Acoustically speaking, vowel quality refers to the spectral properties and patterns that are reflected in the configuration of the place of articulation for different vowels. A few studies reported that vowel quality plays an important role in distinguishing between short and long vowels in MSA (Al-Tamimi, 2007). However, Arabic varieties are an exception since Arabic dialects vary in their vowel inventory. For example, Jordanian Arabic has the mid-long vowels /e:/ and /o:/ (Al-Tamimi, 2007), while Syrian Arabic has mid-short vowels /e/ and /o/ (Almabark, 2011).

4. Objectives

This study aims to present some preliminary observations on acoustic characteristics of the vowels of two dialects spoken in the northern part of Jordan and test some assumptions, such as women tend to have a larger vocalic space than males. Thus, the study purports to answer the following questions:

a. What are the acoustic properties (F1, F2, and duration) of vowels in Madani Dialect (MD) and Fallaħi Dialect (FD)?
b. Are there differences between the vowel systems of the two dialects? Males vs females?
c. Are there any durational differences between dialects and between genders?

II. METHODS

A. Participants

This study intends to present an acoustic analysis of the vowels of two dialects spoken in Irbid city, located northwest of Jordan. One dialect is spoken in the villages of Irbid, which is referred to as the Fallaħi Dialect (Bani-Yasin & Owens, 1987), and the other dialect is spoken by people who live inside the city of Irbid and who are originally from Palestine, which is referred to as Madani Dialect (Alkhatib, 1998). Three males and two females from each dialect were recorded. All the ten speakers were born, lived, and received university education in Irbid, except one Fallaħi female speaker with a high school education.

B. Materials and Procedure

The vowels investigated in the two dialects included a set of monosyllabic words containing five long vowels [/i:/, /a:/, /u:/, /e:/, /o:/] and three short vowels /i, a,u/ in non-pharyngealised environment. The test material involved five real words per vowel. The test words were embedded in a carrier sentence "?uktub……marte:n" (Write……twice) to avoid phrase final effects of lengthening vowels since producing vowels in isolated words tends to be longer than in contexts (Zawaydeh & de Jong, 2011; Alghamdi, 1998). The total number of tokens comprises 3 repetitions×8 test words×12 speakers =720 items.

The recordings were performed using a TASCAM DA-P1 portable DAT recorder with an AKG C420 Headset condenser microphone. Each participant was asked to read the sentences naturally, with normal speech rate, and in a quiet room. The acoustic structure of the vowels for both dialects was manually segmented based on visual information in a broadband spectrogram and auditory assessment. By using the textgrid, the duration of the vowel and the readings of F1

and F2 were extracted from the midpoint of the vowel's duration of the entire vowel. The mean and standard deviation of the vowels' midpoints were calculated to measure the speakers' vocalic spaces. The following section will present the statistical analysis and graphical representations of the vowels for males and females in both dialects. Finally, a linear model was run to examine any significant main effects in the formants and duration using R software.

III. Results

This section presents the short and long vowels produced for females and males in both dialects in figures and graphs. Table 1 reports the mean values and SDs for F1, F2, and duration. Due to the different vocal tract lengths between females and males, the statistical analyses are performed separately in both dialects.

Descriptive statistics

Table 2
Averages and SDs (Between Brackets) for the Duration (MS) and Formant Frequencies (Hertz) for the First Three Formants Produced by 10 Speakers (Three Males and Two Females in Each Dialect)

			/i/	/i:/	/u/	/u:/	/a/	/a:/	/e:/	/o:/
MD	Dur	F	87(7)	160(12.7)	33(43.4)	148(32.8)	91(6.8)	160(12.8)	159(16.5)	159(9)
		M	63(8.6)	140(15.5)	65(7.8)	145(20.5)	124(170.9)	148(13.6)	143(11.8)	141(15)
	F1	F	544(56.6)	391(52.5)	605(79.2)	452(94.1)	740(102.6)	786(165.8)	529(65.4)	588(69.3)
		M	403(54.8)	343(56.96)	427(55.9)	341(36.4)	631(63.1)	615(45.9)	418(17.6)	431(38.2)
	F2	F	2219(45.6)	2720(634.3)	1350(98.7)	1239(385.7)	1811(213.1)	1757(94.9)	2412(86.1)	1270(99.5)
		M	1657(83.5)	2306(98.9)	1074(86.2)	857(163.4)	1730(114.7)	1464(45)	1920(128.5)	917(80.4)
FD	Dur	F	68(10.2)	173(22)	162(24.7)	175(15.3)	97(126)	176(17.4)	185(11)	187(29.6)
		M	87(15.3)	208(26.9)	90(13.8)	189(34.3)	91(15.4)	208(26.9)	214(31.2)	208(35)
	F1	F	533(106.4)	320(36.3)	494(60)	361(32.4)	727(154.7)	621(142.1)	528(104.7)	675(164)
		M	432(24.4)	337(47)	438(27.5)	358(43.1)	503(38.1)	566(47)	445(23)	464(20.8)
	F2	F	2014(83.8)	2352(524.7)	1282(227.2)	842(237.1)	1970(86)	1986(87)	2265(74.3)	1196(155.8)
		M	1614(170.9)	2226(164.4)	1057(82.3)	910(270.4)	1412(153.8)	1405(164.4)	1758(187.7)	929(83.2)

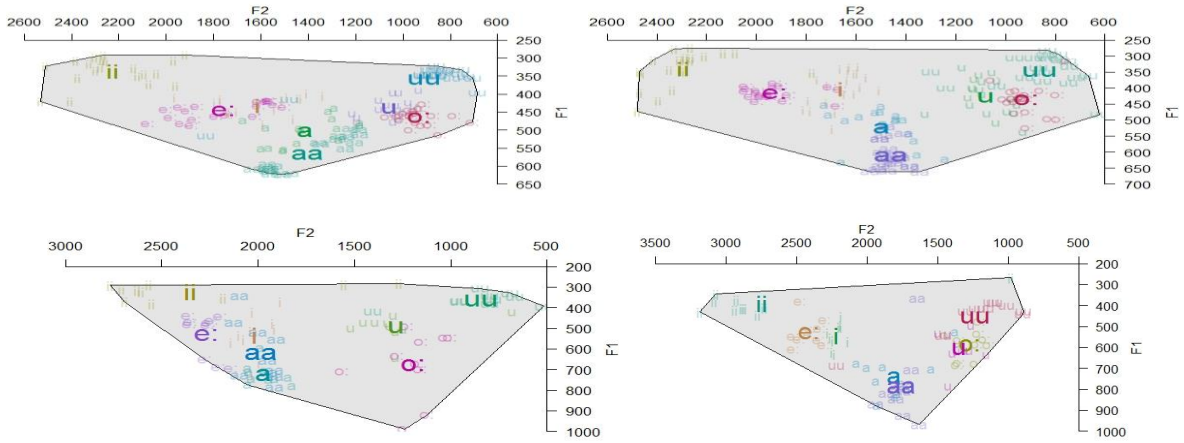

Figure 1. Vowel Space Scatterplots of Short and Long Vowels Produced by Madani and Fallaħi Dialects. The Top Graphs Are for Men, the Bottom Graphs Are for Women, the Left Graphs Are FD, and the Right Ones are MD.

