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An Acoustic Study of Production and Perception of English Vowels by Azeri English Learners[1]

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ABSTRACT

This study examined the 30 Azeri (AZ) EFL (English as a foreign language) speakers' production and perception of English vowels. Two experiments were carried out: A production test to measure the first two formants of the learners' English vowels, and an identification test with natural stimuli to investigate the L2 (second language) perception of English vowels. In the word list context, the participants read carrier sentences with the target vowels embedded in /hVd/ words. This study although investigated the relationship between the perception and production of English vowels by the Azeri speakers. In production test 11 English monophthongs were produced by male and female participants and the results were compared to Native American (AE) and British English (BR) productions. The production results revealed that the Azeri speakers produced some of the vowels closer to the AE, and some others closer to BR. Azeri speakers had difficulty in both producing and perceiving some English vowels in a native-like fashion. Some inter-gender differences were also found in this research. Importantly, a relationship between vowel perception and production was found because most of the target vowels which were better perceived were also the ones produced more accurately by the L2 learners.
KEYWORDS: Azeri English learners, English vowels, Vowel quality, Instrumental analysis, Vowel perception

INTRODUCTION

Azeri language is spoken in Azerbaijan, Iran and some other parts of the world. The majority of Azeri speakers in Iran are populated in three provinces in northwestern regions including East Azerbaijan, west Azerbaijan and Ardabil [1].

In recent years, several studies have been done on L2 speech production and perception of speakers with different first languages. When subjects with different first languages speak English as a foreign language, their pronunciation will be different from native speakers of English. One of the major differences in pronunciation of English lies in different realization of vowels [2]. There are factors that cause a foreign accent which have received too little attention in the technical literature. Piske, MacKay and Flege [3] provide a list of variables which partially determine the degree of foreign accent in a L2, namely gender, age of L2 learning (AOL), length of residence in an L2 speaking country (LOR), formal instruction, motivation, language learning aptitude, and amount of L2 use. Paunovic [4] also states that the process of acquiring a phonological system is immensely complex, as numerous linguistic variables are involved simultaneously.

Peivasti [5] in an acoustic study of Azeri vowels has shown nine Azeri vowels in a vowel space chart. Hillenbrand, Getty, Clark and Wheeler [6] have attempted to explore acoustic characteristics of American English. They have tried to replicate and further extend the study of vowel acoustics by Peterson and Barney [7]. Deterding [8] examined formants of eleven monophthongs vowels of Standard Southern British English pronunciation.

It is generally believed that the pronunciation of non-native speakers (NNSs) of English deviates from that of native speakers.

Since there are limited data available for Azeri English learners' production and perception of English vowels, the aim of this study was to show how Azeri EFL learners differ in their articulation of English vowels and to fill the existing gap.

In this study we used acoustic measurements that are known to have clear correspondences with articulatory properties of vowels [9].

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1.1 Acoustic measurement of vowels

According to Source-Filter theory [10] vocal tract serves as a filter. The production of sound occurs by restriction of the airflow through the pharynx. The sound resonates through the oral cavity and the combination of the resonating frequencies produces a vowel sound. Thus, formants are the natural resonance frequencies of the vocal tract [11]. Vowel quality can be quantified by measuring first formant frequencies of the acoustic signal. First formant (F1) corresponds to the articulatory aspect of vowel height and Second formant (F2) represents the place of maximal constriction [9].

MATERIALS AND METHODS

2.1 Subjects

The selected subjects in this study included 30 volunteer EFL learners from whom 15 were males and 15 were females. All had Azeri as their L1. The subjects were asked to fulfill a questionnaire to obtain information about their language background, contacts with native speakers of English, etc. They were grown up by Azeri parents in Tabriz. All of the participants were university students in Iran at the time of taking tests. 12 of them were studying at Tabriz University and 18 were studying at Islamic Azad University of Tabriz. The participants in same level of English language background were selected for this study. They had a mean age of 23 (3.1) years old and age ranged from 21 to 30. Subjects did not have any contact with any English-speaking friend or family. Also they had never lived in any English speaking country. At the end of the tests, they received a gift for their participation.

2.2 Stimuli

In the production test, the recordings were obtained by subjects reading sentence list containing 11 English vowels. Vowels were embedded in a /hVd/ context and the words were placed in the carrier sentence, *Please say hVd for me*, trying to provide a more naturalistic context. Subjects read different randomizations of the list containing the words *had, hod, hoed, hid, heed, hayed, heard hood, hood, head* and *who'd*. Production test was performed using Sony Stereo microphone and a laptop. A sampling rate of 44.1 kHz at a 16-bit rate was used to ensure high quality recording. Subjects were given 5 minutes to practice the list and read the rhyming words to understand the pronunciation of target words before beginning the test.

