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Phonetic Interference in the Vowel Production of Yemeni Arabic-English Bilinguals

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ABSTRACT

This study observes whether Yemeni Arabic-English bilinguals demonstrate any phonetic interference in their vowel production by examining the acoustic similarities and differences of both of their languages. Besides, it compares Yemeni Arabic vowels of bilinguals to monolingual production to identify any L2 influence on L1. Sixty subjects speaking native Yemeni Arabic were involved. Thirty were bilinguals who had acquired English as an L2, and the remaining 30 were monolinguals. All subjects produced a list of Arabic words with the target vowels /i:, a:, u:/ in the word-medial position. Moreover, the bilingual subjects also produced a list of English words with the target vowels /i:, a:, u:/ in the word-medial position. Vowel Duration, First Formant (F1), Second Formant (F2), and Third Formant (F3) of the target vowels were acoustically analysed. Findings revealed that in the F2 of /a:/, Yemeni Arabic-English bilinguals demonstrate L2 influence on L1 in the form of L1 phonetic drift towards their L2. On the contrary, findings show no significant influence of L2 English on L1 Yemeni Arabic long vowels /i:/ and /u:/. However, findings reveal a slight drift in L1 Yemeni Arabic vowels towards L2 Yemeni English vowels, causing closer acoustic vowel space between both languages, suggesting an assimilatory process. Furthermore, Yemeni Arabic-English bilinguals formed new categories for their L2 Yemeni English vowels for the acoustic properties: vowel duration and F1 of /i:/, F2 of /a:/, as well as F1 and F2 of /u:/ whereas they developed merged categories for the remaining acoustic properties.

Keywords: Acoustic; Arabic-English Bilinguals; Formant Frequency; Vowel Duration; Yemeni Arabic

INTRODUCTION

Several studies have confirmed that the first language (L1) and second language (L2) of a bilingual may influence each other during speech production (Baker & Trofimovich, 2005; Chang, 2011; Dmitrieva et al., 2010; Guion, 2003; MacLeod et al., 2009). In other words, characteristics of an L1 may be transferred to an L2 and/or the acquisition of an L2 may influence L1 production (Alshamiri et al., 2022; Perwitasari et al., 2016; Shahidi & Aman, 2011; Urazbaev & Sukhrobbekov, 2021). Such findings have been interpreted as an indication of a combined L1–L2 phonological system in bilinguals. The combined category may be phonetically distinct from the associated L1 category, L2 category, or somewhere in between, depending on different factors

(Flege, 2007). It has been suggested that a single set of combined categories emerges when (in-between) values are produced. In addition to producing L2 sounds with a foreign accent, this may also result in less native-like L1 production. Whether bilinguals form a single set of combined categories for both of their languages or create separate language-specific phonetic categories for their L2 phones is still up for debate.

Based on the Speech Learning Model (SLM), it is proposed that similar L1 and L2 phonetic categories may undergo "assimilation" or "dissimilation" (Flege, 1995, 2007; Flege & Bohn, 2021). Assimilation of a phonetic category prevents the formation of a new or separate category for the newly learned L2 sound. It may be because an L2 sound is perceptually similar to a native category which is already acquired by an L2 learner. Not all L2 sounds, however, are equally assimilated to an L1 sound category. Bilinguals will, therefore, map one category onto the other, minimising the variations between the two languages' phonetic systems, which causes the L1 and L2 sounds to resemble one another. Thus, a combined L1–L2 category will develop. For instance, Chang (2011) examined the vowel system of 16 monolingual native-American English female subjects acquiring Korean in South Korea. He reported that L1 English vowels drifted in the direction of the L2 Korean vowels, reducing the space between both languages. He found an influence of L2 on L1 in the initial stages of L2 learning. Another study by Kartushina et al. (2016) reported that despite only receiving brief visual articulatory feedback training, native French speakers drifted their native vowels towards the non-native vowels.

On the contrary, dissimilation of a phonetic category occurs when bilinguals form a separate phonetic category for the learned L2 sounds. Speakers contrast similar sounds in a shared L1–L2 phonological space by highlighting their differences during production. Compared to the output of monolingual speech of both languages, they divert L1 and L2 sounds away from one another. In other words, to maintain contrast with the corresponding L2 phoneme category, an L1 category can drift away from that of monolingual L1 speakers. An L1 may drift away from an L2 to maintain the greatest possible distinction between the two groups (Flege, 1995). Moreover, Guion (2003) studied 20 L1 Quichua - L2 Spanish bilinguals' production of three Quichua vowels and five Spanish vowels. The findings showed that to achieve adequate distinction between bilinguals' L1 and L2 categories, L1 vowel space was higher for those who had acquired their L2 vowels than those who had not.

Furthermore, bidirectional L1–L2 phonetic interference is noticed when a bilingual's L1 and L2 differ compared to monolingual speakers of the respective languages (Baker & Trofimovich, 2005; Dmitrieva et al., 2010; Flege, 1995). Baker and Trofimovich (2005) examined the interaction of phonetic systems of early and late bilinguals by comparing Korean-English bilinguals' productions of L1 Korean and L2 English vowels. L1 Korean and L2 English vowels were also compared to Korean and English monolingual productions. The L1 and L2 vowels were realised in different ways acoustically by early bilinguals, showing a bidirectional L1–L2 interference, whereas in late bilinguals, only an L1 influence on L2 was present. Baker and Trofimovich interpreted that early bilinguals are more prone than late bilinguals to redesign their first language (L1) phonetic system and create new second language (L2) phonetic categories. They concluded that the level of acoustic similarity between the bilinguals' L1 and L2 sounds seems to define the direction and extent of L1–L2 influences in both early and late bilinguals.

On the other hand, MacLeod et al. (2009) revealed that bilingual speakers can create distinct language-specific phonetic categories for their L2 vowels. They assessed the production of high vowels produced by Canadian English and Canadian French bilinguals and monolingual speakers. They reported that there was no significant difference between the vowels produced by

monolinguals and bilinguals. Bilinguals produced vowels of both languages with monolingual values. They formed separate categories across both languages during the production of similar vowels. They maintained language-specific L1 and L2 productions even for those phonemes that are very similar in their acoustic space (MacLeod et al., 2009).

An analysis of the literature reveals that interference between a bilingual's L1 and L2 may lead to four possibilities as described by Antoniou et al. (2011): (1) influence of L1 on L2, (2) influence of L2 on L1, (3) bidirectional L1–L2 interference, and (4) no L1–L2 interference. Table 1 below summarises various studies assessing L1–L2 interference in vowel production.

