Formants Analysis of L2 Arabic Short Vowels: The Impact of Gender and Foreign Accent

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Abstract. The paper examines the formant of short vowels in Modern Standard Arabic (MSA) language produced by native and non-natives speakers. The experiment displays variations in MSA vowel quality when the mother tongue of L2 speakers is English. The analysis was conducted on F1, F2, and F3 formants computed from 145 Arabic sentences of the West Point corpus. Statistical analyses were applied on formant values to reveal the impact of foreign accent and the gender on Arabic short vowel quality produced by L2 speakers. Results show a significant effect of gender (female/male) and foreign accent of speakers on the formant frequencies.

Keywords: Formants · Statistical analysis · Modern Standard Arabic · Native speakers · Non-native speakers · Gender

1 Introduction

Recognizing native speakers from non-native speakers is often easier for a human being, but this task becomes a challenging problem when it comes to an automatic system. The distinction of speakers' accents in automatic recognizers and classifiers needs to be trained and tested using several kinds of speech features such as MFCC, rhythm metrics, etc. [1–6]. Formants that refer to the frequency resonance of the vocal tract are important acoustic features that are widely studied in speech processing as well as in: sounds production comparison within languages, second language (L2) acquisition, speech pathology studies, etc. [3, 7–12]. The present study examines vowel variation quality (the first, second, and third formants, hereafter F1, F2, and F3) within L1 and L2 Arabic language. The objective is to put forward formant variation in vowel production in Modern Standard Arabic (MSA) spoken by native vs. non-natives speakers using statistical analyses. Thus, we examined speakers' foreign accent, gender, and variations in the articulation of Arabic short vowels formant within connected sentences produced by Arabic and American participants.

MSA is a Semitic language that is endowed by six vowels: three short vowels (/a/, /u/ and /i/) vs. three long vowels (/a:/, /u:/ and /i:/). However, the English language has fifteen vowel sounds. The investigation examines only short vowels extracted from the speech material.

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The paper is organized as follows. Section 2 exposes speech material and participants used in the study. Section 3 describes the measurement of the formants dataset. Section 4 shows experiments and findings. Section 5 gives the concluding remarks based on the analysis.

2 Speakers and Speech Material

Recordings of 29 speakers (15 natives/14 non-native) were used in the study. Speech material was taken from the West Point corpus that was dedicated to recording MSA texts by Arabic and American speakers [13]. The recordings were collected at a normal speech rate, a sampling frequency of 22.05 kHz. Text material included five sentences from scripts 1 that were read by all speakers. A total of 145 recordings were used in the analysis. Table 1 shows the number and gender of speakers in the sample.

Table 1. Distribution of native and non-native speakers per gender

Native speakers		Non-native speakers	
Male	Female	Male	Female
5	10	6	8
Total	15	14	

3 Measurement

Formants are distinctive frequency features of the speech signal that refer to frequency resonances of the vocal tract cavities. F1, F2,…, F5 express local maxima in the signal spectrum. To compute speech formants, an experimented annotator segmented manually all speech material i.e. 145 recordings of the dataset onto their different segmental units (vowels and consonants) using Praat software. Formants values of the short vowels were calculated using Linear Predictive Coding Coefficients (LPCC). Most often, the two first formants, F1 and F2, are sufficient to identify the kind of vowel. Nevertheless, in the study, we exploited three formants (F1, F2, and F3) values for each vowel to reveal a maximum variation in pronunciation. The data were submitted to a MANOVA to test for significant differences depending on the foreign accent (L1/L2), gender, and kind of vowels.

4 Results

4.1 L1/L2 Formant Analysis

Figure 1 shows the density of vowels spreading on (F1, F2) plan for each vowel for both native and non-native speakers. The outcomes reveal a wide distribution of vowels on