The perception test was run on a laptop and the participants used earphones to hear the stimuli. The words used in perception test were the same as those of production test. These words were read by 10 AE monolinguals, recorded and used in perception test in Praat. The perception test was a forced-choice labeling test which consisted of the participants' listening to one word containing target vowel and clicking on the label which most resembled the vowel heard. The participants were allowed to replay the words before clicking on the label using the "Replay" button on the screen. The stimuli were randomly organized and every time the test was restarted a new order of words was generated.

Both tests were carried out in a quiet room at the Islamic Azad University of Tabriz and Tabriz University.

2.3 Data analysis

The analysis of the production tests were performed using speech processing software, Praat, [12] on computer. These data were then orthographically transcribed using the TextGrid function of Praat and the target vowels were isolated and measured. Formant tracks for the lowest two formants, F1 and F2, were then computed using the Burg LPC algorithm in Praat. In cases where the computer-generated formants were not clear, especially for the back vowels, measurements were carried out manually. For target monophthongs, the midpoint of the vowel where it tended to be at its most steady state and least influenced by co-articulation was measured [13], [14].

The measurements were rechecked by another rater. A statistically significant positive degree of correlation was found for the measurements between Rater 1 and Rater 2 (F1: Pearson's $r = 0.99$, $p < 0.001$; F2: $r = 0.99$, $p < 0.001$).

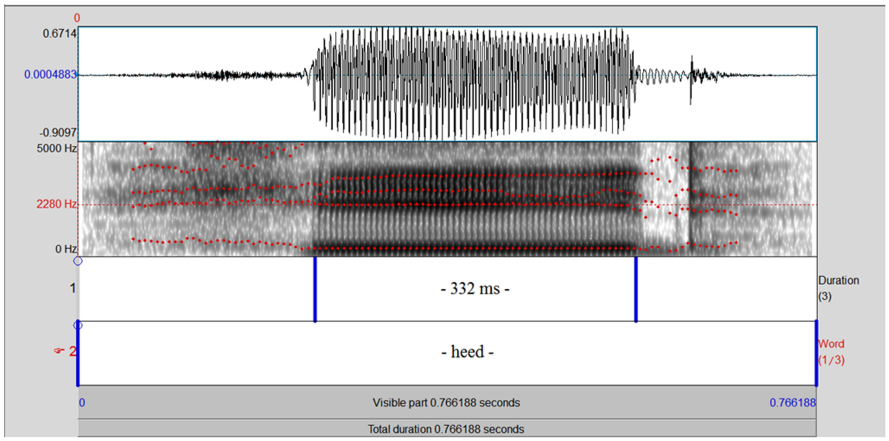

Figure 1: screenshot of the analysis of the production for word "heed" in praat

2.3.1 Statistical analysis

For production test, a one-sample t-test was used to compare the Azeri speakers' F1 and F2 mean values with the corresponding single-sample F1 and F2 values of the native norms (BR and AE). P-values less than 0.05 were considered to be significant.

RESULTS

3.1 Comparison of AZ production of English vowels to AE

Figure 2 suggests that virtually most of the AZ F1 and F2 values (indicating vowel height and backness) were articulated significantly different from AE.

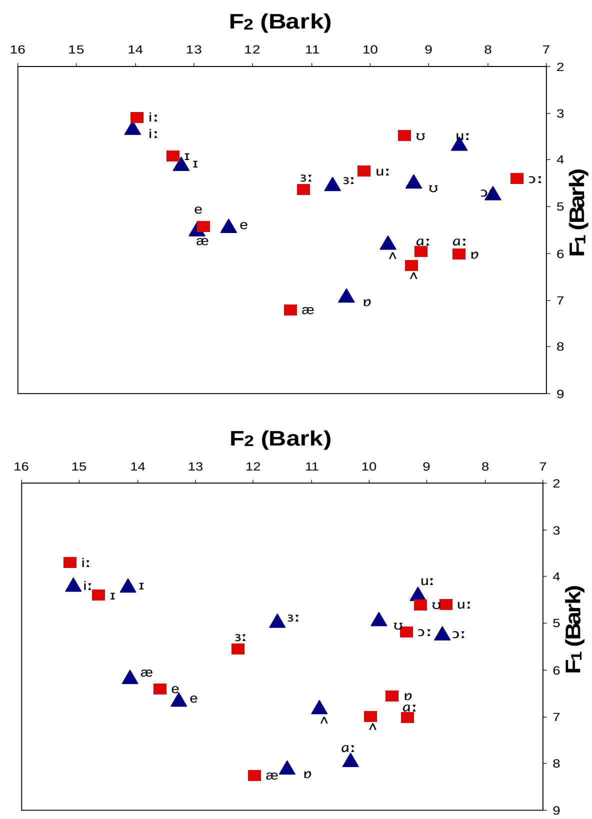

Figure 2: Vowel plot of non-native (NNE) ■ and Hillenbrand et al [5] data for ▲AE English
The left panel contains men's data and the right panel represents women's data.