TABLE 1. Studies Assessing Bilingual Phonetic Interference in Vowel Production

Study	Bilinguals under investigation	L1 – L2 Phonetic Interference
Munro (1993)	L1 Arabic – L2 English	L1 influence on L2
Guion (2003)	L1 Quichua – L2 Spanish	Bidirectional L1 - L2 interference
Baker and Trofimovich (2005)	Early L1 Korean – L2 English	Bidirectional L1 – L2 interference
	Late L1 Korean – L2 English	L1 influence on L2
MacLeod et al. (2009)	Canadian English – Canadian French	No L1 – L2 interference (Bilinguals formed separate categories across both languages)
Chang (2011)	L1 English – L2 Korean	L2 influence on L1 (L1 drift toward L2)
Bergmann et al. (2016)	Late L1 German – L2 English	L2 influence on L1
Kartushina et al. (2016)	Native French learning Russian /ɨ/	L2 influence on L1 (drift of L1 toward non–native vowel)
Perwitasari et al. (2016)	L1 Javanese – L2 English L1 Sundanese – L2 English	L1 influence on L2

VOWEL DURATION

Arabic and English, along with many other languages, distinguish phonemically between short and long vowels. Furthermore, within each vowel phoneme, there are allophonic variations in vowel duration (VD). Numerous studies that acoustically analyse Arabic vowels have focused on measuring their VD (e.g., Abunima et al., 2021; Alghamdi, 1998; Fathi & Qassim, 2020). VD is measured in milliseconds (ms). For instance, Fathi and Qassim (2020) investigated the pure vowels /i, a, u, iː, aː, uː, oː, eː/ uttered by 15 native speakers of Mosuli Iraqi Arabic in terms of the vowels' quality and quantity. Mean values of the VD of /iː, aː, uː/ were 112 ms, 144 ms and 139 ms, respectively. Data revealed that the long vowels /iː, aː, uː/ were twice as long as their short counterparts /i, a, u/, which is consistent with the findings of other studies (Alghamdi, 1998; Kalaldeh, 2018).

Alghamdi (1998), on the other hand, showed longer VD values than those of Fathi and Qassim. He investigated formant frequencies and VD of 15 male native speakers of three different Arabic dialects: Saudi, Sudanese, and Egyptian. VD of /iː/ for Saudi Arabian, Sudanese, and Egyptian participants were 247.6 ms, 275.13 ms, and 255 ms, while VD for /aː/ were 311.4 ms, 294.8 ms, and 315.5 ms, respectively. Moreover, the VD of /uː/ for the three dialects were 237.33 ms, 304.47 ms, and 243.4 ms, respectively.

Furthermore, the VD of English vowels has been the focus of investigation in several studies (e.g., Abunima et al., 2021; Bello et al., 2020; Fox & Jacewicz, 2009; Munro, 1993). Fox and Jacewicz (2009), for instance, investigated American English vowels produced by 48 women in three distinct regional varieties in the United States: Central Ohio, Southern Wisconsin, and Western North Carolina. They examined VD and formant frequencies, among other acoustic properties. Findings revealed that vowels preceding voiced consonants had a higher VD than those before voiceless ones. Differences in VD were reported as a function of dialect. Subjects from

North Carolina exhibited the highest VD values, followed by those from Ohio and Wisconsin. This highlights the presence of cross-dialect differences within the same language, underscoring the importance of examining individual dialects.

In addition, an earlier study by Munro (1993) analysed the VD and the first two formants of L2 English vowels produced by L1 Arabic speakers. He observed to what extent native Arabic speakers' productions of ten English vowels in words of the structure /bVt/ and /bVd/ differed from equivalent native English productions. He collected data from 23 native Arabic speakers, 21 males and two females, representing the following Arabic dialects: Egyptian, Jordanian, Kuwaiti, Palestinian, Saudi Arabian, Sudanese, and Syrian. Every subject had spent an average of 5.7 years in the United States. They have been using English for 7.7 years on average. The results indicated that Arabic speakers, when learning English, typically over-articulate the durational differences of English vowels. He described the English vowels produced by the Arabic subjects as "Arabic-accented vowels that tend to show Arabic-like properties" (Munro, 1993, p. 51).

FORMANT FREQUENCY

Vowels are pronounced in combination with consonants, which causes the vocal tract configuration to change numerous times from the vowel-appropriate configuration to the consonant-appropriate configuration. Variations in the formant pattern correspond to these changes. Investigating formant frequency, i.e., First Formant (F1), Second Formant (F2), and Third Formant (F3), is a dominant approach to the acoustic description of vowels. The first three formants are the most prominent for vowel identification and are measured in Hertz (Hz). Several studies have examined the formant frequencies of L2 English vowels (Al-Hamzi et al., 2021; Alqarni, 2018; Baker & Trofimovich, 2005; Munro, 1993; Ramadan & Thai, 2021). Besides, Hawkins and Midgley (2005) examined native English vowels. They measured F1 and F2 of monophthongs in /hVd/ contexts produced by male speakers recruited into four age groups. For subjects of the age group (35 – 40), which is closer to the mean age of the subjects in the current study, mean F1 of /iː, ɑː, uː/ were 269 Hz, 608 Hz, and 288 Hz, while mean F2 values were 2312 Hz, 1062 Hz, and 1336 Hz, respectively.

Although formant frequencies of Arabic vowels were not sufficiently addressed in the literature, a number of studies are available (Alghamdi, 1998; Alotaibi & Husain, 2009; Fathi & Qassim, 2020; Kotby et al., 2011; Munro, 1993; Natour et al., 2011; Tsukada, 2009). For instance, Natour et al. (2011) examined the formant frequency of Jordanian Arabic by investigating six long vowels /iː, ɑː, uː, eː, aː, oː/. Data was collected from adults and children. The findings indicated that Jordanian Arabic speech had a tendency for vowel formation with lower formant values.

Furthermore, an earlier study by Alghamdi (1998) investigated formant frequencies and VD of six short and long Arabic vowels /i, a, u, iː, aː, uː/ in the CVC context. The subjects were 15 male native speakers, aged between 29 - 48, representing three different dialects of Arabic: Saudi Arabian, Sudanese and Egyptian. Long vowels were in meaningful words, whereas short vowels were in nonsense words. Findings revealed significant differences between dialects in F1 and F2, whereas no differences for F3. For F1, Saudis produced the highest for /u, uː, iː/ while Egyptians produced the highest for /i/. There were differences in F1 between all three dialects, whereas only Sudanese showed a higher F2 value than the remaining dialects. Table 2 below provides the mean values of formant frequencies of different Arabic dialects.