Overall, the vowel space produced by Male Madani speakers (MMs) is greater than that of Male Fallaħi speakers (MFs), while the vowels by Female Madani speakers (FMs) and Female Fallaħi speakers (FFs) are slightly similar. This observation contradicts Henton's (1995) findings that females have larger vocalic space than males'. Thus, this leads to the question: What are the reasons behind this change? It could be that, in addition to physiological differences, sociolinguistic variables might be involved here. Moreover, unlike males' vocalic space, it can be noticed that the central area of the space is almost empty in Females. MFs appear to form a triangular shape like the one reported by Newman and Verhoeven (2002) for MSA. Generally, vowels are peripheral, except for FFs' productions of /a/. FFs tend to produce /a:/ higher than /a /. Overall, the vowel space produced by males in both dialects is larger and more spread in the F1 and F2 dimensions, but it is proportionately more upward for MD.

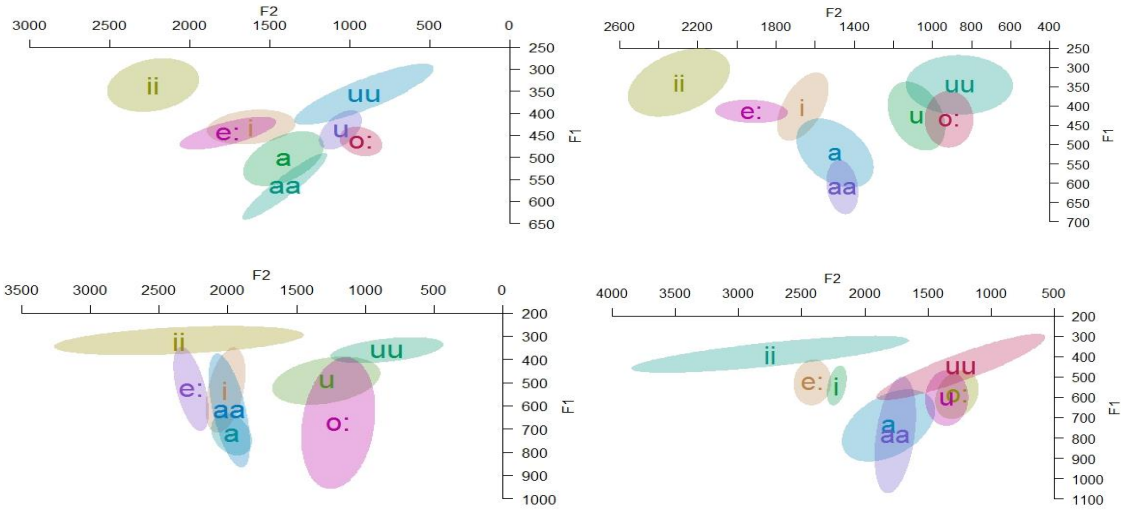

Figure 2. Vowel Space Plots of Short and Long Vowels Produced by Madani and Fallaḥi Dialects. The Top Graphs Are for Men, the Bottom Graphs Are for Women, the Left Graphs Are FD, and the Right Ones Are MD.

Figure 2 reveals that the long vowel /i: / for females in both dialects is more advanced with horizontal expansion in the vowel space compared to /i/ produced by males, which are retracted and spread. Moreover, the mid-long vowel /e:/ is more fronted than /i/ in both dialects, while the mid-long back /u:/ vowel is more posteriorized than /u/. However, back vowels in MMs occupy a larger space than those produced by the FMs. All short vowels tend to be centralized. This means that duration does not play a central role in determining between those vowels.

IV. Discussion

A. Exploratory Analysis of F1 and F2

(a). Vowel /i:/

This is a long, high-front vowel, as in /tiin/ (figs) and /siin/ (an Arabic alphabet). This vowel is realized differently in both dialects. As shown in Figure 3, MMs tend to produce this vowel more fronted and clustered, while it is more retracted and spread in FMs.

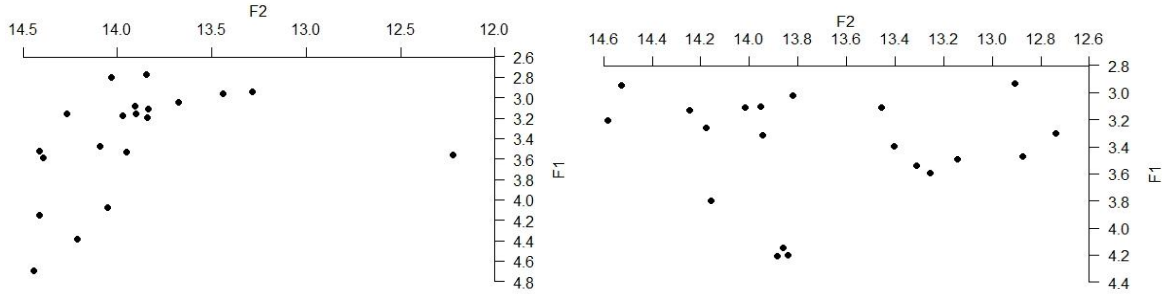

Figure 3. The Acoustic Realisations of /i:/ by MMs (Right) vs. FMs (Left)

This variation in the realization of the high long front vowel between both dialects is also confirmed by descriptive statistics. It can be noticed in Tables 1 and 2 that the range and the standard deviation are higher in F2 than F1 in both dialects. This indicates that the back–front dimension is more variable than the height dimension. That is to say, the F2 value for this vowel is considered a strong determiner in Jordanian male dialects. However, compared to other dialects, the mean F1 value of /i:/ is the lowest, meaning this vowel has a lower space in Jordanian dialects (see Table 1). Regarding the female's production of /i:/, Figure 4 below shows that females tend to produce this vowel more fronted, yet it is crowded downward in MF while it is produced slightly clustered upward in FF.

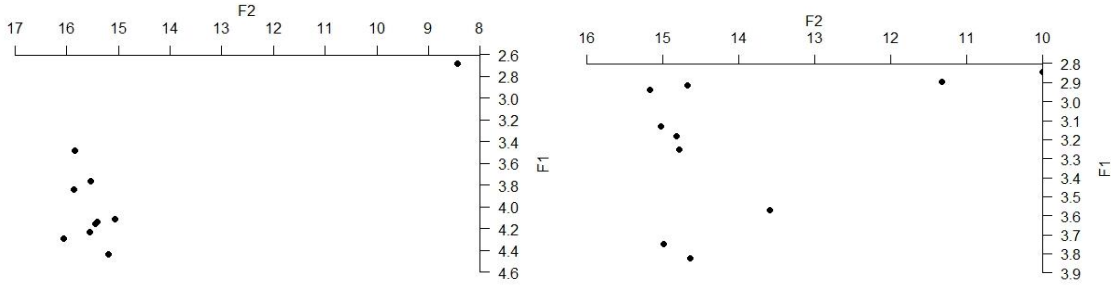

Figure 4. The Acoustic Realisations of /i:/ by MFs vs. FMs

A closer look at the descriptive statistics reveals that females have higher F2 values than males. This indicates that there is more variation among females in both dialects. The range of the F1 and F2 is 98 Hz and 1498 Hz in FF, while it is 179 Hz and 2198 Hz in FM, respectively. This means the vowel space for females is greater in F1 space size than for males, and they also have larger F2 space sizes.