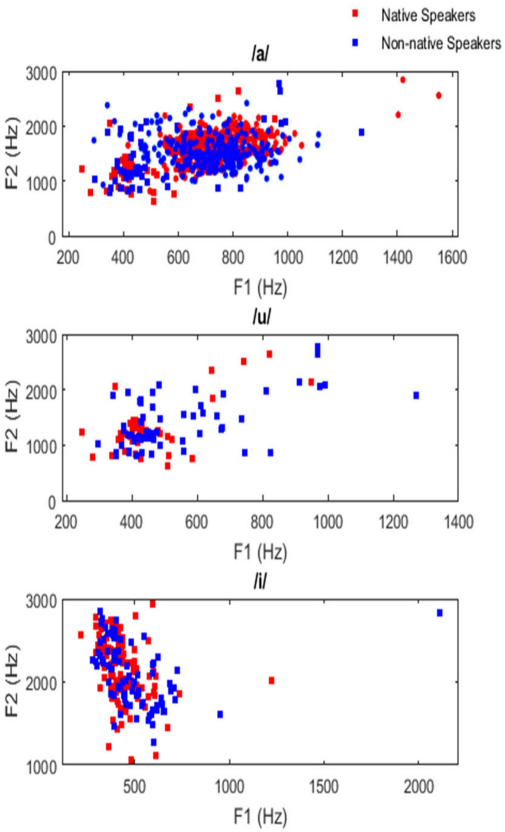

Fig. 1. Vowel distribution of native and non-native speakers in (F1, F2) plan

(F1, F2) plan especially /a/ and /u/ both speakers groups. Regarding the vowel /i/, we can see from the figure that formants computed for natives and non-native speakers are gathered in one consolidated area.

The assessment of the mean values of all formants for both corpora was conducted regardless of the gender of speakers (male/female). Table 2 expresses the average and standard deviation values of F1, F2 and F3 measured from L1 and L2 formants for each short vowel /a/, /u/, and /i/.

The outcomes performed for the vowel /a/: the average value of F1 of native speakers is close to that calculated for non-native ones. The same observation is valid for F3. However, the results express a deviation in the case of F2 formant. It can be noticed that the standard deviation measured for all formants for both categories (L1/L2 speakers) is nearby to each other. Regarding findings of /u/ analysis, the most significant difference between L1 and L2 formants scores is distinguished in F2 value. For the vowel /i/, the higher value is reached in the case of F3. Moreover, we point out, for /u/ and /i/, a slight variation in formant standard deviations between L1 and L2.

Table 2. Means and standard deviation of F1, F2 and F3 (Hertz) of native (L1) and non-native (L2) speakers

		/a/		/u/		/i/	
		M	SD	M	SD	M	SD
F1	L1	756,50	125,39	456,54	130,13	435,19	116,58
	L2	722,95	130,50	544,68	200,89	487,36	217,41
F2	L1	1643,09	244,87	1284,66	441,14	2139,58	357,23
	L2	1514,58	264,37	1420,32	472,96	2089,83	368,68
F3	L1	2735,39	325,26	2712,75	253,23	2929,33	289,58
	L2	2702,39	275,37	2785,36	356,50	2819,84	301,39

A statistical analysis (One Way ANOVA) was directed on the data formant set for each L1/L2 vowels (/a/; /u/ and /i/) with $\alpha = 0.05$. The outcomes display a significant effect of L2 accent in both F1 and F2 formant for the vowel /a/. The results found are F1: $F(1,658) = 11.32$ $p = 0.01$; second formant F2: $F(1,658) = 42$ $p = 0.00$ and for the third formant F3: $F(1,658) = 1.95$ $p = 0.163$. Likewise, findings obtained from /u/ and /i/ analyses show a significant effect L1/L2 accent on F1 for both vowels and only on F3 in the case of /i/. The results are F1: $F(1,103) = 6.58$ $p = 0.012$; second formant F2: $F(1,103) = 2.024$ $p = 0.13$; third formant F3 $F(1,103) = 1.35$ $p = 0.24$; F1: $F(1,199) = 4.77$ $p = 0.03$; F2: $F(1,199) = 0.9$ $p = 0.33$; F3 $F(1,199) = 6.80$ $p = 0.01$ respectively. We can observe from the results that all first formants F1 for all vowels were significant to foreign accent. Regarding formants F2 and F3, the effect depends on the vowel type. We can suggest that the difference in generating Arabic vowels between Arabic speakers and their counterpart Americans maybe occurs in the first level of production of the segment i.e. at the F1 formant stage. The statement is valid for all Arabic short vowels. In the case of the vowel /a/, a difference is also noticed in the second formant. As the analysis excludes the physiological study of the vocal cavities and as regards the vowel diagram, the outcomes can be explained as follow: F1, which refers to the position of the tongue on a vertical axis and ranges from open to close, reveal a deviation in F1 when L2 speakers produced all Arabic vowels. Regarding F2, which refers to the position of the tongue on a horizontal axis in the vowel diagram, shows also a deviation in the case of /a/ pronounced by L2 subjects. These variations can be explained by the English mother tongue influence on L2 vowels production.