TABLE 2. Mean Formant Frequencies in Hertz for the Vowels /iː, aː, uː/ of different Arabic Dialects

Study	Dialect	Gender	/iː/			/aː/			/uː/		
			F1	F2	F3	F1	F2	F3	F1	F2	F3
Alghamdi (1998)	Saudi Arabian	M	292	2286	2793	655	1587	2660	350	958	2443
	Sudanese	M	272	2255	2933	635	1492	2467	319	984	2408
	Egyptian	M	256	2175	2773	462	1677	2629	319	942	2326
Alotaibi and Husain (2009)	Modern Standard Arabic	M	412	2132	2788	684	1193	2751	429	85	2595
Natour et al. (2010)	Jordanian	M	329	2167	2869	616	1427	2644	369	953	2502
		F	382	1970	2760	888	1947	3089	487	1402	2586
Kotby et al. (2011)	Egyptian	M	287	2202	-	611	1043	-	241	857	-
		F	356	2662	-	666	1130	-	269	876	-
Alqarni (2018)	Saudi Arabian	M/F	406	2655	-	623	2224	-	454	1914	-
Fathi and Qassim (2020).	Iraqi	M/F	354	2169	2809	726	1437	2676	409	1235	2615

Besides, among the studies examining the vowels of various Arabic dialects, studies addressing Yemeni Arabic vowels remain scarce. Acoustical studies that addressed Yemeni Arabic sounds, in general, were not directed toward comparing them to L2 production. The current study goes beyond earlier research in that it compares the acoustic features of Yemeni Arabic (YA) and Yemeni English (YE) vowels produced by Yemeni Arabic-English bilinguals. YE refers to a variety of English spoken by Arabic-English bilinguals from Yemen. Furthermore, this study compares the YA vowels produced by Yemeni Arabic-English bilinguals and compares them to YA monolingual production. It aims at observing any L1–L2 phonetic interference among Yemeni Arabic-English bilinguals. The amount of similarity or difference between L1 and L2 sounds verifies the direction and extent to which the L1 and L2 of Yemeni Arabic-English bilinguals affect one another. The present study investigates whether Arabic-English bilinguals are capable of forming separate L2 categories for their equivalent sounds or whether merged categories are formed. Thus, the present study investigates the VD, F1, F2, and F3 of the long vowels /iː, aː, uː/ of YA monolinguals and bilinguals as well as the long vowels /iː, ɑː, uː/ of YE. The following research questions were answered:

1. What are the acoustic similarities and differences of native Yemeni Arabic vowels produced by monolingual and bilingual subjects?
2. What are the acoustic similarities and differences between Yemeni Arabic vowels and Yemeni English vowels produced by Yemeni Arabic-English bilinguals?
3. What is the extent of L1–L2 phonetic interference in the vowel production of Yemeni Arabic-English bilinguals?

METHOD

SUBJECTS

Two different groups of subjects participated in the study. The first group consisted of 30 monolingual native Yemeni Arabic subjects, while the second group consisted of 30 L1 Yemeni Arabic - L2 English bilinguals. The monolingual subjects included 16 females and 14 males, ranging in age from 25 to 54 years old, while the bilingual subjects included 17 females and 13 males, ranging in age from 27 to 47 years old. The subjects were selected using purposive sampling. To ensure the eligibility of the subjects, a language background questionnaire was designed for each sample. All of the subjects in both samples spoke the Taizzi Yemeni Arabic dialect, which is one of the four major Yemeni Arabic dialects (Aldubai, 2015). It is mainly spoken in Taiz, a governorate located in the East-West of Yemen with a population exceeding three million, as well as other neighbouring governorates. All the subjects received their primary and secondary schooling in Yemen. They were residents of Klang Valley, Malaysia, at the time of the recordings.

All the subjects selected for the monolingual sample reported only speaking their native language and having been in Malaysia for less than six years. They all have limited exposure to any foreign language as they live within an Arabic community. Moreover, all the subjects selected in the bilingual sample reported being fluent in Arabic and English and not acquiring any other language. They mastered their English after finishing their secondary school education. They are postgraduate students from various faculties studying at the University Kebangsaan Malaysia, University of Malaya, or University Putra Malaysia with English as their medium of instruction. They have spent somewhere between one and six years in Malaysia, with an average of four.

MATERIALS

This study is based on acoustic analysis using Praat (Boersma & Weenink, 2019), a computer software for the phonetic analysis of speech. The vowels investigated in this study are in the word-medial position. They are YA /iː, aː, uː/ and YE /iː, ɑː, uː/. For each target vowel sound, a word with the target vowel in the word-medial position was investigated. For the vowel /aː/, the Arabic word investigated was سَار [saːr], and the English word was 'car' [kɑːr]. For the vowel /iː/, the Arabic word investigated was دِيك [diːk], and the English word was 'seek' [siːk]. For the vowel /uː/, the Arabic word investigated was تُوت [tuːt], and the English word was 'boot' [buːt]. Besides, extra words were added before and after the target Arabic and English words to help maintain the speech rate. These extra words were not included in the analysis.

PROCEDURES

The data collection process involved three recording sessions. Speech samples were recorded and acoustically analysed. The recordings were made using a Sony IC Recorder model (ICD-UX560F) with an internal speaker and microphone. For the monolingual sample, one recording session took place for each subject, which included a recording of the Arabic target words. However, two recording sessions took place for the bilingual sample because both the Arabic and English target words were recorded. In both samples, each subject was separately recorded and instructed to read each target word five times. Recordings were held in quiet rooms to ensure the high quality of the sounds. Altogether, 90 recording sessions were held. Each speech sample was acoustically

analysed. Measurements of each target vowel sound were made based on the display of the waveform and spectrogram. For the monolingual subjects, there were 450 tokens for analysis (3 sounds /iː, aː, uː/ x 30 subjects x 5 repetitions). Furthermore, for the bilingual subjects, there were 450 Arabic tokens for analysis (3 sounds /iː, aː, uː/ x 30 subjects x 5 repetitions) as well as 450 English tokens for analysis (3 sounds /iː, ɑː, uː/ x 30 subjects x 5 repetitions). Trials in which the subject mispronounced the word were not included in the analysis (6 tokens from the monolingual subjects, 1 Arabic token and 3 English tokens from the bilingual subjects). The remaining tokens were 444 monolingual Yemeni Arabic, 449 bilingual Yemeni Arabic, and 447 Yemeni English. A total of 1340 tokens were present in the entire dataset. Four acoustic measurements (VD, F1, F2, and F3) were made on each token.

RESULTS

Examining the acoustic characteristics of native YA vowels uttered by monolingual and bilingual speakers, as well as YE vowels produced by bilinguals, was the goal of this investigation. The analysis of YA and YE vowels included the measurement of VD, F1, F2, and F3. VD was measured by first placing the cursors on the starting and ending of the vowel. The beginning of the vowel was indicated by the onset of energy in F1, while the ending was indicated by a sharp decrease in energy in F1 and F2. Then, F1 was measured by clicking on (Formant > Get first formant) from the PRAAT objects menu, and a small window named "Praat Info" popped up to display the mean F1 value. Similarly, F2 and F3 were measured by clicking on (Formant > Get second formant) and (Formant > Get third formant) respectively. An example of the formant frequencies of the vowel /iː/ is shown in Figure 1 below. Arrow 1 points to the onset of the vowel /iː/, while arrow 2 points to the offset of the vowel. The area in between indicates the duration of the vowel. The red-dotted lines are the formant frequencies. From bottom to top, the lowest line is F1, then F2 and so on.