(b). Vowel /i/

This is a high front short vowel as in /zitt/ (throw) and /tiff/ (spat). Figure 5 reveals that this vowel is retracted and more centralized in both dialects than the long vowel /i:/. However, it is produced slightly higher and more advanced in MMs than FMs.

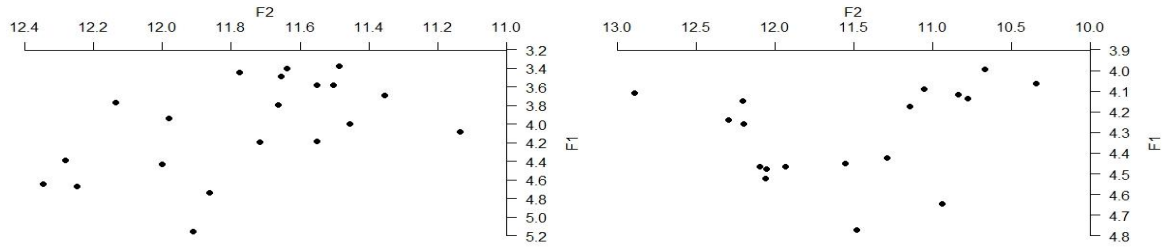

Figure 5. The Acoustic Realizations of /i/ by FMs (Right) vs. MMs (Left)

Upon inspecting the descriptive statistics of the vowel /i/ for males, it can be observed that the range of the F1 and F2 in the MMs are 85 Hz and 1614 Hz, while it is 82 Hz and 316 Hz in the FMs, respectively. In contrast, the females' realizations of this short vowel exhibit that it is more fronted in both dialects. In more detail, Figure 6 illustrates that the FFs' production of /i/ is mostly clustered upward compared to a wider spread in MFs' production.

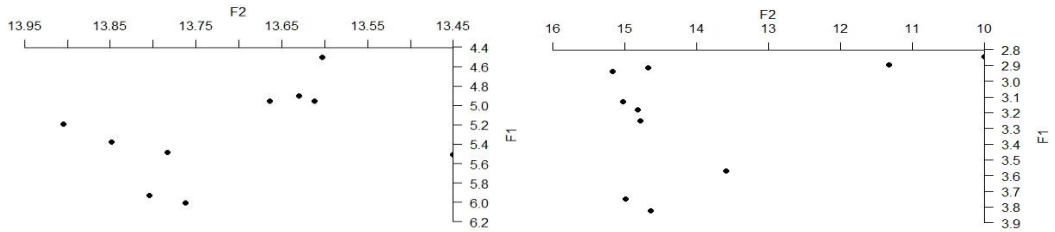

Figure 6. The Acoustic Realizations of /i/ by FFs (Right) vs. FFs (Left)

The range of F1 has higher values in MFs and FFs than in the F2 range. It is 400 Hz and 179 Hz, respectively. Expectedly, that females tend to have higher F1 values than men has been found and reported in the literature (Peterson & Barrey, 1952). By extension, this is due to the differences in the vocal tract length between females and males. The following graphical representations (Figure 7) compare the production of /i/ and its long cognates in each dialect:

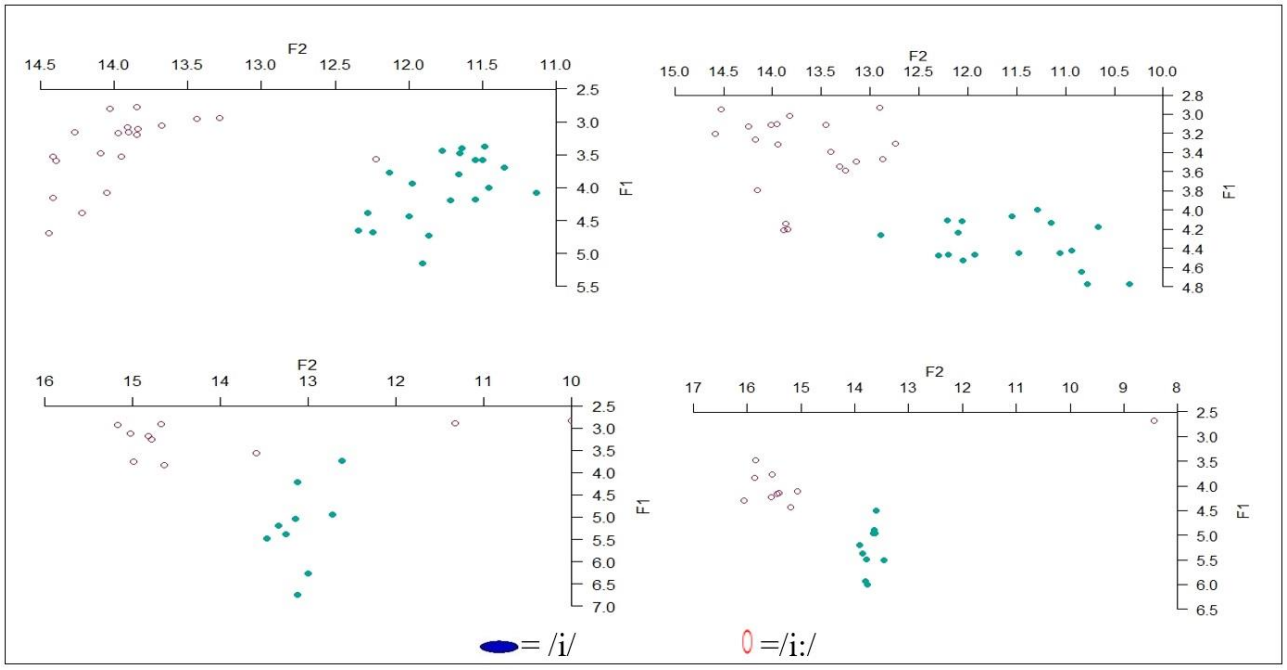

Figure 7. The Realizations of /i/ and /i:/ by FMs (Right Top) vs. MMs (Left Top) and FFs (Right Bottom) vs. MFs (Left Bottom)

Figure 7 displays that the realisations of /i/ and /i:/ for the two dialects in each group are close without any overlapping. Moreover, a linear model was performed on F1 and F2 for the vowel /i/as a dependent variable. The results show that F1 for MMs is lower than that of FMs by 0.28 barks and 2.1 standard error, yet the MMs' productions of /i/ are more significantly centralized ($p<0.0385$). As for F2, no significant main effect was found for dialect ($p>0.05$). An opposite pattern emerges from the females; no significant main effect is found for F1. However, F2 for MFs was higher and highly significant, fronted by 0.65 barks and 0.09 standard error, while the significant main effect is $p<3.31$. The linear model results for the vowel /i:/ reveal that no significant main effects were seen for males in both dialects. MMs are higher than FMs by 0.005 barks, 0.16 standard error, $p<0.971$ for F1 and 0.20 barks, 0.16 standard error, $p<0.222$ for F2. There is a significant main effect in F1 for MFs $p<0.003$ in which MFs are higher than FF by 0.68 barks and standard error 0.19. Regarding F2, no significant main effect is found.

