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The Influence of Bilingualism on the Production of Stop Consonants in L1 (Arabic) and L2 (English): Acoustic Analysis of Stop's Closure Duration

Abstract

This paper investigates the impact of bilingualism on the difficulties of pronunciation for both L1 (Arabic) and L2 (English). It assesses the production of stop sounds in Arabic and English through an acoustic analysis of stops' closure duration (henceforth CD), as pronounced by Arabic-English bilinguals whose L1 is Palestinian Arabic. Additionally, the paper aims to highlight the difficulties of pronunciation in both languages. Three groups of same-aged adult subjects participated in the production tests; 1) Arabic-English bilinguals whose L1 is Palestinian Arabic, 2) Arabic-monolinguals, and 3) English-monolinguals. The stops in word-medial and final positions were included in closed syllables (CVC) in meaningful words inserted in carrier sentences. The results revealed that the CD of the interaction of stops was represented in four categories; 1) unidirectional effect of L1 on L2 that caused a foreign accent, 2) bidirectional influence resulting in L1-L2 interference, 3) unidirectional impact of L2 on L1, and 4) nativelikeness in both languages without language interference. In addition, the findings showed that bilinguals faced pronunciation challenges in both similar and dissimilar sounds. This paper is expected to initiate more comprehensive studies in the field of interaction between Arabic and English in the Arabic context.

Keywords: acoustic analysis, language interaction, stop sounds, Arabic-English bilinguals, pronunciation difficulties, closure duration

Introduction

One of the most problematic issues related to L2 learning difficulties is the acquisition of the L2 sound system in a native-like way (Alnajjar 2017). L2 sounds that differ from L1 sounds are more difficult to obtain, according to the Contrastive Analysis Hypothesis (CAH), whereas those that are identical should

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be simpler. In other words, the CAH suggests that L2 sounds that do not occur in L1 may cause difficulties in learning (Lado 1957). On the other hand, the Speech Learning Model (SLM) (Flege 1995) contradicts the CAH in that it is expected that L2 sounds that are identical to L1 sounds will be more difficult to learn while mastering L2 sounds that are different. In addition, sounds of L2 that differ phonemically and phonetically from L1 sounds are considered new. In contrast, those L2 sounds that are phonemically similar but phonetically different from L1 sounds are deemed identical and thus difficult to be acquired. Although the polarisation and assimilatory processes and the complexity of the sound system complicate cross-language interactions, researchers categorised four key possibilities of two languages interactions that vary widely between accentedness and nativeness (Antoniou *et al.* 2011).

Accentedness is the first and most apparent possibility. Due to the influence of L1 on L2, the L2 sounds produced by bilinguals takes the form of a foreign accent and looks different from those of native L2 speakers. In addition, the sequential acquisition of two languages leads to L2 learning through a "filter" of L1, which creates what is called "language interference" (Antoniou *et al.* 2011). Bidirectional interaction is the second possibility for L1-L2 interaction, as the phonological systems of the two languages affect each other, resulting in language interference (Antoniou *et al.* 2011; Dmitrieva, Jongman, and Sereno 2010).

The third potential L1-L2 interaction is the effect of L2 on L1 with almost free language interference, which arises due to the high fluency of L2 speakers in cases of the dominant L2 language (Flege, MacKay, and Piske 2002). The final possibility is that the two languages do not influence each other, which means that the bilinguals can produce L1 and L2 sounds as monolinguals do in each language. For example, Greek–English early bilinguals succeed in producing the stop sounds /b, d, p, t/ in both L1 and L2. With negative VOTs for /b, d/ and short-lag VOTs for /p,t/ in Greek, simultaneously, they also produced English /b, d/ with short lag and English /p, t/ with long-lag VOT, which meets both English and Greek with the monolingual pattern of VOTs (Antoniou *et al.* 2010).