4.2 Gender L1/L2 Formant Analysis

The second experiment concerns the assessment of the mean values of all formants regarding L1 and L2 speakers' gender (male/female). The analysis aims to express possible foreign accent influence in vowel production regarding both the gender and the origin of speakers. Tables 3 and 4 present the average and standard deviation values of F1, F2, and F3 measured for female and male speakers for each short vowel.

Table 3. Means and standard deviation of F1, F2 and F3 (Hertz) for MSA native and non-native female short vowels

		/a/		/u/		/i/	
		M	SD	M	SD	M	SD
F1	L1	790,37	114,39	462,90	139,74	443,76	131,60
	L2	747,34	124,14	505,68	131,04	474,50	114,90
F2	L1	1701,24	223,40	1223,66	393,33	2227,62	329,61
	L2	1615,99	260,06	1369,23	387,40	2172,78	371,36
F3	L1	2810,87	329,06	2763,83	167,85	3004,11	285,92
	L2	2747,26	309,52	2705,47	296,18	2865,76	294,14

Table 4. Means and standard deviation of F1, F2 and F3 (Hertz) of MSA native and non-native male speakers

		/a/		/u/		/i/	
		M	SD	M	SD	M	SD
F1	L1	688,74	119,21	443,80	111,83	417,34	74,94
	L2	691,91	132,23	599,96	263,49	507,39	319,53
F2	L1	1526,78	245,35	1406,68	516,90	1955,71	346,23
	L2	1385,57	208,17	1491,83	572,84	1960,51	329,60
F3	L1	2584,41	329,06	2610,57	355,52	2773,69	231,86
	L2	2645,29	212,30	2897,18	407,20	2748,25	302,85

As it can be seen from Tables 3 and 4 all formants values computed for L1 speakers (females and males), in the case of the vowel /a/, are relatively higher than those measured for L2 speakers (females and males). The only exception is noticed in the F1 score of L2 male participants where the tendency is inversed. Moreover, findings of formants /u/ vowel show increased F1, F2, and F3 values for L2 males in comparison to their L1 counterparts; and higher F1 and F2 in L2 female speakers. For the/i/ vowel, the results vary depending on gender and formants.

Statistical analyses (One Way ANOVA) were applied separately on the data formant set for female speakers then for male speakers for each short vowels (/a/; /u/ and /i/). The results achieved for females: vowel /a/ showed a significant effect of L2 accent on formant values (F1, F2 and F3). The findings for first formant F1 are $F(1, 405) = 13, 08$ $p = 0.0$, for the second formant F2 are $F(1, 405) = 12,58$ $p = 0.0$ and for the third formant F3 are $F(1, 405) = 3,90$ $p = 0.049$. For the vowels /u/ and /i/; the findings are for F1: $F(1, 63) = 1,58$ $p = 0.21$; F2: $F(1, 63) = 2,24$ $p = 0.13$ and for F3: $F(1, 63) = 0,91$ $p = 0.037$; F1: $F(1, 128) = 1,90$ $p = 0.17$, F2: $F(1, 128) = 0,78$ $p = 0.37$ and F3: $F(1, 128) = 7,17$ $p = 0.08$ respectively. The results above showed significant effects of

speaker origin for female group in all formants of the vowel /a/ and only on F3 formant of /i/ vowel. The same analysis was conducted on male formant group. The outcomes indicated a significant effect of foreign accent on male formant measures F2 and F3 in case of /a/: F1, $F(1, 251) = 0.4$ $p = 0.84$; F2, $F(1, 251) = 24.52$ $p = 0.0$; F3: $F(1, 251) = 4.21$ $p = 0.04$. For /u/, there is significant effect only on F1 and F3. The results are: F1, $F(1, 38) = 4.7$ $p = 0.03$; F2: $F(1, 38) = 0{,}22$ $p = 0.64$ and finally F3: $F(1, 38) = 5{,}09$ $p = 0.03$. Thus, we can conclude that the quality of Arabic vowels pronounced by L2 speakers depends on gender and the kind of vowel.