(c). Vowel /a:/

This is a low front long vowel as in /ta:b/ ‘repent,'/na:m/ 'sleep.' In general, the productions of /a:/ in MMs are more dispersed than in FMs’ productions. There is variation along the front-back dimension and the vowel height, as shown in Figure 8.

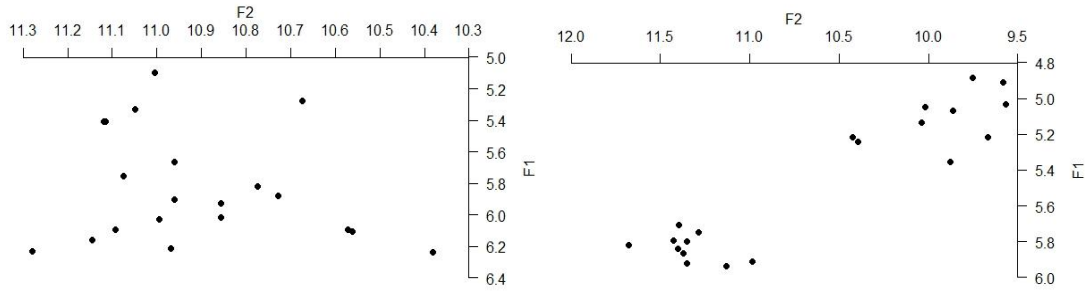

Figure 8. The Acoustic Realizations of /a:/ by MMs (Left) vs. FMs (Right)

As for the qualitative differences, The F1 range for MMs is 153 Hz compared to 127 Hz for FMs. Moreover, the F2 range for MMs is only 172 Hz compared to 454 Hz for FMs. This indicates that this vowel is realized lower in FMs than in MMs. In contrast, FMs and FFs show more considerable variation in the production of this long vowel, as represented in Figure 9. It is realized that it is approximately more dispersed in both dialects. However, FFs tend to produce it slightly higher, while it is more pulled downward in FMs, as illustrated in Figure 9.

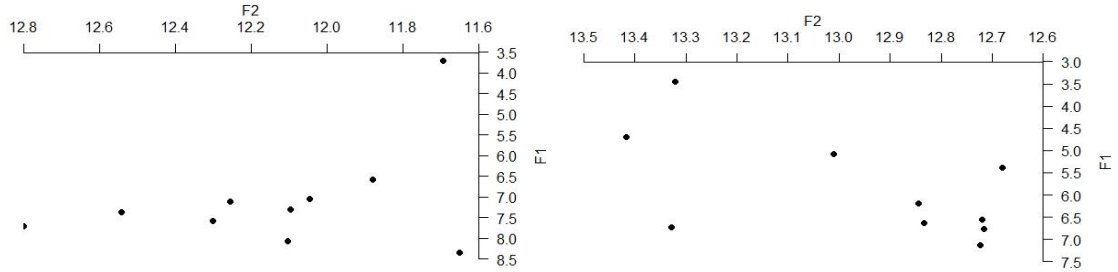

Figure 9. The Acoustic Realizations of /a:/ by FFs (Right) vs. FMs (Left)

Regarding quantity, The F1 range for MFs is 786 Hz compared to 621 Hz for FFs. Unlike the F2 values produced by males, the F2 range is 1757 Hz for MFs compared to 1986 for FFs. This reveals that the F2 values are an acoustic cue for FFs' production of this vowel.

(d). Vowel /a/

This is a low front short vowel, as in /sadd/ 'dam' and /laff/ 'turn.' It is clear that this vowel is realized with a wider spread in both dialects, yet it is more pulled upward for MMs, while it is somehow retracted for FMs, as shown in Figure 10.

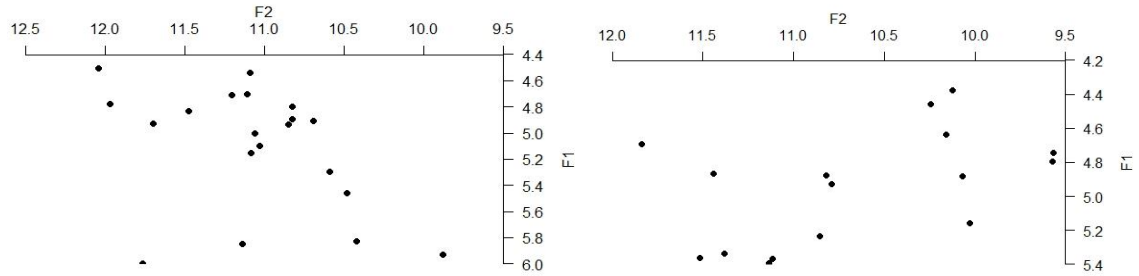

Figure 10. The Acoustic Realizations of /a/ by FMs (Right) vs. MMs (Left)

Qualitatively speaking, both dialects seem to have nearly similar F1 and F2 values. The F1 range for MMs is 178 Hz compared to 117 Hz for FMs. However, the range of F2 is 468 Hz for MMs, while it is 581 Hz for FMs. Thus, F2 was an acoustic cue for FMs for this vowel. However, compared to other dialects, the mean F1 of /a/ is the lowest, suggesting that this vowel has higher vowel space in Jordanian dialects (see Table 1). As for females, both dialects show that the expansion of variation in the production of this vowel is relatively downward compared to slightly upward for males, as shown in Figure 11.

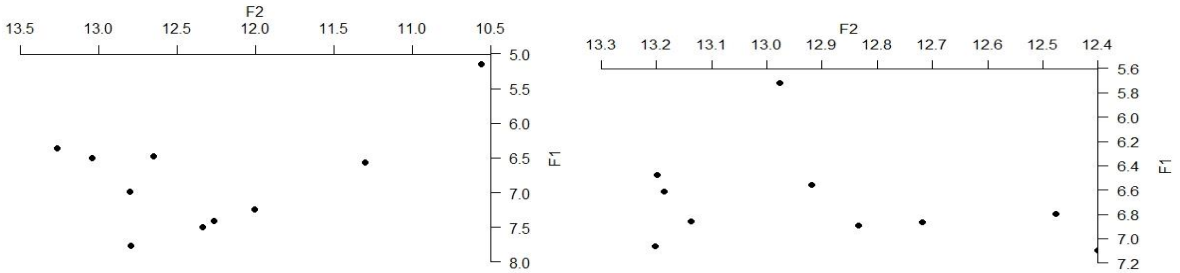

Figure 11. The Acoustic Realizations of /a:/ by FFs (Right) vs. MFs (Left)

The descriptive statistics show that this vowel has higher F1 and F2 values for both dialects. For the F1 range, it is 353 Hz for MFs compared to 183 Hz for FFs. Unexpectedly, the F2 range for FFs is only 232 Hz compared to 729 Hz for MFs, which means the front-back dimension is a strong acoustic cue in MFs. The following graphic representations (Figure 12) compare the production of /a/ and its long counterpart.