In the field of bilingualism and multilingualism, previous studies applied the voice onset time (VOT) as a cue identifying the production and perception of the individual to determine the "nativeness" and "accentedness" of speech sounds (Wrembel 2011; Llama, Cardoso, and Collins 2010). Regarding Arabic and English sounds interaction, some inter-language studies focused on the vowels (Al-Hamadi 2012; Hubais and Pillai 2017; Khalil 2014). Others were concerned about stop consonants among English- Arabic bilinguals (Khattab 2002).

In this study, we applied another important acoustic cue of stop sounds, which is closure duration (CD), to investigate the language interaction between the two sound systems of Modern Standard Arabic (MSA) and English produced by English-Arabic bilinguals. Besides, in the light of the CAH and SLM theories, we also examined to what extent the phonetic dis/similarity influences the difficulties of nativelikeness production of stops across the two languages.

As shown in Table 1, The Arabic stops include plain voiceless /t, k, q/ and voiced stops /b, d/ with their empathic counterparts /t^{ʔ}, d^{ʔ}/. With no existence of /g/ and /g/ in the Arabic inventory. In addition, it is worth mentioning that the place of articulation of the Arabic /t/ and /d/ is different from English, as these sounds are alveolars in English but dental-alveolars in Arabic (Kopczynski and Meliani 1993). Thus, the English stops /b/, /k/ are familiar to Arabic learners of English, /t/, /d/ are not fully familiar as they vary in the place of articulation, /p/, /g/ are completely new. A few Arabic stops such as /q/, /t^{ʔ}/, and /d^{ʔ}/, on the other hand, are not represented in the inventory of the English stops.

Table 1. The stop sounds in the Modern Standard Arabic and English consonant inventories. (When there are two sounds in one cell, voiceless sounds to the left and voiced to the right).

		Bilabial	Dental-alveolar	Alveolar	Velar	Uvular
Arabic	Plates	- b	t d		k -	q -
	empathic		tˀ dˀ			
English		p b		t d	k g	

1. METHODOLOGY

In this section, we explain the criteria used to select the subjects and illustrate the process of data collection and analysis.

1.1. Subjects

In this study, 28 native Arabic speakers (14 females) were recruited and divided into two groups: The English-Arabic bilingual group (experimental group) and the Arabic monolingual group (control group). In addition, the subjects included a second control group of five native American monolingual speakers (3 females). All subjects aged between 20 and 30 years and had no health or hearing problems. The whole population had an interview and filled out a questionnaire before the data collecting to ensure that all the participants complied with the criteria.

1.2. Stimuli

The target stop consonants in both languages were inserted in closed syllables (CVC) with the short vowel /i/ through meaningful words that are framed by the carrier sentences; (Aqulu kalımata ...) in Arabic, and (I say the word ...) in English. The data were collected through three production tests we applied in this study to collect the data through; one Arabic test for Arabic monolinguals and two Arabic and English tests for bilinguals. A total of 3338 tokens were generated in the acoustic analysis. 1088 tokens for Arabic monolinguals (13 subjects * 7 stops * 5 repetitions * 2 word-positions; medial and final), 1950 tokens for bilinguals (15 subjects* (7 Arabic stops + 6 English stops) * 5 repetitions * 2 word-positions), and 300 tokens for English monolinguals (5 subjects * 6 stops * 5 repetitions * 2 word-positions).

1.3. Data Collection and Analysis

The data were recorded separately using the facilities of the Islamic University of Gaza's sound production studio. Each participant was asked to read the sentences of the production test in one 15-20 minute session. The sentences were displayed on a computer-connected LCD screen; high-quality recorder software was used during the audio recording session, and a microphone (AKG C414) was mounted on a platform at face height, approximately 20 mm to the right of the mouth, to reduce the effect of direct airflow turbulence on the microphone. The recordings were saved to separate sound files, then the target tokens were selected, extracted, normalized, and were prepared for the acoustic analysis in the PRAAT

software 6.0.25 (Boersma and Weenink 2019). The spectrogram parameters were set to standard values with a window duration of 5 ms, a dynamic range of 50 dB and a maximum frequency of 5000Hz. The CD measurements were taken manually by PRAAT in the word-medial and final positions.