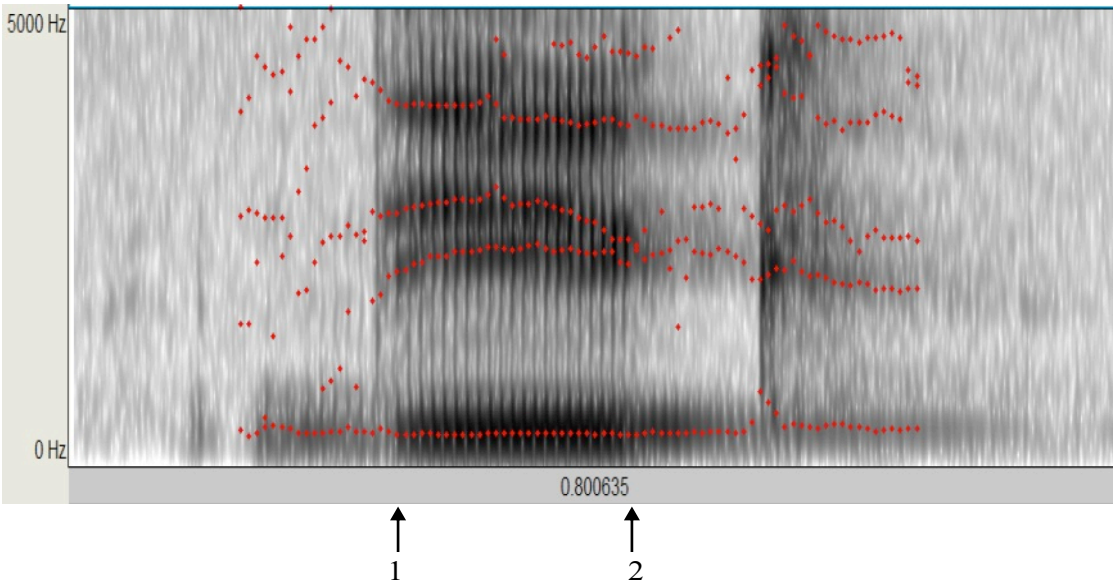

FIGURE 1. Spectrogram of the Arabic word "دِيك" [diːk] showing the formant frequencies in red dots

RELIABILITY

Inter-rater reliability and intra-rater reliability were tested on the data collected in this study using the Intraclass Correlation Coefficient (ICC) to measure the degree of agreement between measurements. Besides, "ICC is a widely used reliability index in inter-rater and intra-rater reliability analyses" (Koo & Li, 2016, p. 155). There may be some inaccuracy since measuring VD was a manual process done by just one researcher (the first author). Thus, to ensure optimal reliability, a portion of the acoustic analysis was carried out once more by an independent researcher who is knowledgeable about the acoustic process. The tokens of a total of nine participants, three representing YA monolinguals, three for YA bilinguals, and three for YE, were randomly selected. Ten per cent of the overall total tokens were remeasured. The obtained ICC value for inter-rater reliability was 0.883, indicating good reliability. Furthermore, to evaluate intra-rater reliability, VD was measured a second time by the researcher at least six months later. The obtained ICC value for intra-rater reliability was 0.914, indicating excellent reliability.

YEMENI ARABIC VOWELS (MONOLINGUALS VS. BILINGUALS)

This section answers the first research question. To determine if the bilingual subjects' productions of YA long vowels were influenced by the acquisition of L2 English vowels, this section compares the bilingual subjects' Arabic vowel productions to those of the monolingual individuals.

VOWEL DURATION

An independent samples t-test was performed to compare mean VD values of YA vowels produced by monolinguals (N = 30) and bilinguals (N = 30). Levene's F test was used to test the hypothesis of homogeneity of variance, and equal variances were reported for /iː/ and /uː/, F (58) = .707, p = .404 and F (58) = 1.26, p = .082, respectively whereas unequal variance was reported for /aː/, F (46.08) = 5.03, p = .029. Mean VD values between YA /iː/ produced by monolinguals (Mean (M) = 233.46, Standard Deviation (SD) = 46.33) and bilinguals (M = 222.70, SD = 55.36) conditions; t (58) = .816, p = .418, 95%, CI [-15.63, 37.13] revealed no significant difference. Moreover, there was no significant difference in mean VD values of YA /aː/ produced by monolinguals (M = 288.62, SD = 33.83) and bilinguals (M = 291.37, SD = 59.28) conditions; t (46.08) = -.220, p = .827, 95%, CI [-27.83, 22.33]. Like /iː/ and /aː/, mean VD values between YA /uː/ produced by monolinguals (M = 251.72, SD = 47.10) and bilinguals (M = 237.70, SD = 61.13) conditions; t (58) = .995, p = .324, 95%, CI [-14.18, 42.22] showed no significant difference.

TABLE 3. VD of Yemeni Arabic Vowels Produced by Monolingual and Bilingual Subjects

Sound	Monolingual		Bilingual		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/iː/	233	46.33	223	55.36	58	.816	p= .418
/aː/	289	33.83	291	59.28	46.08	-.220	p= .827
/uː/	252	47.10	238	61.13	58	.995	p= .324

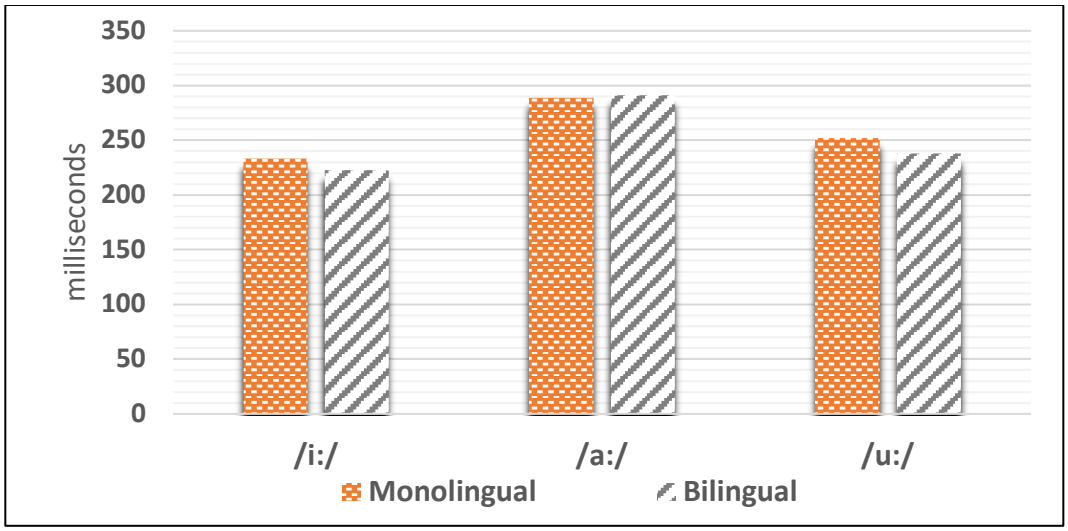

FIGURE 2. Mean VD of Yemeni Arabic Vowels Produced by Monolinguals and Bilinguals

FIRST FORMANT

To compare mean F1 values of YA vowels produced by monolinguals (N = 30) and bilinguals (N = 30), an independent sample t-test was conducted. Like VD, Levene's F test was used to test the hypothesis of homogeneity of variance, and equal variances were reported for /i:/ and /u:/, F (58) = .163, p = .688 and F (58) = .289, p = .593, respectively whereas unequal variance was reported for /a:/, F (51.98) = 4.44, p = .039. There was no significant difference in mean F1 values of YA /i:/ produced by monolinguals (M = 382.56, SD = 47.48) and bilinguals (M = 370.03, SD = 42) conditions; t (58) = 1.07, p = .289, 95%, CI [-10.88, 35.94]. Furthermore, there was no significant difference in F1 for /a:/, *t* (51.98) = -1.13, *p* = .265, 95%, CI [-63.03, 17.70] despite bilinguals (M = 734.31, SD = 90.20) attaining higher mean F1 values than monolinguals (M = 711.65, SD = 63.28). Like /i:/ and /a:/, mean F1 values between YA /u:/ produced by monolinguals (M = 436.75, SD = 36.62) and bilinguals (M = 423.60, SD = 39.24) conditions; t (58) = 1.34, p = .185, 95%, CI [-6.46, 32.77] revealed no significant difference.