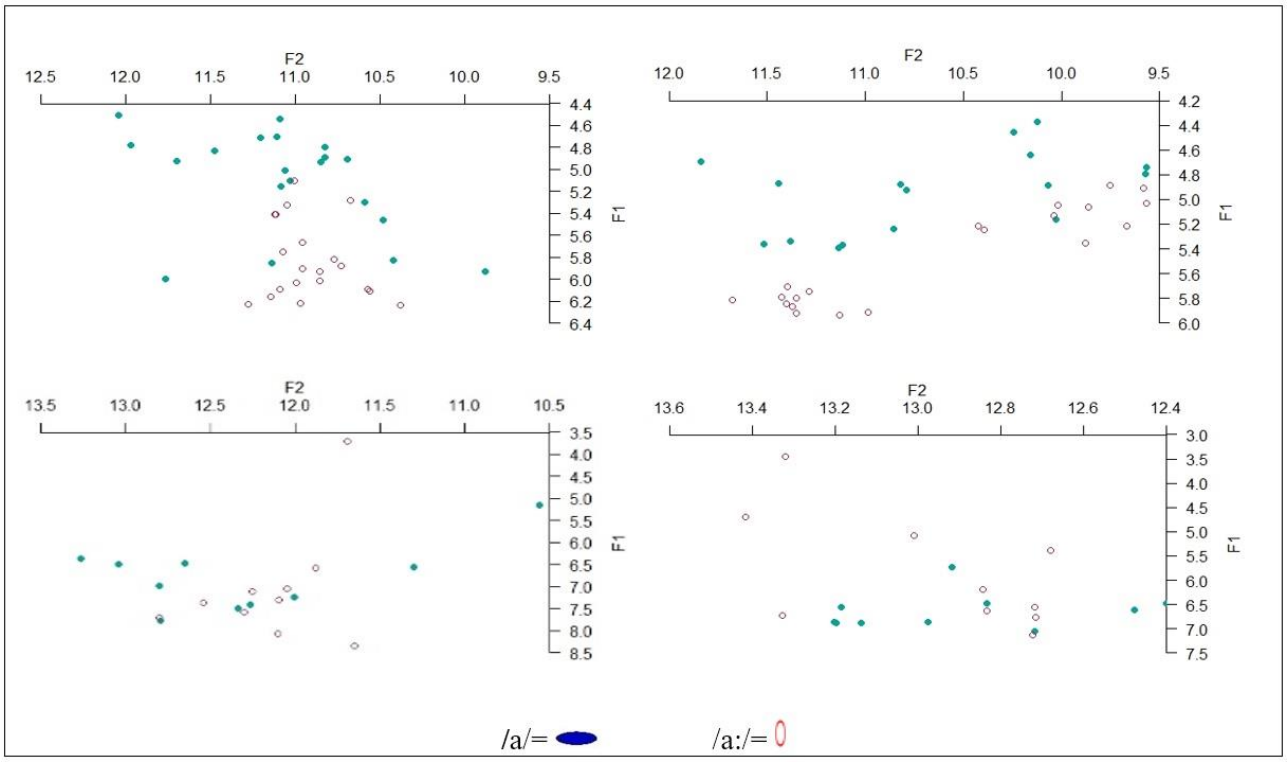

Figure 12. The Realizations of /a/ and /a:/ by FMs (Right Top) vs. MMs (Left Top) and FFs (Right Bottom) vs. MFs (Left Bottom)

Figure 12 The realization of /a/ and /aa/ in both dialects for each group shows many variations and overlaps in their productions. The results of a linear model of the vowel /a/ indicate that no significant main effect is found in F1 and F2 for MMs and FMs. As for females, a significant main effect is found in F2 for MFs ($p<0.0442$). MFs are higher than FFs by -0.60 barks and a standard error of 0.27. Regarding F1, no significant main effect is found. The results of the linear model for the vowel /aa/ show that F1 for MMs has a significant main effect ($p<0.00391$), and they are higher than FMs by 0.36 barks and standard error 0.11. As for F2, no significant main effect is found. In comparison with males' results, the results of the linear model for females show that F1 and F2 for MFs have significant main effects ($p<0.0409$) and ($p<0.001$), respectively. By extension, MFs are higher than FFs by 1.21 bark and 0.55 standard error in F1, while -0.82 bark and 0.14 standard error.

(e). Vowel /u/

This is a short, low back vowel as in /full/ 'jasmine' and /dubb/ 'a bear'. When comparing the long vowel /u:/ with the short vowel /u/ in gender-dialect distinction, it can be observed that the vowel /u:/ is more backer, higher, and clustered upward for FMs, FFs, and MFs than /u/, while production of MMs who tend to realize/u:/ more lowered, fronted and dispersed than that of /u/. Moreover, there is a clear separation between those vowels, as represented in Figure 13.