1.4. Statistical analysis

The statistical analysis was applied by SPSS software, where an independent sample t-test was performed to determine whether there are any statistically significant differences in the means of the CDs among the experimental and the control groups; the critical p-value was set at 0.05. The descriptive of means, standard deviations, and ranges for each measurement were calculated too.

2. RESULTS AND DISCUSSION

This section presents and discusses the results of the independent sample t-tests regarding the difference in the stops' acoustic characteristics between the bilinguals and native monolinguals.

2.1. Closure Duration of Similar Sounds

Starting with the CD of word-medial position similar stops /b, t, d, and k/ that occur in both of the Arabic and English consonant inventories, the results showed that the bilinguals' production of the CD for /b/, /d/, and /t/ was significantly affected by their L1. In detail, bilinguals produced the CD of Arabic /d/ in the medial position without significant differences than Arabic monolinguals do ($p=0.271$). But they could not acquire the same CD of /d/ for English natives. The English /d/ produced by bilinguals had a significantly longer CD than that produced by English native speakers with almost double the duration ($p< 0.0001$, MD= 30.6 ms). Similarly, the differences between the CD of Arabic /b/ produced by Arabic monolinguals and bilinguals were not significant ($p= 0.404$, MD= 9 ms), but the English /b/ produced by bilinguals had a significantly longer CD position than /b/ produced by English monolinguals in stop's word-medial ($p < 0.0001$, MD= 27 ms). The same effect of L1 on L2 was witnessed in the production of /t/. The Arabic /t/ produced by the Arabic bilingual and monolingual groups were not significantly different ($p= 0.104$, MD= 10 ms). In contrast, the bilinguals produced the English /t/ with more than double the duration of the English /t/ produced by native English speakers. ($p< 0.0001$, MD= 37 ms). However, the results showed that bilinguals witnessed a bidirectional L1-L2 effect in their production of the voiceless velar /k/ in word-medial position regarding the CD. The bilinguals produced the Arabic /k/ with a significantly longer CD than that of Arabic monolinguals (MD= 8 ms, $p= 0.047$), while the CD of the English /k/ was significantly longer than that of English monolinguals (MD = 21 ms, $p= 0.001$). Table 2 provides information about the CD of similar stops in both languages in word medial, including the means of the CD, the number of subjects, the standard deviation, and the minimum and maximum values of CD. In addition, Figure 1 illustrates the differences in the means of CD in the medial position of similar Arabic and English stops for the bilinguals and monolinguals.

Table 2. Means, number of subjects, the standard deviation, and the minimum and maximum values for the CD of similar stops in both languages in word-medial position.

Stops	Language	Mono/ bilinguals	N	Mean	Std. Deviation	Minimum	Maximum
k	Arabic	Monolingual	13	73	12	50	93
	Arabic	Bilingual	16	65	9	53	80
	English	Bilingual	16	84	18	52	119
	English	Monolingual	15	63	15	42	85
d	Arabic	Monolingual	13	64	11	44	87
	Arabic	Bilingual	16	59	10	39	77
	English	Bilingual	16	64	19	32	99
	English	Monolingual	15	33	20	16	86
t	Arabic	Monolingual	13	84	18	46	118
	Arabic	Bilingual	15	74	9	53	94
	English	Bilingual	16	70	22	15	119
	English	Monolingual	15	33	20	16	86
b	Arabic	Monolingual	13	67	10	50	81
	Arabic	Bilingual	15	58	36	5	127
	English	Bilingual	14	80	15	59	105
	English	Monolingual	15	53	18	30	100