TABLE 4. F1 of Yemeni Arabic Vowels Produced by Monolinguals and Bilinguals

Sound	Monolingual		Bilingual		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/i:/	383	47.48	370	42	58	1.07	p= .289
/a:/	712	63.28	734	90.20	51.98	-1.13	p= .265
/u:/	437	36.62	424	39.24	58	1.34	p= .185

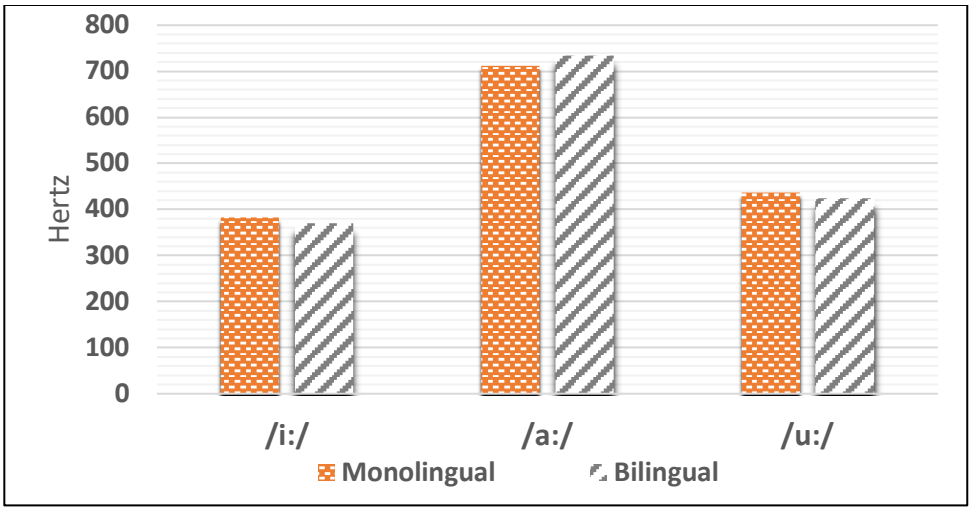

FIGURE 3. Mean F1 of Yemeni Arabic Vowels Produced by Monolinguals and Bilinguals

SECOND FORMANT

An independent sample t-test was performed to compare mean F2 values of YA vowels produced by monolinguals (N = 30 except for /u:/ where one subject was excluded) and bilinguals (N = 30). The assumption of homogeneity of variance was tested and satisfied via Levene's F test for /i:/, /a:/ and /u:/, F (58) = .611, p = .438, F (58) = 2.56, p = .115 and F (57) = 1.27, p = .265, respectively. There was no significant difference in mean F2 values of YA /i:/ produced by monolinguals (M = 2406.75, SD = 295.14) and bilinguals (M = 2373.72, SD = 275.88) conditions; t (58) = .448, p = .656, 95%, CI [-114.62, 180.68]. On the contrary, there was a significant difference in F2 for /a:/ where monolinguals (M = 1635.71, SD = 217.12) showed higher values than bilinguals (*M* = 1495.76, *SD* = 177.12) conditions; *t* (58) = 2.74, *p* = .008, 95%, CI [37.54, 242.35]. In addition, mean F2 values between YA /u:/ produced by monolinguals (M = 1202.37, SD = 164.67) and bilinguals (M = 1160.69, SD = 124.96) conditions; t (57) = 1.09, p = .277, 95%, CI [-34.36, 117.72] showed no significant difference.

TABLE 5. F2 of Yemeni Arabic Vowels Produced by Monolingual and Bilingual Subjects

Sound	Monolingual		Bilingual		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/i:/	2407	295.14	2374	275.88	58	.448	p= .656
/a:/	1636	217.12	1496	177.12	58	2.736	p= .008
/u:/	1202	164.67	1161	124.96	57	1.098	p= .277

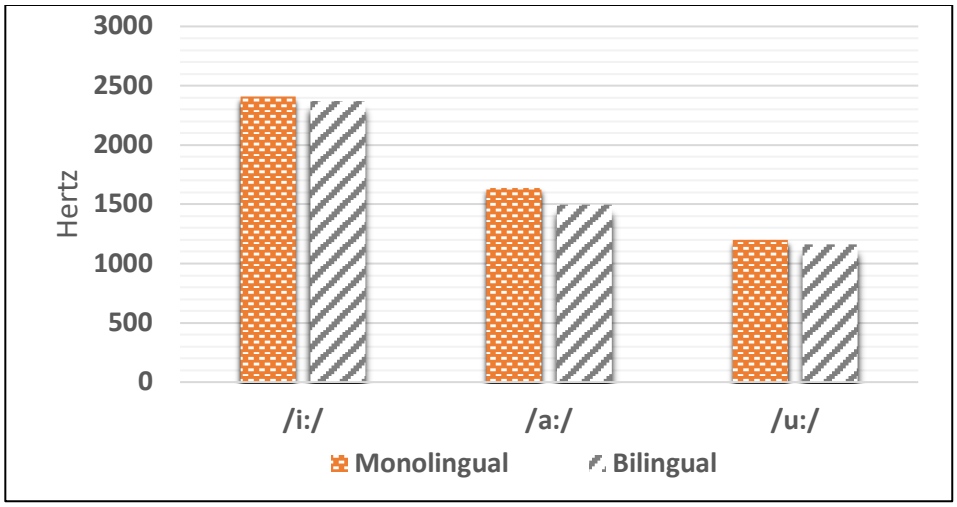

FIGURE 4. Mean F2 of Yemeni Arabic Vowels Produced by Monolinguals and Bilinguals

THIRD FORMANT

Like F1 and F2, an independent sample t-test was conducted to compare mean F3 values of YA vowels produced by monolinguals (N = 30) and bilinguals (N = 30). Levene's F test was used to test the hypothesis of homogeneity of variance, and equal variances were reported for /iː/, /aː/ and /uː/, F (58) = 1.99, p = .164, F (58) = 1.71, p = .196 and F (58) = .495, p = .485, respectively. Mean F3 values between YA /iː/ produced by monolinguals (M = 3081.05, SD = 208.40) and bilinguals (M = 3090.69, SD = 254.05) conditions; t (58) = -.161, p = .873, 95%, CI [-129.73, 110.44] showed no significant differences. Furthermore, the monolingual group showed (M = 2712.22, SD = 226.25) for /aː/ and (M = 2806.23, SD = 277.38) for /uː/. By comparison, the bilingual group showed a numerically lower mean F3 value for /aː/ (M = 2589.82, SD = 305.04) and /uː/ (M = 2705.23, SD = 264.75). However, there was no statistically significant difference between monolinguals and bilinguals in mean F3 values for /aː/ and /uː/, conditions; t (58) = 1.77, p = .083, 95%, CI [-16.40, 261.19] and t (58) = 1.44, p = .154, 95%, CI [-39.14, 241.13], respectively.