5 Conclusion

A formant analysis was directed on Modern Standard Arabic (MSA) language produced by native and non-natives speakers. The experiment displays variations in MSA vowel quality between L1 and L2 speakers. Thus, we examined speakers' foreign accents, gender, and variations on short Arabic vowels. The study was conducted basing on 145 speech files recorded by 15 speakers. Three formants were computed from a set of vocalic segments (/a/, /u/, and /i/) of L1 and L2 speech material. Two experiments were done on the dataset. The first consisted on studying L1 and L2 formant regardless of the speaker's gender. The average values and statistical analysis were performed for F1, F2, and F3 and all vowels. Results expose that the difference in generating Arabic vowels between L1 speakers and their counterpart L2 speakers occurs in the F1 formant stage. The statement is valid for all Arabic short vowels. In the case of the vowel /a/, a variation in the F2 formant value is also noticed. The second experiment concerned the assessment of the mean values of all formants regarding L1 and L2 speaker's gender (male/female), followed by two MANOVA executed on the L1/L2 female group than on the L1/L2 male group. The outcomes state that Arabic vowels pronounced by L2 speakers in the speech material do not answer to a unique pattern of MSA short vowel quality. The production depends on the gender of speakers and the kind of pronounced vowel.

References

1. Nicolao, M., Beeston, A.V., Hain, T.: Automatic assessment of English learner pronunciation using discriminative classifiers. In: IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brisbane, QLD, pp. 5351–5355 (2015). https://doi.org/10.1109/ICASSP.2015.7178993
2. Marzieh Razavi, M., Magimai Doss, M.: On Recognition of Non-native Speech Using Probabilistic Lexical Model INTERSPEECH 2014 15th Annual Conference of the International Speech Communication Association, Singapore, 14–18 September (2014)
3. Alotaibi, Y.A., Hussain, A.: Speech recognition system and formant based analysis of spoken Arabic vowels. In: Lee, Y.-H., Kim, T.-H., Fang, W.-C., Ślęzak, D. (eds.) FGIT 2009. LNCS, vol. 5899, pp. 50–60. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-10509-8_7
4. Droua-Hamdani, G., Selouani, S.A., Boudraa, M.: Speaker-independent ASR for modern standard arabic: effect of regional accents. Int. J. Speech Technol. **15**(4), 487–493 (2012)

5. Droua-Hamdani, G., Sellouani, S.A., Boudraa, M.: Effect of characteristics of speakers on MSA ASR performance. In: IEEE Proceedings of the First International Conference on Communications, Signal Processing, and their Applications (ICCSPA 2013), pp. 1–5 (2013)
6. Droua-Hamdani, G.: Classification of regional accent using speech rhythm metrics. In: Salah, A., Karpov, A., Potapova, R. (eds.) SPECOM 2019. LNCS, vol. 11658, pp. 75–81. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-26061-3_8
7. Droua-Hamdani, G.: Formant frequency analysis of MSA vowels in six algerian regions. In: Karpov, A., Potapova, R. (eds.) SPECOM 2020. LNCS, vol. 12335, pp. 128–135. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-60276-5_13
8. Farchi, M., Tahiry, K., Soufyane, M., Badia, M., Mouhsen, A.: Energy distribution in formant bands for Arabic vowels. Int. J. Elect. Comput. Eng. Yogyakarta **9**(2), 1163–1167 (2019)
9. Mannepalli, K., Sastry, P.N., Suman, M.: Analysis of emotion recognition system for Telugu using prosodic and formant features. In: Agrawal, S.S., Dev, A., Wason, R., Bansal, P. (eds.) Speech and Language Processing for Human-Machine Communications. AISC, vol. 664, pp. 137–144. Springer, Singapore (2018). https://doi.org/10.1007/978-981-10-6626-9_15
10. Korkmaz, Y., Boyacı, A.: Classification of Turkish vowels based on formant frequencies. In: International Conference on Artificial Intelligence and Data Processing (IDAP), Malatya, Turkey, 2018, pp. 1–4 (2018). https://doi.org/10.1109/IDAP.2018.8620877
11. Natour, Y.S., Marie, B.S., Saleem, M.A., Tadros, Y.K.: Formant frequency characteristics in normal Arabic-speaking Jordanians. J. Voice **25**(2), e75–e84 (2011)
12. Rusza, J., Cmejla, R.: Quantitative acoustic measurements for characterization of speech and voice disorders in early-untreated Parkinson's disease. J. Acoust. Soc. Am. **129**, 350 (2011). https://doi.org/10.1121/1.3514381
13. Linguistic Data Consortium LDC. http://www.ldc.upenn.edu