Table 1 summarizes the obtained p-values of the one-sample t-test. Men's results suggest that in terms of vowel height, /ʊ/ vowel and in terms of vowel height and backness, /æ/, /ɒ/ and /u:/ vowels were articulated significantly different from AE, with p-values that are below 0.05.

Females' results suggest that /æ/ vowel in terms of height and backness, and /ʌ/, /ɒ/, and /ʊ/ vowels in terms of backness are articulated significantly different from AE.

Table 1: T-Test significance values of AZ vowels tested by the F1 and F2 of AE.

Vowels	F1(Male) p	F2(Male) p	F1(Female) p	F2(Female) p
iː	0.303	0.766	0.084	0.749
ɪ	0.557	0.468	0.766	0.058
e	0.976	0.085	0.192	0.128
æ	0.024	0.001	0.001	0.005
ʌ	0.199	0.331	0.257	0.014
ɑː	0.919	0.196	0.333	0.558
ɒ	0.024	0.003	0.046	0.004
ɔː	0.096	0.096	0.895	0.094
ʊ	0.02	0.879	0.159	0.063
uː	0.09	0.01	0.732	0.196
ɜː	0.698	0.184	0.194	0.111

3.2 Comparison of AZ production of English vowels to BR

Figure 3 shows that nearly every vowel in both gender groups is pronounced different from BR.

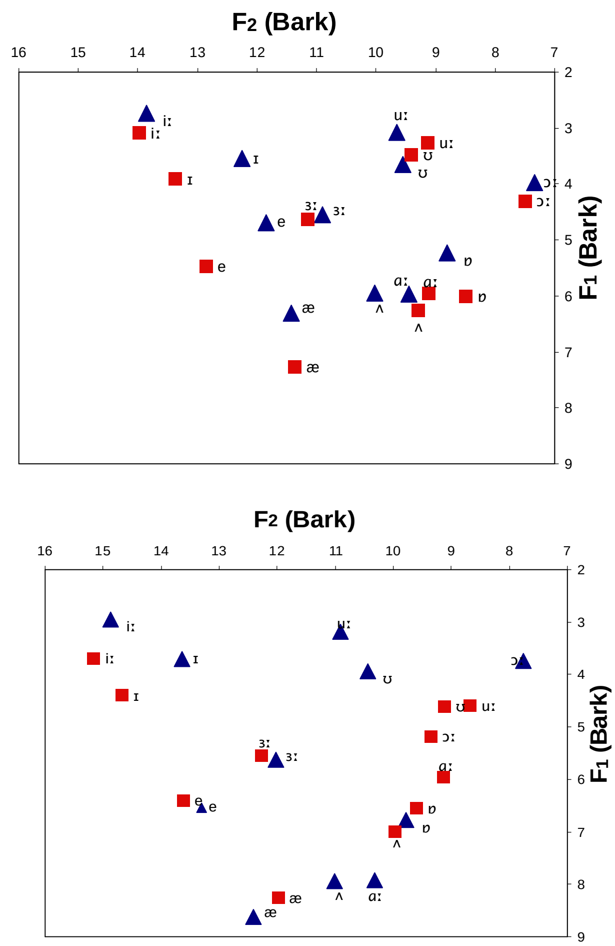

Figure 3: Vowel plot of non-native (NNS) ■ and Deterding (1997) data for ▲BR English
The left panel contains men's data and the right panel represents women's data.

Analogous to the previous statistical test, the same one-sample t-test procedure applied to AZ F1 and F2 values in comparison to BR data. Table 2 shows the calculated p-values. According to these statistics, in terms of vowel height (F1) and backness (F2), male participants articulated /e/ vowel significantly different from BR norm, with p=0.004 for F1 and p=0.008 for F2. In terms of height, /ı/ vowel and in terms of backness, /æ/ and /ɒ/ vowels were articulated significantly different from BR productions. AZ females articulated /ʌ/, /ı/, /ɔ:/ and /u:/ vowels significantly different in terms of height and backness. Considering height, /ɑ:/ vowel and in terms of backness /ʊ/ vowel were produced significantly different from BR norms by AZ female participants.