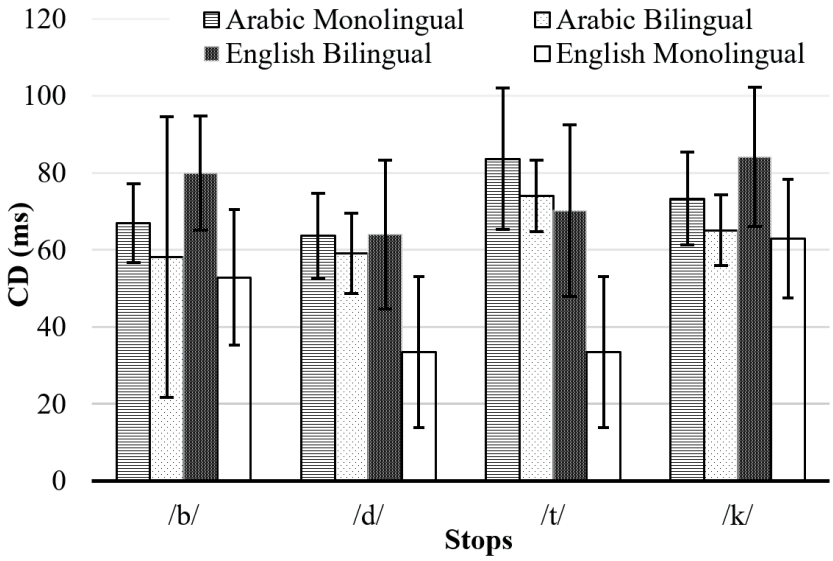

Figure 1. The CDs of similar Arabic and English stops for monolinguals and bilinguals in word-medial position.

The CDs of similar stops in word-final position were either affected by L1, e.g. /b, t, and d/, or had free language interaction, i.e. /k/. The bilinguals succeeded in maintaining the CDs of Arabic /b/ (p= 0.1, MD= 50 ms), /t/ (p= 0.206, MD= 19 ms), and /d/ (p= 0.693, MD= 6 ms) with no significant differences from their counterparts for Arabic monolinguals. Though, the bilinguals produced these sounds in English with significantly longer CDs than those of English monolinguals (/b/; p= 0.001, MD= 60 ms. /t/; p= 0.023, MD= 34 ms. /d/; p< 0.000, MD= 66 ms). However, the bilinguals maintained the CDs of the voiceless velar /k/ in both Arabic and English without significant differences from those of Arabic (p= 0.823, MD= 3 ms) and English (p= 0.177, MD= 18 ms) monolingual native speakers. Table 3 presents details about the means, the standard deviation, and the minimum and maximum values of the CD of similar stops in both languages in word-final position. Also, Figure 2 represents the differences in the means of CD in the word-final position of similar Arabic and English stops for the bilinguals and monolinguals.

Table 3. Means, number of subjects, the standard deviation, and the minimum and maximum values for the CD of similar stops in both languages in word-final position.

stops	Language	Mono/bilinguals	N	Mean	Std. Deviation	Minimum	Maximum
k	Arabic	Monolingual	13	200	98	71	405
	Arabic	Bilingual	14	150	35	97	195
	English	Bilingual	16	198	46	125	277
	English	Monolingual	14	137	41	82	222
d	Arabic	Monolingual	13	155	37	121	225
	Arabic	Bilingual	15	136	42	73	207
	English	Bilingual	15	172	27	129	219
	English	Monolingual	14	138	44	75	207
t	Arabic	Monolingual	11	138	52	60	213
	Arabic	Bilingual	16	131	36	59	179
	English	Bilingual	16	160	37	98	253
	English	Monolingual	11	94	35	47	173
b	Arabic	Monolingual	13	142	33	77	211
	Arabic	Bilingual	16	138	43	77	232
	English	Bilingual	16	169	36	110	247
	English	Monolingual	15	150	37	89	212