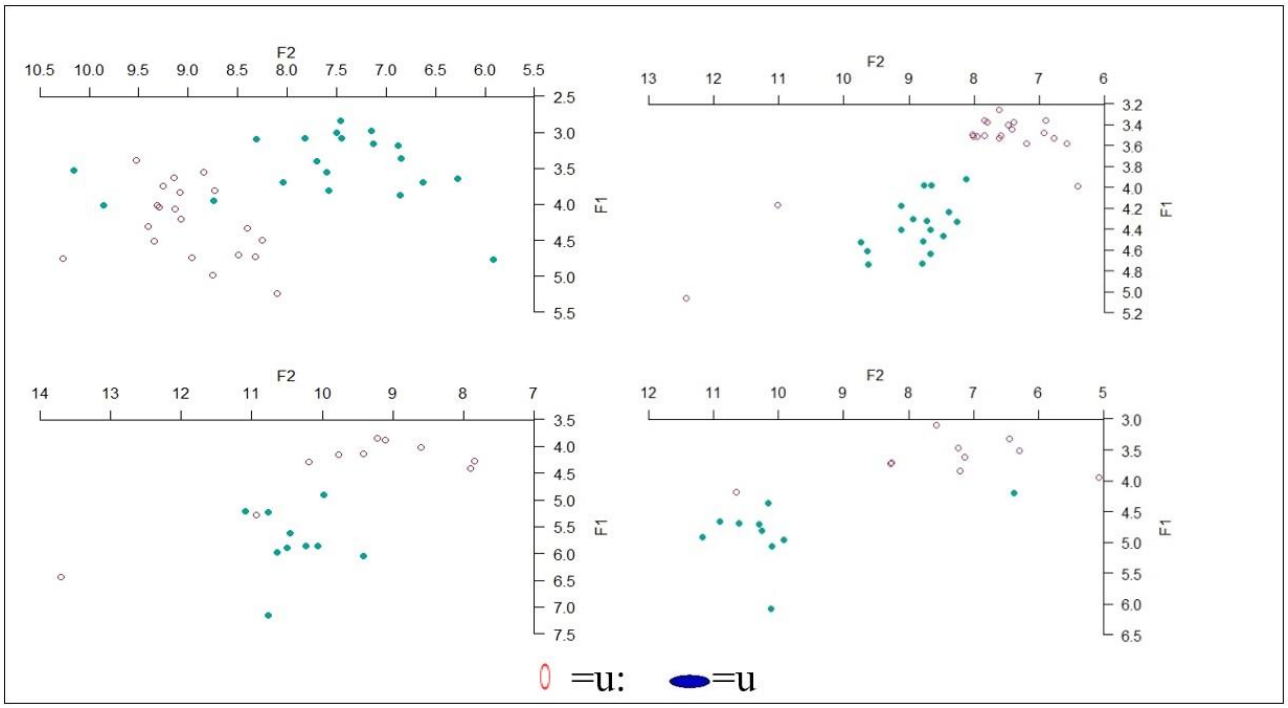

Figure 13. The Realizations of /u/ and /u:/ by FMs (Right Top) vs. MMs (Left Top) and FFs (Right Bottom) vs. MFs (Left Bottom)

On the other hand, the descriptive statistics results indicate a tendency in both dialects to produce more centralized than its long cognate. For example, the F1 and F2 range of the vowel /u/ for MMs is 206 and 323 compared to 282 and 618 in /u:/, respectively. As for FMs, the F1 and F2 range of the vowel /u/ is 89 Hz and 281 Hz compared to 194 Hz and 1146 Hz in /u:/, respectively. As can be noticed, the long vowel /u:/ has higher F2 values than that of F1, which means F2 is a strong acoustic cue to distinguish between the short-long high-back vowels in addition to the quantity measurements. When it comes to females' results, the F1 range for MFs is 252 Hz, while it is 198 Hz for FFs. Regarding the F2 range, MFs have 341 Hz, while FFs have 837. In contrast, the F1 and F2 range of the long /u:/ are 1318 and 885, respectively.

(f). Vowel /u:/

This a high back long vowel as in /fuul/ 'beans' and /suug/ 'a market.' This vowel shows a wide variation within the MMs speakers, while it is more retracted, clustered, and pulled upward for FMs speakers, as illustrated in Figure 14.

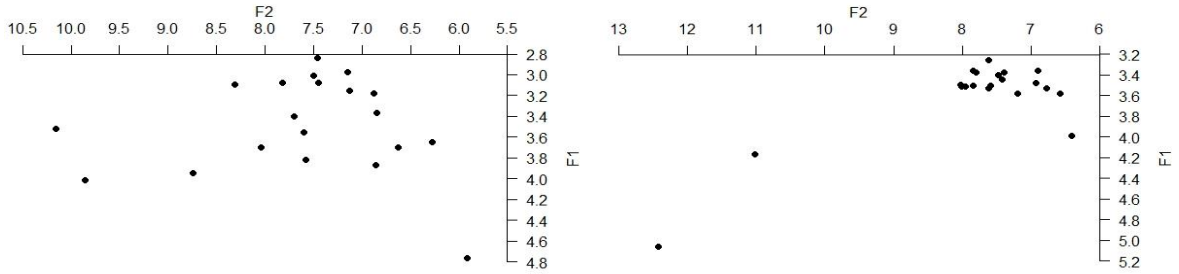

Figure 14. The Acoustic Realizations of /u:/ by FMs (Right) vs. MMs (Left)

More Interestingly, comparing the descriptive statistics between the F1 and F2 values of /i:/ and /u:/ reveals that the vowel /u:/ has higher F2 values in MMs and FMs than that of /i:/. It is 618 Hz and 1146 Hz compared to 448 Hz and 386 Hz, respectively. Interestingly, this confirms our earlier observations that F2 values play an important role in distinguishing the front-back dimension between dialects. In Figure 15, a similar variation in the realization of this vowel can be seen in the females' productions of this vowel. MFs' production of /u:/ is pulled upward and clustered, while /u:/ is spread in FFs' productions.

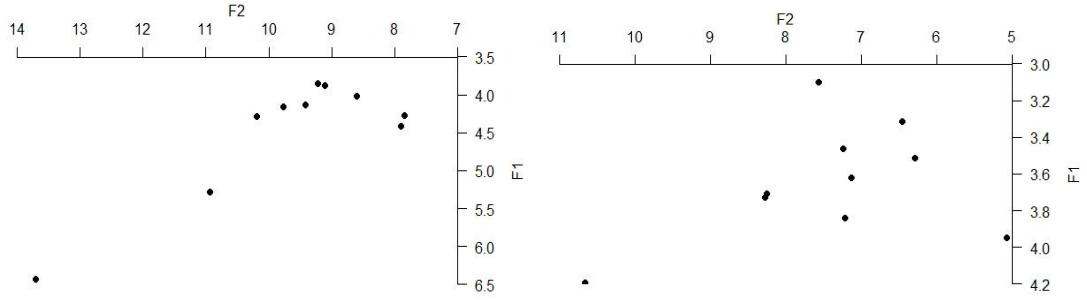

Figure 15. The Acoustic Realizations of /u:/ by FFs (Right) vs. MFs (Left)

Contrary to the values of F2 found in MMs and FMs, the descriptive statistics show that FMs and FFs have lower F2 values than the F2 values of /i:/. The range of F2 for /u:/ is 1318 Hz for MFs and 885 Hz for FFs compared to 1498 Hz and 2198 Hz in vowel /i:/, respectively. However, MFs still have a higher F2 range than FF, 1318 Hz, and 885 Hz, respectively. These statistical analyses provide strong cues to the regional background of the speaker. From an acoustic-articulatory perspective, it is well-understood that F2 reflects the position of the tongue and lip-rounding, which means that the MFs and FFs' productions of /u:/ are more fronted and slightly unrounded in FFs.

(g). Vowel /e:/

This is a mid-high long vowel as in /ze:t/ ‘oil’ and /se:l / ‘flood.' Figure. 16 displays the position of the sound /e:/ compared to the high front vowels /i/ and /i:/. As can be seen, the vowel space of the /e:/ sound shares some acoustic area with /i/, primarily found in the productions of male and female speakers in both dialects. Moreover, it can be observed that the /e:/ sound is lower than the vowel /i:/ and nearly in the same level of height as the vowel /i/, yet slightly more front than the vowel/i/ in both dialects.