TABLE 6. F3 of Yemeni Arabic Vowels Produced by Monolingual and Bilingual Subjects

Sound	Monolingual		Bilingual		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/iː/	3081	208.40	3091	254.05	58	-.161	p= .873
/aː/	2712	226.25	2590	305.04	58	1.765	p= .083
/uː/	2806	277.38	2705	264.75	58	1.443	p= .154

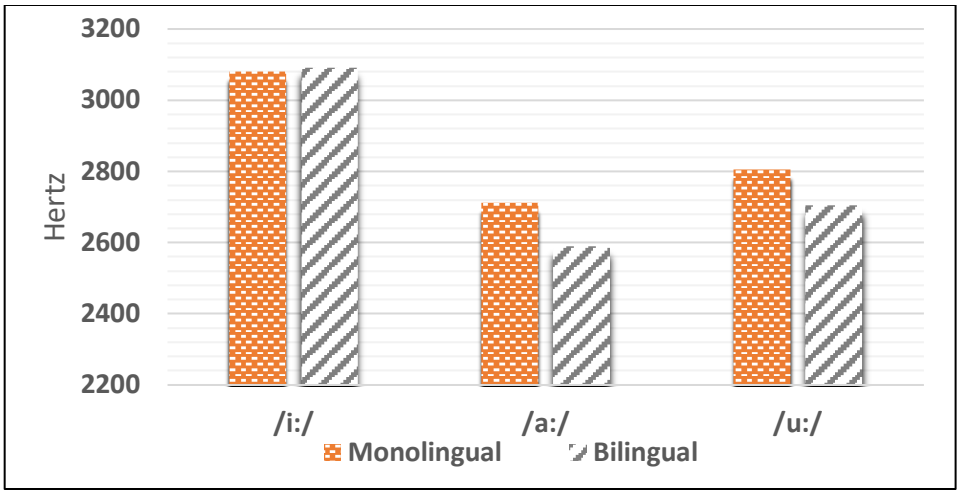

FIGURE 5. Mean F3 of Yemeni Arabic Vowels Produced by Monolinguals and Bilinguals

L1 YEMENI ARABIC VS. L2 YEMENI ENGLISH

This section answers the second research question by comparing the vowel productions of the bilingual subjects' L1 and L2. The bilingual subjects' own productions of YA vowels were compared to their YE vowels. Measurements of VD, F1, F2, and F3 of YA and YE vowels were compared.

VOWEL DURATION

A paired sample t-test was performed to compare the mean VD values of YA and YE vowels. The mean VD values of /iː/ (N = 30) between YA (M = 222.70, SD = 55.36) and YE (M = 181.93, SD = 72.32) conditions; t (29) = 4.318, p = .000, 95%, CI [21.46, 60.08] differed significantly from one another. However, there was no significant difference in mean VD values of (N = 30) between YA /aː/ (M = 291.37, SD = 59.28) and YE /ɑː/ (M = 286.96, SD = 60.52) conditions; t (29) = .552, p = .585, 95%, CI [-11.92, 20.74]. Besides, there was no significant difference in mean VD values of /uː/ (N = 28) between YA (M = 230.29, SD = 56.16) and YE (M = 219.92, SD = 58.74) conditions; t (27) = .968, p = .341, 95%, CI [-11.60, 32.34].

TABLE 7. VD of Yemeni Arabic and Yemeni English Vowels

Sound	Yemeni Arabic		Yemeni English		Df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/iː/	223	55.36	182	72.32	29	4.318	p = .000
/aː/ - /ɑː/	291	59.28	287	60.52	29	.552	p = .585
/uː/	230	56.16	220	58.74	27	.968	p = .341

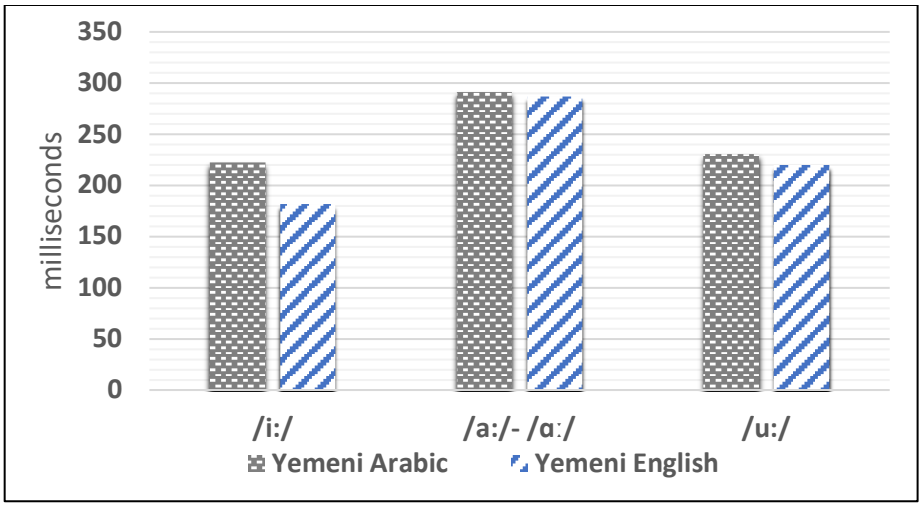

FIGURE 6. Mean VD values of Yemeni Arabic and Yemeni English Vowels

FIRST FORMANT

To compare mean F1 values of YA and YE vowels, a paired sample t-test was performed. There was a significant difference in mean VD values of /i:/ (N = 30) between YA (M = 370.03, SD = 43.00) and YE (M = 383.92, SD = 46.35) conditions; t (29) = -2.334, p = .027, 95%, CI [-26.06, -1.72]. Moreover, there was no significant difference in mean F1 values of (N = 30) between YA /a:/ (M = 734.31, SD = 90.20) and YE /ɑ:/ (M = 732.53, SD = 84.82) conditions; t (29) = .227, p = .822, 95%, CI [-14.28, 17.84]. Yet, there was a marginally significant difference in mean F1 values of /u:/ (N = 29) between YA (M = 422.91, SD = 39.75) and YE (M = 436.27, SD = 51.61) conditions; t (28) = -2.050, p = .050, 95%, CI [-26.71, -.012].