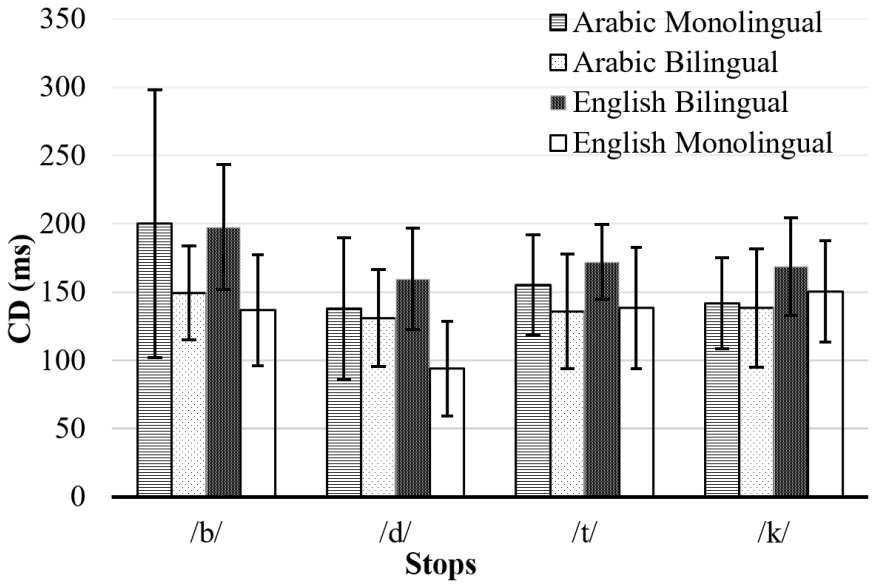

Figure 2. The CDs of similar Arabic and English stops for monolinguals and bilinguals in word-final position.

2.2. Closure Duration of Dissimilar Arabic stops

Three different Arabic stops do not occur in English consonants /d, t, q/. The findings of the independent sample t-test indicated that bilinguals succeeded in producing the CDs of /dˁ/ in medial (p= 0.241, MD= 4 ms) and final (p= 0.067, MD= 18 ms) positions without significant differences from the Arabic monolinguals. Similarly, the CDs of voiceless uvular /q/ were also produced without statistically considerable differences in both medial (p= 0.114, MD= 4 ms) and final (p= 0.713, MD= 5 ms) positions. Besides, bilinguals succeeded to produce the CD of /tˁ/ in word-final position with no significant differences from monolinguals (p= 0.369, MD= 15 ms). Still, they failed to do that in the for /tˁ/ in word-medial position as they produced it with significantly shorter CD than Arabic monolinguals (p= 0.048, MD= 10 ms). For more details, Figures 3 and 4 demonstrate the means of CD for Arabic stops that do not belong to the English inventory as produced by Arabic bilinguals and monolinguals. Besides, Table 4 presents the means, the number of subjects, and the standard deviation of the CD in the word-medial and final positions of these sounds.

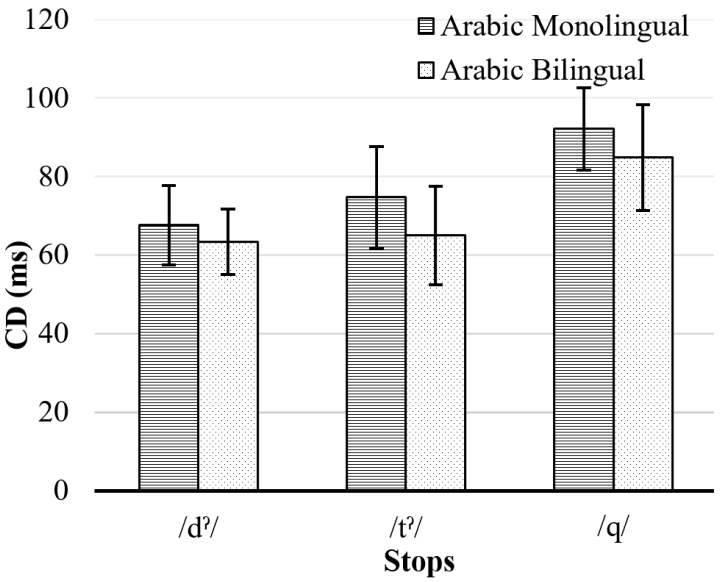

Figure 3. CDs of word-medial Arabic stops that do not belong to the English inventory for Arabic monolinguals and bilinguals.

