Acoustic Analysis of Iraqi Arabic Stop Consonants

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Abstract:

This study presents a detailed acoustic analysis of Iraqi Arabic stop consonants. These sounds have been investigated but with few studies tackling their acoustic properties. The study investigates stops produced by eleven male Iraqi Arabic speakers. The target items are monosyllabic words containing long vowels with stops at two word positions, initial and final. The investigations included: 1- auditory and visual analyses of spectrograms for the realisations of stops in both word positions; 2- VOT of these stops; 3- F1 and F2 frequency at onset, midpoint and offset of vowels neighbouring the stops, compared with F1 and F2 of the same vowels produced in isolation. Results showed that: 1- in initial position, voiceless stops are realised with a burst or a number of bursts released into aspiration and/or friction before the start of the adjacent vowel, voiced stops are realised with a number of bursts and releases into the voicing of the adjacent vowel; 2- in final position, stops start with a closure followed by a release of voicing in the voiced and friction and/or aspiration in the voiceless; 3- IA has a negative VOT in voiced stops and a positive one in voiceless ones; 4- at onset and offset most stops have a lowering effect on F1 values suggesting a more close quality; at the three positions, stops have a lowering effect on F2 except for /t, d/ which show a rising effect for all positions.

<u>Key words</u>: Iraqi Arabic (IA), stop consonant, acoustic analysis, consonant realisation, VOT, formants .

دراسة فيزيائية للأصوات الانفجارية العراقية

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الملخص:
يتناول البحث الحالي تحليل تفصيلي صوتي فيزيائي للأصوات الانفجارية العراقية. تناولت بعض الدارسات السابقة لهذه الاصوات ولكن القليل منها قام بتحليلها فيزيائيا. هذه الدراسة تهدف الى تحليل لفظ الاصوات الانفجارية لاحد عشر متحدث للهجة العراقية. الكلمات قيد التحليل هي كلمات من اللهجة العراقية تتكون من مقطع واحد يكون فيها الصوت الانفجاري اما في بداية الكلمة قبل صوت العلة الطويل او في نهايتها بعد صوت العلة. تضمن البحث الجوانب التالية: ١- تحليل فيزيائي (سماعي/مرئي) لطرق لفظ هذه الاصوات ومايصاحبها من انفجارات صوتية، احتكاك و(او) هسهسة، ٢- وقت بدء الصوت الانفجاري VOT في بداية الكلمة، ٣- ترددات الفورمانتات الاول F1 والثاني F2 لأصوات العلة المجاورة لهذه الاصوات وفي المواقع الثلاثة (بداية صوت العلة، اوسطه، ونهايته) ومقارنتها مع تلك التي تنتج عن اصوات العلة في وضع منعزل عن الكلمة. اظهرت الدراسة النتائج التالية: ١- وجود انفجار واحد او انفجارات متعددة للأصوات الانفجارية الصامتة في بداية الكلمة تتبعها احتكاك او هسهسة والمجهورة منها يستمر فيها الجهر موصولا الى صوت العلة المجاور لها، ٢- في نهاية الكلمة ينتهي الصوت الجهوري بانتهاء الذبذبات الصوتية بينما ينتهي الصامت بالاحتكاك او الهسهسة، ٣- وقت بدء الصوت VOT في اللهجة العراقية سلبي للأصوات الانفجارية المجهورة وايجابي للصامتة منها، ٤- تؤثر معظم الاصوات الانفجارية بهبوط تردد الفورمانتات الاول F1 والثاني F2 عن وضعها عندما تكون بها اصوات العلة منعزلة والتي ينتج عنها صوت علة اكثر انغلاقا ماعدا في الصوتين (ب، ت) حيث ترتفع فيهما قيمة الفورمانت الثاني في جميع المواقع وينتج عنها صوت علة اكثر مفتوحا.

الكلمات المفتاحية: اللهجة العراقية، الاصوات الانفجارية، تحليل فيزيائي، انماط لفظ الاصوات، توقيت بداية التنغيم، الفورمانتات .

1. Introduction

Arabic stop consonants have been investigated but with few studies carrying out instrumental investigations such as tackling their acoustic properties, Al-Ani (1970) being the most detailed of the full set of Arabic sounds to date. Since Al-Ani, interest was mainly focused on controversial sounds such as pharyngeals, emphatics and gutturals, which tend to show differing features among Arabic dialects particularly that of Iraq. Other sounds have been investigated but mostly from a descriptive or a theory-based phonological point of view.