TABLE 8. F1 of Yemeni Arabic and Yemeni English Vowels

Sound	Yemeni Arabic		Yemeni English		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/i:/	370	43.00	384	46.35	29	-2.334	p = .027
/a:/ - /ɑ:/	734	90.20	733	84.82	29	.227	p = .822
/u:/	423	39.75	436	51.61	28	-2.050	p = .050

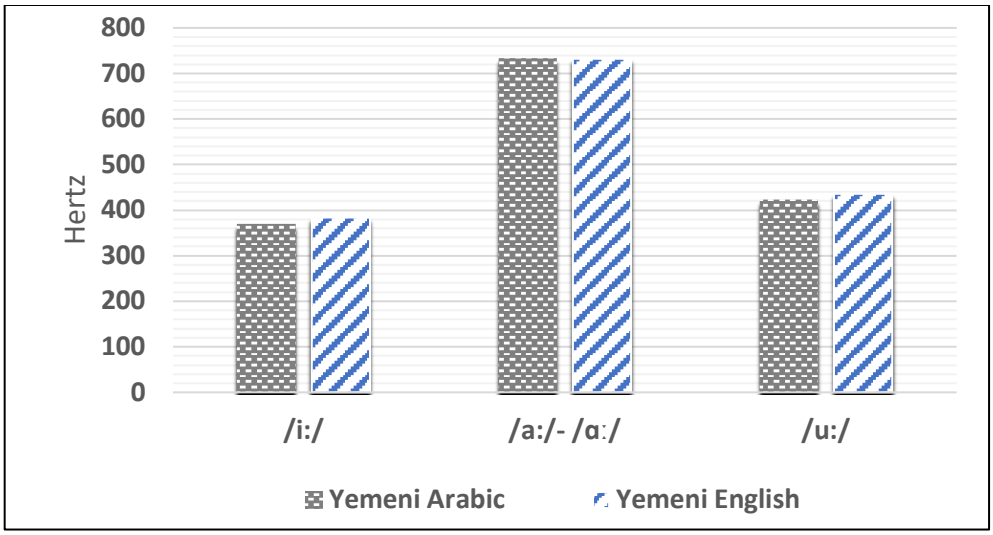

FIGURE 7. Mean F1 values of Yemeni Arabic and Yemeni English Vowels

SECOND FORMANT

A paired sample t-test was performed to compare the mean F2 values of YA and YE vowels. There was no significant difference in mean F2 values of /iː/ (N = 30) between YA (M = 2373.72, SD = 275.88) and YE (M = 2344.30, SD = 254.04) conditions; t (29) = .543, p = .592, 95%, CI [-81.48, 140.33]. On the contrary, there was a significant difference in F2 where YA /aː/ (M = 1495.76, SD = 177.12) showed a significantly higher mean value than YE /ɑː/ (M = 1384.69, SD = 160.53) conditions; *t* (29) = 3.616, *p* = .001, 95%, CI [48.25, 173.89]. Likewise, there was a significant difference in mean F2 values of /uː/ between YA (M = 1159.90, SD = 127.09) and YE (M = 995.78, SD = 104.36) conditions; t (28) = 7.390, p = .000, 95%, CI [118.63, 209.62].

TABLE 9. F2 of Yemeni Arabic and Yemeni English Vowels

Sound	Yemeni Arabic		Yemeni English		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/iː/	2374	275.88	2344	254.04	29	.543	p = .592
/aː/ - /ɑː/	1496	177.12	1385	160.53	29	3.616	p = .001
/uː/	1160	127.09	996	104.36	28	7.390	p = .000

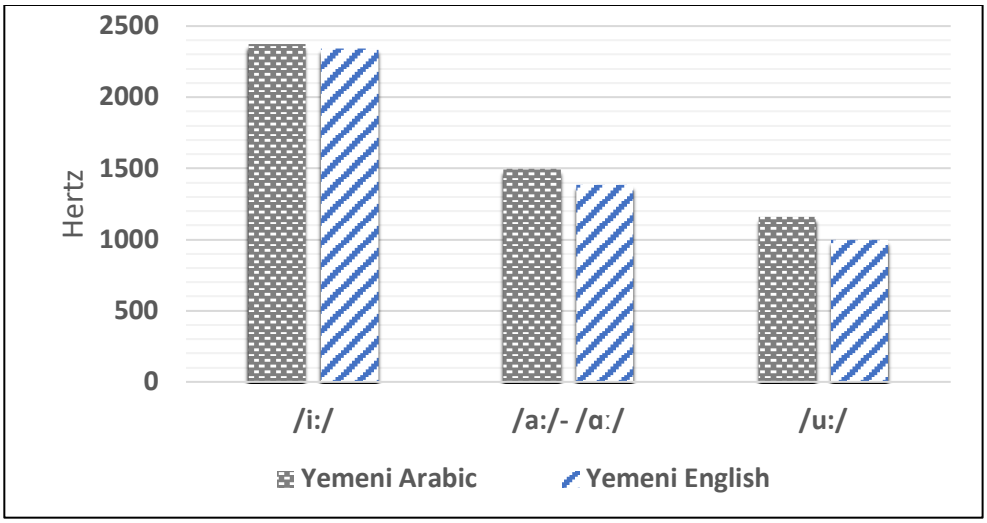

FIGURE 8. Mean F2 values of Yemeni Arabic and Yemeni English Vowels

THIRD FORMANT

Like F1 and F2, a paired sample t-test was performed to compare mean F3 values of YA and YE vowels. Mean F3 values of /i:/ (N = 30) between YA (M = 3090.69, SD = 254.05) and YE (M = 3033.30, SD = 269.39) conditions; t (29) = 1.468, p = .153, 95%, CI [-22.57, 137.36] revealed no significant difference. Moreover, there was no significant difference in mean F3 values of (N = 30) between YA /a:/ (M = 2589.82, SD = 305.04) and YE /ɑ:/ (M = 2596.72, SD = 347.73) conditions; t (29) = -.101, p = .920, 95%, CI [-146.79, 133]. Likewise, mean F3 values of /u:/ (N = 29) between YA (M = 2709.84, SD = 268.20) and YE (M = 2712.71, SD = 238.24) conditions; t (28) = -.092, p = .928, 95%, CI [-66.88, 61.15] showed no significant difference.