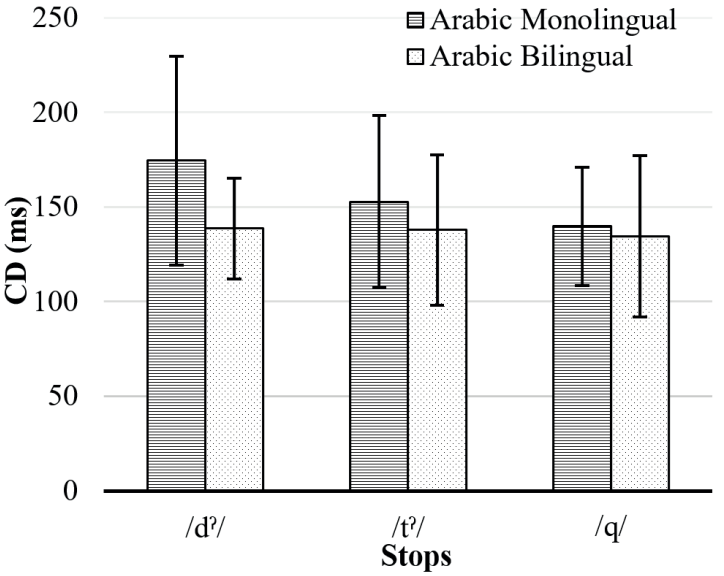

Figure 4. CDs of word-final Arabic stops that do not belong to the English inventory for Arabic monolinguals and bilinguals.

Table 4. Means, number of subjects, and the standard deviation for the CDs of word-medial and final Arabic stops that do not belong to the English inventory for Arabic monolinguals and bilinguals.

stops	Mono/bilinguals	Stops' position	N	Mean	Std. Deviation
tˀ	Monolingual	medial	12	153	46
	Bilingual	Medial	16	138	40
	Monolingual	Final	13	75	13
	Bilingual	Final	16	65	13
dˀ	Monolingual	medial	11	175	55
	Bilingual	Medial	15	139	27
	Monolingual	Final	12	68	10
	Bilingual	Final	15	63	8
q	Monolingual	Medial	13	140	31
	Bilingual	Medial	16	134	43
	Monolingual	Final	13	92	11
	Bilingual	Final	16	85	14

2.3. Closure Duration of Dissimilar English stops

Two English stops are not represented in the consonantal inventory of the Arabic language /p, g/. The results revealed that bilinguals failed to produce the English voiced velar /g/ without significant differences in the CD from English monolinguals. Instead, they had longer CDs than native English speakers in both word-medial ($p<0.0001$, MD= 72 ms) and final ($p< 0.0001$, MD= 71.6 ms) positions. Likewise, the voiceless bilabial /p/ in the word-medial position was also produced with a significantly longer CD than that of English monolingual ($p= 0.05$, MD= 38). However, the differences in the CD for word-final /p/ were not significant ($p= 0.066$, MD= 38 ms). Thus, the bilinguals generally failed to acquire a nativelike /g/ and /b/ in terms of the CD. Figures 5 and 6 present the means of CD for word-medial and final English stops that do not belong to the Arabic inventory as produced by English bilinguals and monolinguals. Besides, Table 5 shows the means, the number of subjects, and the standard deviation of the CD in the word-medial and final positions for these sounds.