Table 2: T-Test significance values of AZ vowels tested by the F1 and F2 of BR.

Vowels	F1(Male) p	F2(Male) p	F1(Female) p	F2(Female) p
i:	0.151	0.595	0.048	0.252
ɪ	0.294	0.007	0.04	0.02
e	0.004	0.008	0.09	0.198
æ	0.01	0.839	0.084	0.062
ʌ	0.369	0.111	0. 01	0.023
ɑ:	0.986	0.465	0.001	0.532
ɒ	0.045	0.401	0.817	0.198
ɔ:	0.09	0.379	0.004	0.046
ʊ	0.543	0.83	0.085	0.021
u:	0.582	0.25	0.015	0.023
ɜ:	0.789	0.481	0.642	0.191

3.3 Perception experiment

Vowel perception test results are shown in tables 3 and 4 . The results of this test revealed that AZ male participants had better performance in identification of /i:/, /ı/, /e/, /ʊ/, and /ɜ:/ vowels than the other vowels. The vowel /ɑ:/ was heard as /ʌ/ vowel by all male participants and vowel /ʌ/ was heard as /ɑ:/ by 60% of participants. i.e., the majority of males misidentified these vowels as each other.

The data indicated that the /ɒ/ vowel was heard as /ʌ/, and /ɔ:/ vowel was heard as /ɑ:/ by 60% of male participants. Also 80% of the male participants heard /ʊ/ while target vowel was /u:/.

Table 3: Confusion Matrix (%) for AZ males' Perception of AE Monophthongs
(The percentage of correct identification for each vowel is in bold face.)

	Target Vowels										
Heard	i:	ɪ	e	æ	ʌ	ɑ:	ɒ	ɔ:	ʊ	u:	ɜ:
i:	**93.3**										
ɪ	6.7	**100**									
e			**100**	73.3							
æ				**26.7**							
ʌ					**13.3**	100	60				
ɑ:					60			60			
ɒ					6.7		**26.7**				
ɔ:							13.3	**20**			
ʊ								20	**100**	80	
u:					20					**20**	
ɜ:											**100**

Similar to AZ male's results, AZ females also identified vowels /i:/, /ı/, /e/, /ʊ/, and /ɜ:/ better than other vowels. Majority of the females heard vowel /ɑ:/ as /ʌ/ (86.7%) and /ʌ/ as /ɑ:/ (66.6%) i.e., most of the females misidentified these vowels as each other. The /ɒ/ vowel was heard as /ʌ/ (73.3%), /ɔ:/ as /ɑ:/ (60%) and /u:/ as /ʊ/ (66.6%).

Table 4: Confusion Matrix (%) for AZ females' Perception of AE Monophthongs
(The percentage of correct identification for each vowel is in bold face.)

Heard	Target Vowels										
	iː	ɪ	e	æ	ʌ	ɑː	ɒ	ɔː	ʊ	uː	ɜː
iː	**80**	6.7									
ɪ	20	**73.3**									
E		13.3	**93.3**	80							
æ		6.7	6.7	**20**							
ʌ					**20**	86.7	73.3				
ɑː					66.6	**6.66**	6.7	60			
ɒ					6.7	6.66	**13.3**				
ɔː					6.7		6.7	**33.3**		6.7	
ʊ								6.7	**73.3**	66.6	
uː									26.7	**26.7**	
ɜː											**100**

DISCUSSION

Table 5 combines the results of conducted comparisons (Table 1 & 2) to demonstrate which AZ vowels were articulated closer to BR and which were closer to AE. For this goal, each AZ vowel and its corresponding p-values, obtained through the tests between AZ & BR and AZ & AE, will be scrutinized. The last column in each table shows whether the articulated English vowels by AZ are closer to BR or AE. The more the p-value approximates zero, the greater the differences in articulation between the groups.

Table 5: P- values comparison, cf. Tables 1 & 2. The last column indicates whether the AZ are closer to BR or AE. Right table represents males' data and left table represents females' data.