TABLE 10. F3 of Yemeni Arabic and Yemeni English Vowels

Sound	Yemeni Arabic		Yemeni English		df	T	Sig
	Mean	Std. Deviation	Mean	Std. Deviation			
/i:/	3091	254.05	3033	269.39	29	1.468	p = .153
/a:/- /ɑ:/	2590	305.04	2597	347.73	29	-.101	p = .920
/u:/	2710	268.20	2713	238.24	28	-.092	p = .928

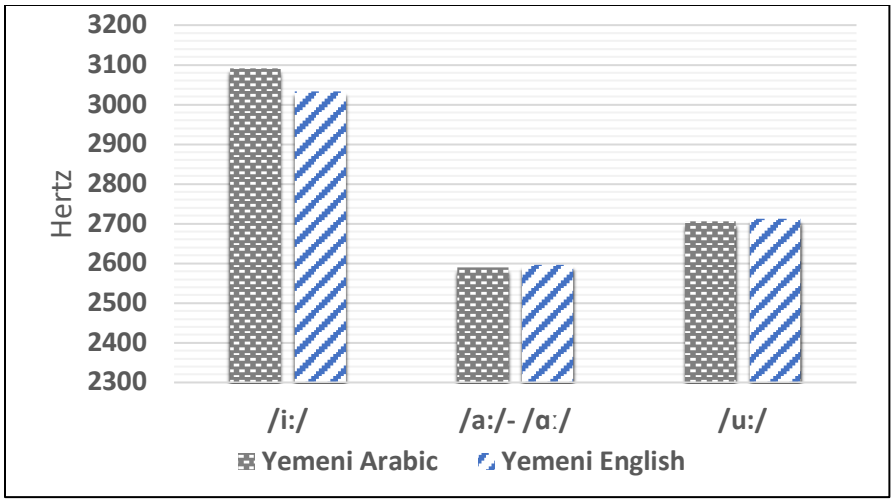

FIGURE 9. Mean F3 values of Yemeni Arabic and Yemeni English Vowels

DISCUSSION

This study presented the acoustical characteristics of YA and YE long vowels. Mean VD values of YA /i:, a:, u:/ produced by monolinguals and bilinguals showed no statistically significant differences. Moreover, there were no statistically significant differences between mean F1, F2 and F3 values of YA /i:, a:, u:/ produced by monolinguals and bilinguals except for F2 of /a:/ where results revealed bilinguals having a significantly lower mean F2 value for /a:/ than monolinguals. This significant difference of YA /a:/ in F2 between monolinguals and bilinguals indicates an L2 influence on L1.

In the production of /i:/, Yemeni Arabic-English bilinguals showed significant differences in VD and F1 between YA and YE. They formed new VD and F1 categories for their L2 YE /i:/, whereas, for F2 and F3, they developed a merged category for both YA and YE, which are close to those produced by YA monolinguals. On the contrary, in the production of /a:/-/ɑ:/, Yemeni Arabic-English bilinguals showed significant differences between YA /a:/ and YE /ɑ:/ in F2 which is highly likely since they are qualitatively different vowels. Though bilinguals formed a separate F2 category for their L2 English /ɑ:/, F2 alone is not an indication of native-like production. However, for VD, F1 and F3, bilinguals developed a merged category for both YA and YE, which are close to those produced by YA monolinguals. Results uncovered that the bilingual subjects' pronunciation of YA /a:/ showed indications of English-induced L1 phonetic drift. They produced /a:/ with F2 values that are in-between and significantly different from both monolingual YA /a:/ and YE /ɑ:/. Moreover, in the production of /u:/, Yemeni Arabic-English bilinguals showed significant differences in F1 and F2 between YA and YE. They formed new F1 and F2 categories for their L2 YE /u:/, whereas, for VD and F3, they developed a merged category for both YA and YE, which are similar to those produced by YA monolinguals. The L1 and L2 of Yemeni Arabic-English bilinguals were found to differ significantly on at least one of the acoustic properties for every vowel examined, indicating a separate L2 category formation for the acoustic property included. Unlike F1 and F2, F3 showed no significant differences between monolingual YA and bilingual YA, as well as between bilingual YA and YE.

In addition, /aː/ and /ɑː/ showed the highest mean VD value among the other vowels, whereas /iː/ showed the lowest, which is consistent with the findings of Fathi and Qassim (2020). VD of YA vowels were close to those of Saudi Arabian, Sudanese and Egyptian, as reported by Alghamdi (1998). Besides, the F2 findings of YA agree with the findings of Tsukada (2009), where Arabic among Thai and Japanese showed the highest F2 values. Overall, YA formant frequencies show some similarities with the other Arabic dialects mentioned in the literature above.

CONCLUSION

Yemeni Arabic-English bilinguals' production of L1 /aː/ revealed phonetic drift towards their L2 English in F2. On the contrary, findings show no impact of L2 English on the production of L1 Yemeni Arabic long vowels /iː/ and /uː/ since monolinguals and bilinguals revealed no significant differences between their productions in all the acoustic measurements investigated. However, findings reveal a slight drift in L1 Yemeni Arabic vowels towards L2 YE vowels, causing closer acoustic vowel space between both languages, suggesting an assimilatory process. Furthermore, Yemeni Arabic-English bilinguals formed new categories for their L2 English vowels for the acoustic features VD and F1 for /iː/, F2 for /ɑː/, and F1 and F2 for /uː/, whereas they developed merged categories for the remaining acoustic features. Overall, these findings indicate that Yemeni Arabic-English bilinguals produce the long vowels of both of their languages differently. The current study is anticipated to serve as a foundation for subsequent research by providing the acoustic-phonetic patterns of Yemeni Arabic and YE long vowels. Given the significant differences in F1 and F2 between YA and YE in this study, it would be worth exploring the gaps in vowel space between native Yemeni Arabic vowels and native English vowels. Such knowledge of the gaps in the vowel space area would alert L2 learners to the diverging L2 sound areas, which would, in return, increase L2 competence.

Studies on bilingual speech have examined their vowel perception (AL Abdely & Thai, 2016). However, since this study examined the production of YA and YE without considering perception, further research investigating the vowel perception of Yemeni Arabic-English bilinguals is recommended. Besides, to minimise the impact of dialect on L1, this study was restricted to subjects speaking the Taizzi Yemeni Arabic dialect. Thus, the acoustic characteristics of further Yemeni Arabic dialects may be the subject of future study. Moreover, it is recommended that additional research be done on the spontaneous speech of Yemeni speakers' productions of Arabic and English vowels. Though recording productions in laboratory settings guarantees a greater degree of control, analysing spontaneous speech is believed to provide data that reflects, to a greater extent, naturally occurring speech.

Studies on the coarticulatory dominance of different vowels in various languages have generally discovered that high vowels like /i/ and /u/ show more dominance and resistance than low vowels like /ɑ/ and /æ/ (Recasens, 1987). YA and YE target vowels in this study were in word-medial position preceded by a consonant. However, for YA and YE /iː/ and /uː/, the preceding consonants were not of the same voice quality, which may lead to coarticulatory effects on the acoustic measurements of the target vowel. Therefore, it is recommended that in future research, the coarticulatory effect of the preceding vowel should be controlled.

One practical conclusion that may be drawn from the data is the necessity of providing Yemeni English language learners with specialised instruction and practice. The output of the present study is very important to English Foreign Language (EFL) teachers and to the teaching

staff members at various EFL institutes in Yemen. It is also relevant to those responsible for the curriculum design of English in the Ministry of Education. Hence, the teaching of EFL in Yemen should take into consideration the need to focus on English pronunciation, which tends to be given less focus than other language skills. To receive the desired level of intelligibility, training should be imposed on L2 teaching/learning in Yemen.

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