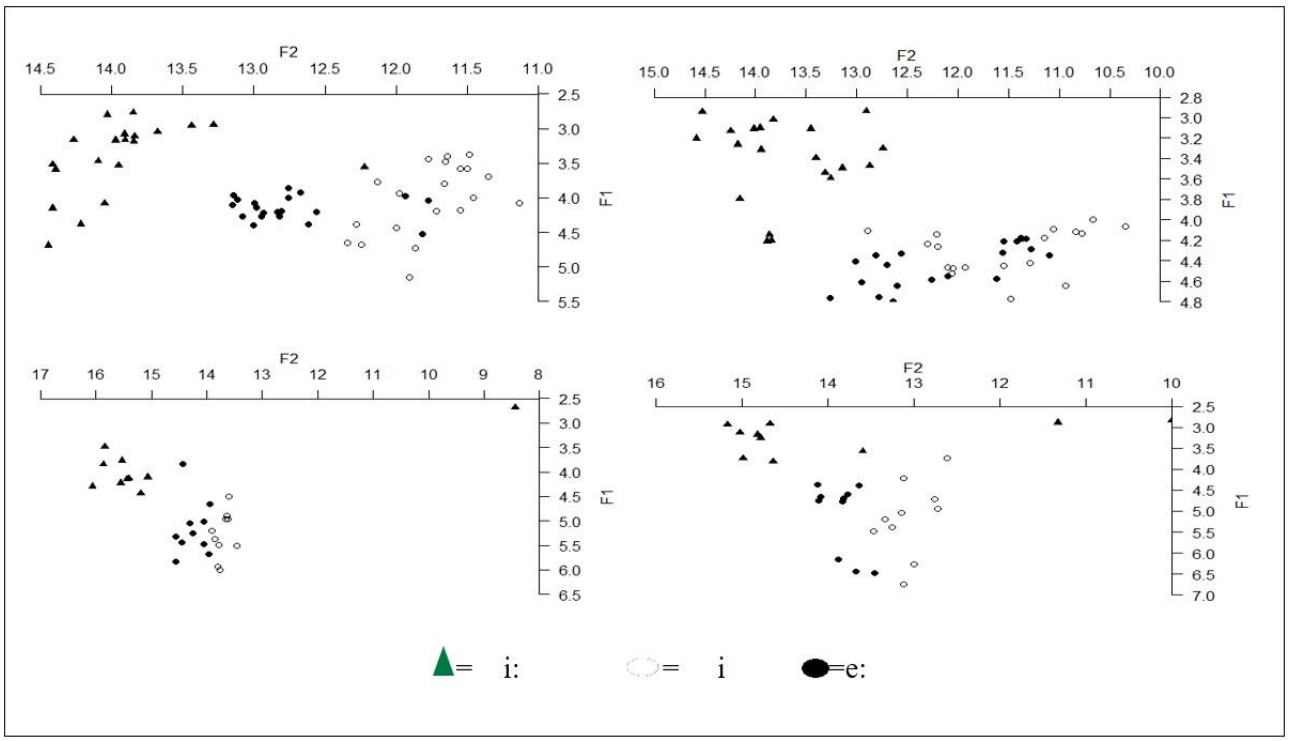

Figure 16. The Acoustic Realizations of /i:/, /i/, and /e:/ by FMs (Right Top) vs. MMs (Left Top) and FFs (Right Bottom) vs. MFs (Left Bottom)

In terms of quality, the F1 and F2 range for MMs and FMs are very similar. For F1, MMs are 65 Hz and 69 Hz for FMs, while 492 Hz and 576 Hz for F2, respectively. Accordingly, F2 is a strong acoustic correlate for males in both dialects. On the other hand, the females have higher F1 values and identical F2 values. The F1 range is 227 Hz for MFs and 256 Hz for FFs, while the F2 range is 222 Hz in both dialects.

On the other hand, the linear model results indicate that MMs have lower F1 than FMs by 0.28 bark, standard error 0.06, and significant main effect ($p<0.001$). However, in F2, no significant main effect is found. As for females, F1 reveals no significant main effect, while F2 for MFs is higher than that of FFs by 0.41 bark, 0.10 standard error, and a significant main effect is found ($p<0.001$).

(h). Vowel /o:/.

This is a mid-back vowel as in /to:m/ ‘twins’ and /lo:n/ ‘color.' An inspection of Figure17 reveals that /o:/ is lower than /u:/ and slightly lower than /u/ in MMs’ productions, while it is slightly lower than /u:/ and more centralized with small overlapping with /u/ in FMs'. Moreover, there is a considerable variation in the realization of this vowel among the females of both dialects. As can be seen, there is a great overlap with /u/ in FFs. For FMs, /o:/ and /u:/ are overlapped slightly with /u/, as shown in Figure 17.

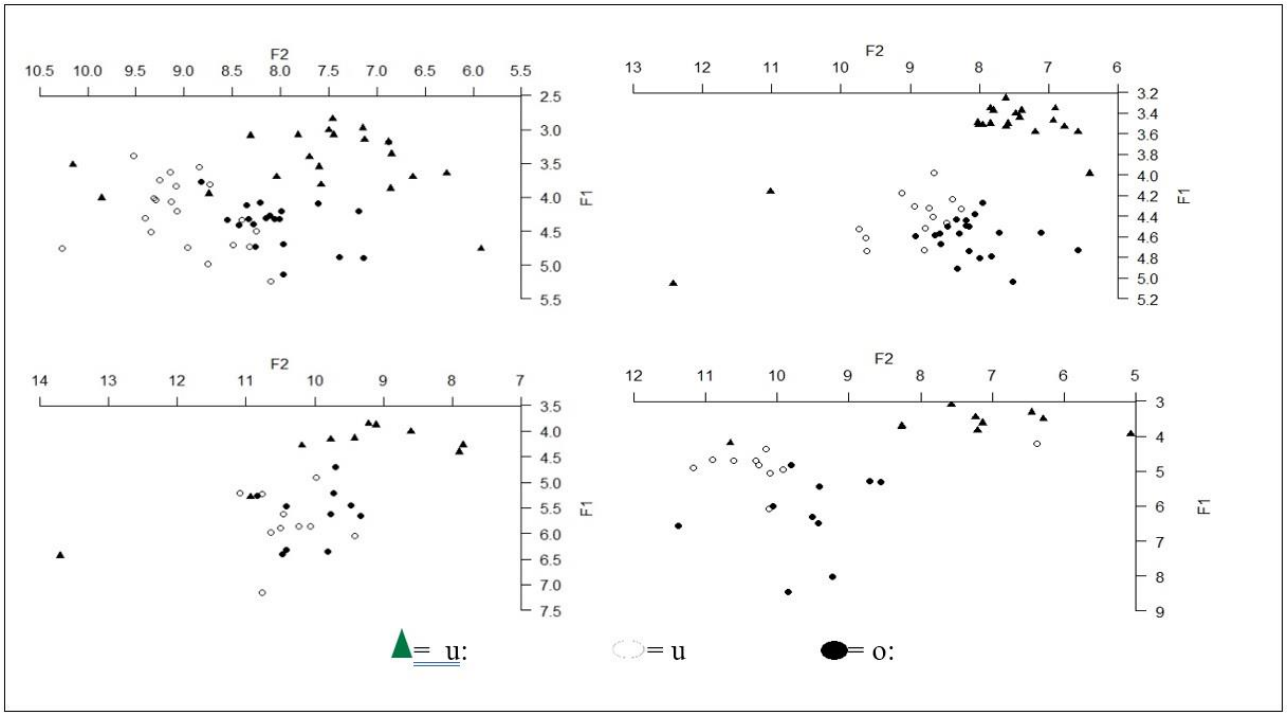

Figure 17. The Acoustic Realizations of /u:/, /u/, and /o:/ by FMs (Right Top) vs. MMs (Left Top) and FFs (Right Bottom) vs. MFs (Left Bottom)