Vowel	F1/F2	BR	AE	AZ Closer to
iː	F1	0.048	0.084	AE
	F2	0.252	0.749	AE
ɪ	F1	0.04	0.766	AE
	F2	0.02	0.058	AE
e	F1	0.09	0.192	AE
	F2	0.198	0.128	BR
æ	F1	0.084	0.001	BR
	F2	0.062	0.005	BR
ʌ	F1	0. 01	0.005	BR
	F2	0.023	0.014	BR
ɑː	F1	0.001	0.333	AE
	F2	0.532	0.558	AE
ɒ	F1	0.817	0.046	BR
	F2	0.198	0.004	BR
ɔː	F1	0.004	0.895	AE
	F2	0.046	0.094	BR
ʊ	F1	0.085	0.159	AE
	F2	0.021	0.063	AE
uː	F1	0.015	0.732	AE
	F2	0.023	0.196	AE
ɜː	F1	0.642	0.194	BR
	F2	0.191	0.111	BR

Vowel	F1/F2	BR	AE	AZ Closer to
iː	F1	0.151	0.303	AE
	F2	0.595	0.766	AE
ɪ	F1	0.294	0.557	AE
	F2	0.007	0.468	AE
e	F1	0.004	0.976	AE
	F2	0.008	0.085	AE
æ	F1	0.01	0.024	BR
	F2	0.839	0.001	BR
ʌ	F1	0.369	0.199	BR
	F2	0.111	0.331	AE
ɑː	F1	0.986	0.919	BR
	F2	0.465	0.196	BR
ɒ	F1	0.045	0.024	BR
	F2	0.401	0.003	BR
ɔː	F1	0.09	0.096	AE
	F2	0.379	0.096	BR
ʊ	F1	0.543	0.02	BR
	F2	0.83	0.879	AE
uː	F1	0.582	0.09	BR
	F2	0.25	0.01	BR
ɜː	F1	0.789	0.698	BR
	F2	0.481	0.184	BR

Table 5 highlights how /iː/ and /ı/ vowels in both F1 and F2 values and in two gender groups are articulated more closer to AE. In case of /æ/, /ɒ/ and /ɜː/ vowels, they were produced more BR-like by both groups. In terms of F1, both gender groups articulated /e/ and /ɔː/ vowels more AE-like and /ʌ/ more BR-like. Also both gender groups in terms of F2 pronounced /ɔ:/ BR-like and /ʊ/ more AE-like. Considering /u:/ and /ɑ:/ vowels' backness, the AZ males group is closer to BR and AZ female group is closer to AE and in case of /e/ and /ʌ/ vowels, males are more AE-like and AZ females more BR-like. In terms of the vowel's height, AZ males' production of /u:/, /ɑ:/ and /ʊ/ vowels sound more BR-like, and females' more AE-like.

4.1 Relationship between the production and perception

It was hypothesized that the vowel pairs which were perceived similar to natives would also be produced similar to natives, and the vowels which were misperceived would also be misproduced [15], [16]. The results indicate that perception of both female and male participants were similar to each other. For example the vowel /æ/ which participants produced more BR-like and different from AE, was also the vowel least distinguished in perception. Generally, results showed that the vowels which were distinguished better in production were also distinguished better in perception. Although, research in this area has to be continued

CONCLUSIONS

The aim of this study was to investigate how AZ EFL learners produced and perceived L2 English monophthongs. According to our literature review, there have been practically no studies on Azeri speakers' perception and production of English vowels. The present study provides new data regarding the gap in this area. Since we used British English and American English as separate pronunciation standards, we attempted to clarify whether Azeri-accented English monophthongs were closer to British English or American English. The findings indicate that Azeri speakers produced some of the vowels closer to the AE, and some others closer to BR. Azeri speakers had difficulty in both producing and perceiving some English vowels in a native-like fashion. There was more inter-gender differences in production test than perception test.

There seems to be an interrelation between perception and production and that the former precedes the latter. Overall, it is possible to state that the vowels which were well identified in perception test were the ones also well produced in production test. The findings in the present study are in concordance with perception/production theories [16], [17].

In summary, this study can be considered an interesting starting point to better understand the difficulties Azeri EFL speakers have when perceiving and producing English vowels. The present study provides a database that can be used by other researchers in studies on vowels. It is suggested that future researchers include larger sample sizes from various levels of L2 knowledge in order to extend the information in this area.

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Appendices

Appendix (A)

Word list used in production test

Word	Vowel	Rhymes With	Word	Vowel	Rhymes With
hod	/ɒ/	God	heed	/iː/	feed
hoed	/ɔː/	road	hid	/ɪ/	kid
hood	/ʊ/	good	head	/e/	red
who'd	/uː/	rude	had	/æ/	bad
heard	/ɜː/	bird	hawed	/ɑː/	fraud
hud	/ʌ/	mud			

Appendix (B)

Screenshot of perception test