Table 5. Means, number of subjects, and the standard deviation for the CDs of word-medial and final English stops that do not belong to the Arabic inventory for English monolinguals and bilinguals.

stops	Mono/bilinguals	Stops' position	N	Mean	Std. Deviation
g	Bilingual	medial	16	86	15
	Monolingual	Medial	15	51	13
	Bilingual	Final	16	163	33
	Monolingual	Final	15	91	21

stops	Mono/bilinguals	Stops' position	N	Mean	Std. Deviation
p	Bilingual	medial	14	97	13
	Monolingual	Medial	15	85	13
	Bilingual	Final	16	185	35
	Monolingual	Final	14	147	64

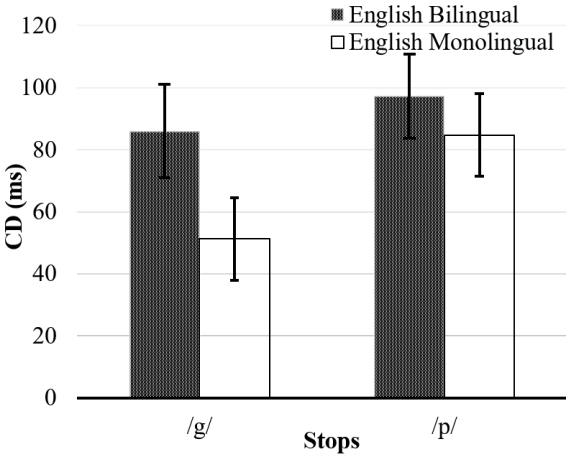

Figure 5. CDs of word-medial English stops that do not belong to the Arabic inventory for English monolinguals and bilinguals.

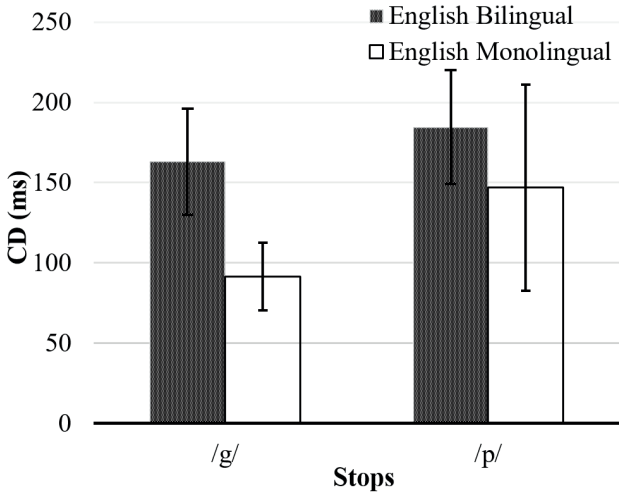

Figure 6. CDs of word-final English stops that do not belong to the Arabic inventory for English monolinguals and bilinguals.

2.4. Discussion

In this paper, we used CD as a feature to estimate the "nativeness" and "accentedness" of stop consonants in L1 (Arabic) and L2 (English) produced by Arabic-English bilinguals. The complicated L1-L2 interactions were categorized into four varieties that fluctuate within "accentedness" and "nativeness". In this study, the interaction of stops' CD represented all of the four possibilities of language interaction as proposed by (Antoniou *et al.* 2011).

First, the CD of /b/, /d/, and /t/ in both word-medial and final positions was produced with a foreign accent in L2 because of the unidirectional effect of L1 on L2. Besides, /p/ in medial position and /g/ in medial and final positions were also produced with a foreign accent regarding the CD due to the effect of L1.

The second type is the bidirectional contact that arose when Arabic and English affect each other, resulting in interference with language. The only example of this is the CD of the voiceless velar /k/ in word-medial position, as the Arabic-English bilinguals produced it in Arabic and English with CDs that differ significantly from those of both Arabic and English monolingual speakers. The third category was the impact of L2 on L1, with L1 interference being almost free. This impact concentrated on an L1 stop (Arabic) that does not occur in the inventory of the L2 consonant. Bilinguals produced the empathic dental alveolar /tˁ/ in word-medial position with significantly shorter CD than that of Arabic monolinguals. The final category is the nativelikeness in both languages' stops without language interference in the CD. In detail, the bilinguals succeeded in keeping some of the stops without being affected by the sound system of the other language. This effect included similar sounds (i.e., the CD of final /k/), stops that are different from the L2 stops (i.e., the CD of final /tˁ/, /dˁ/, and /q/), and new L2 sounds (i.e., the CD of word-final /p/).