In terms of quality, the results showed that the F1 and F2 range for MMs are 166 Hz and 350 Hz, while they are 86 Hz and 359 Hz for FMs, respectively. Females have higher F1 and F1 values than males. For MFs, the F1 and F2 range is 208 Hz and 300 Hz, while they are 499 Hz and 560 Hz for FFs, respectively. A possible reason for this may be that females have more variability due to their restricted physiological boundaries. A linear model was run to examine F1 and F2 differences in both dialects; the results show that F1 for MMs has a significant main effect ($p<0.0121$), and it is lower than that of FMs by 0.27 bark and standard deviation 0.10. Regarding F2, no significant main is found. As for females, the results confirm no significant main effects in F1 and F2.

B. Exploratory Analysis of Duration

The differences between MD and FD vowels in vowel duration were examined using a linear model. Overall, the vowel durations of FMs’ realizations are longer than that of MMs’, and MFs have a relatively longer duration than FFs, as seen in the following Table.

TABLE 3
MEAN DURATION OF THE EIGHT VOWELS

Dialect/Gender	/i/	/i:/	/a/	/a:/	/u/	/u:/	/e:/	/o:/
MMs	63	140	124	148	65	145	143	141
FMs	87	208	91	208	90	189	214	208
MFs	87	160	91	160	33	148	159	159
FFs	68	173	97	176	162	175	185	187

As can be observed, the quantity contrast in both dialects displays that long vowels are almost more than times longer than their short cognate. However, the vowel /a/-/a:/ contrast does not have distinctively durational differences in MMs. Likewise, the vowels /u/-/u:/contrast for FFs show no significant durational differences (See SD in Table 3). The longest vowel duration for MMs is /a:/ and /u:/, while it is /e:/ and /o:/ for FMs. As for females, /o:/ for MFs have the most extended vowel duration compared to /e:/ and /o:/ for FFs. Surprisingly, the vowel /u/, produced by FFs, has the shortest duration. Comparing the results of vowel duration produced by Palestinian, Saudi, Sudanese, and Egyptian males, it can be deduced that the Madani and Fallaħi Males in Jordanian Arabic have smaller duration values for short and long vowels.

TABLE 4
THE MEAN DURATION FOR MALE PALESTINIAN, SAUDI, SUDANESE, AND EGYPTIAN (ALGHAMDI, 1998; SAADAH, 2011)

	/i/	/i:/	/a/	/a:/	/u/	/u:/
Palestinian	84	219	97	247	90	226
Saudi	110	247	132	311	113	237
Sudanese	116	275	128	294	116	304
Egyptian	98	255	122	315	109	253

1. High front vowel contrast: (/i/, /i:/)

The linear model results showed that the MMs' productions of /i:/ are significantly shorter than FMs'($p<0.001$). More details, it is shorter by 0.07 barks and 0.008 standard error. As for the short counterpart /i/, MMs have a longer duration than FMs by 0.11 barks and 0.05 standard error. In contrast, the duration of /i/ as produced by MFs is significantly longer than FFs ($p<0.000$). However, MFs have a shorter duration than FFs by 0.006 barks and 0.008 standard error.

2. High back vowel contrast: (/u/, /u:/)

The linear model statistics reveals that the vowels /u/ and /u:/ have no significant main effects in MMs and FMs. However, the /u/ vowel for MMs has a shorter duration than FMs by 0.02 barks and 0.01 standard error. As for the /u:/ vowel, MMs have a shorter duration than FMs by 0.01 barks and 0.03 standard error. Compared with males' results, the duration of the vowel /u/ also shows no significant main effect in MFs and FFs. At the same time, its long counterparts have significantly shorter duration for MFs than that of FFs ($p<0.0293$).

3. Low Front vowel contrast: (/a/, /a:/)

The linear model analysis indicates no significant main effect in the /a/ vowel for MMs and FMs. However, the /aa/ vowel displays a significant main effect for MMs ($p<0.001$) with 0.07 bark and 0.007 standard error. A similar pattern is found in females where /u/ has no significant main effect, while its counterpart /u:/ for MFs is significantly shorter than FFs ($p<0.0293$) with 0.02 bark and 0.01 standard error.

4. Mid-high long /e:/

As can be observed from the linear model results, MMs are significantly shorter than FMs ($p<0.001$) with 0.07 bark and 0.007 standard error. As for females' duration, MFs are significantly shorter than FFs ($p<0.000$), with 0.02 bark and 0.006 standard error.

5. Mid-back vowel (/o:/)

The linear model results show that /o:/ is found to have a significant main effect on MMs ($p<0.001$). MMs have a shorter duration than FMs by 0.07 bark and 0.009 standard error. The same pattern emerges in the durational significance with MFs and FFs. MFs have a shorter duration than FFs ($p<0.011$), with 0.027 bark and 0.009 standard error.

V. CONCLUSION

The present study confirms that Madani and Fallaħi dialects have a five-long and three-short vowel system, as represented in Figure 1 above. Moreover, they have several general properties that other Arabic dialects, such as Cairene Arabic and Libyan Arabic (Ahmed, 2008; Yousef, 2010; Abushihab, 2010; Abushihab et al., 2011) exhibit: females have higher formants than males, duration is a cue for vowel identity, and length is phonemic. As for dialect-specific findings, one is that FMs have longer vowel duration for high front and back vowels than MMs, yet MMs have longer duration for low short vowels than FMs. Another is that the long-low vowel /a:/ is higher in FFs than in MMs, FMs, and MFs, a situation where speculation of future mergers would be involved in FFs. A similar situation is observed in the duration of /u-u:/ in FFs and /a-a:/ in MMs, where the short vowel and its cognates have relatively close duration and, thus, no significant quantitative differences are found. This also raises the question of whether the quantity measurement is reliable for determining short-long vowel contrast in Arabic varieties. Most notably, the vowels of the Madani and Fallaħi dialects were found to have shorter durations than their Arabic counterparts by Egyptian, Palestinian, Saudi, and Sudanese (see Tables 3 & 4). Finally, the vowel-intrinsic F2 for all vowels is greater in MMs than in FMs, which means it is a strong cue to distinguish Males' speech in both dialects. Future research will have to verify this speculation using dynamic analysis.

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