The findings also showed that in both similar and dissimilar stop consonants, bilinguals faced pronunciation challenges. It was difficult for bilinguals to produce a native-like CD of certain dissimilar stop consonants in both Arabic and English. These results agree with the Contrastive Analysis Hypothesis (CAH) (Lado 1957), which stated that different sounds are more difficult to be acquired. For example, bilinguals found it challenging to produce the new sounds /p/ and /g/ without significant differences from the English monolinguals. They produced /p/ in word-medial position and /g/ in word-medial and final positions with significantly longer CDs than those of the native English group. Moreover, even some Arabic (L1) dissimilar stops that do not belong to English consonant inventory were affected. For instance, the Arabic /tˁ/ in word-medial position was produced by bilinguals with significantly shorter CD than that of Arabic native speakers.

On the other hand, the results agreed with the Speech Learning Model (SLM), which considers that similar sounds are harder to be acquired (Flege 1995). In other words, bilinguals met some challenges in the production of some similar stops that belong to the consonant inventories in both Arabic and English. For example, the CD of the stops /b/, /d/, /t/ in L2 was influenced by L1 in both medial and final positions as the bilinguals produced them with longer CD than those of English native speakers. Table 6 shows the details of the interaction between L1 (Arabic) and L2 (English) CDs among the similar and the different Arabic and English stops as produced by Arabic-English bilinguals whose L1 is Arabic.

Table 6. The CD interaction of Arabic (L1) and English (L2) stops for Arabic-English bilinguals.

Stops' similarity	Stops' Word-position	L1 affects L2	L2 affects L1	Bi-directional effect	No interaction
Similar stops (Exist in L1 and L2)	Medial	/d/, /b/, /t/		/k/	
Dissimilar stops (exist in L1 only)	Medial		/tˀ/		/dˀ/, /q/
Dissimilar stops (exist in L2only)	Medial	/g/, /p/			
Similar stops (Exist in L1 and L2)	Final	/b/, /t/, /d/			/k/
Dissimilar stops (exist in L1 only)	Final				/tˀ/, /dˀ/, /q/
Dissimilar stop (exist in L2only)	final	/g/			/p/

Conclusion

In this paper, we used CD as a measurement to assess the "nativeness" and "accentedness" of L1 (MSA) and L2 (English) stops as produced by Arabic-English bilinguals. The study revealed that the difficulties of pronunciation occur in both similar and dissimilar stop consonants. Some Arabic and English dissimilar sounds were challenging for bilinguals, i.e. L2 affected L1 in the medial position of /tˀ/, and L2 affected L1 in the final position of /g/. Nevertheless, some other dissimilar stops were less difficult i.e. Arabic /tˀ/, /dˀ/, and /q/ and English /p/ in word-final position. Furthermore, bilinguals also faced difficulties in the production of some stops that belong to both Arabic and English inventories, i.e. L1 affected L2 /b/, /t/ and /d/ in both word-medial and final positions. Besides, /k/ in word-medial position was affected in both Arabic and English. The results also showed that interaction among the L1 and L2 stop sounds was complicated and categorized into four effects: First, the unidirectional influence of L1 on L2 for /b/, /d/, /t/, g/, and /p/ in word-medial position in addition to /b/, /t/, /d/, and /g/ in final position.; second, the L1-L2 interference (bidirectional interaction), i.e /K/ in word-medial position; third, the influence of L2 on L1 with no interference i.e. /tˀ/ in word-medial position, and finally, the native-like pronunciation with free L1-L2 interaction i.e. Arabic /tˀ/, /dˀ/, and /q/ in word-final position, and /k/ and /b/ in word-final position. The results of this paper allow bilingual Arabic-English speakers to develop their pronunciation in both Arabic (L1) and English (L2) by highlighting the difficulties with stop sounds' pronunciation.

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