However, Al-Ani's (1970) study investigates Modern Arabic, or what Al-Ani calls 'Contemporary Standard Arabic', produced by the author himself as the primary informant along with a group of eight speakers from Iraq and two from Jordan. Although the study applied both acoustic and x-ray investigations, it has always been criticized for its humble acoustic analysis which Obrecht (1972: 729) describes as being "useful to readers not skilled in reading spectrograms". Accordingly, there is a necessity to carry out acoustic investigations of all sounds of IA in order to map out its sound inventory.

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2. Varieties of Arabic Found in Iraq

Arabic is spoken by Arabs in the Arab World. It is also spoken or considered important by Muslims because it is the language of the Holy Qur'an. However, Arabic countries speak three varieties of Arabic: Classical, Standard, Vernacular (also called Dialectal or Local). Classical Arabic is the language of the Qur'an and the literature of its era, as well as the literary works of the 17th and 19th centuries. It is a variety mostly learned for religious purposes but no one speaks it.

Standard Arabic, on the other hand, is a variety of Arabic understood by all Arabic speakers. This variety is also called Modern Standard Arabic (MSA) (McCarthy and Raffouli, 1964; Blanc, 1964; Versteegh, 2001). It is used in education with most educated people being able to speak and understand it. It is used in formal situations such as in radio and TV broadcasting, public speeches and sermons. Therefore, it is not usually used in everyday speech unless by a limited number of people such as religious preachers, Arabic and religion teachers, and in schools.

The third variety is the locally spoken variety particular to each country. Thus, like all other Arabic countries, Iraq has the above two varieties spoken in addition to a local dialect variety called Iraqi, or 'Mesopotamian', Arabic (see: Van Ess, 1918; O'Leary, 1925; Blanc, 1964; Jastrow, 1994; Versteegh, 2001; Alsiraih, 2013). According to Blanc (1964), this variety is divided into two types: 1- the '*gelet*' dialects, to represent those spoken by Muslim people living in Baghdad and the rest of the Southern areas of Iraq; 2- the 'qeltu' dialects, to represent those spoken by Muslims and Christians of Northern cities of Iraq and Christians of the rest of Iraq. The latter also include the speech of Jews who used to live in Iraq but fled the country after 1948. The words *qeltu* and *gelet* are derived from the word *qultu*, meaning 'to say' in the first person singular of the present perfect tense in Standard Arabic, which is used as a representative of a vast number of vocabularies containing the Arabic phoneme /q/ (Blanc, 1964). This phoneme is realised differently among each dialectal group, with [q] and [g] as the main variants. Blanc (ibid) first noted this feature in the speech of the three communities of Baghdad he investigated, i.e. Muslim, Christian and Jew; which he later noted existing in other Arabic dialects. In addition to these two types, other linguists as Ingham (1997) and Abu-Haidar (1988), along with Blanc, found more divisions of IA into sub-dialects as: Central *gelet* vs. Southern *gelet*, Bedouin vs. Sedentary, *ḥaḍar vs.ʻArab*, and *xašš* ([xɛʃ] *vs. ṭabb* ([ṭab]) meaning 'he entered' which Abu- Haidar (1988) found distinguishing between urban and rural Baghdadi speakers. For a detailed overview of all these subdivisions see Alsiraih (2013).

Journal of Basra Research for Human Sciences No. : 2 Vol. : 45 Yr. August 2020

3. Stop Consonants in Iraqi Arabic

Researchers differ in classifying Iraqi Arabic (henceforth IA) stop consonants in as far as their number, manner and places of articulations are concerned. Table (1) provides an inventory of IA stop consonants adopted from studies by Blanc (1964), Al-Ani (1970), Ghalib (1984), Mahdi (1985), Abu-Haidar (1991), Ingham (1997) and Alsiraih (2013), with disputed ones in brackets. It classifies the stop consonants as: /(p), b, (t), (d), k, q, (ʕ), **(ʡ),** ʔ/. Differences in classification of place of articulation only include the consonants /t, d/ which Blanc (1964: 17) considers them as alveolars, Ghalib (1984: xii-xiii) as denti-alveolars, and Mahdi (1985: 1) as dentals (though his description of their place of articulation suggests a denti-alveolar place as well). The sound /ʕ/ is also between brackets due to the variety of descriptions this sound has showed whether in manner of articulation (stop, fricative, approximant) or place of articulation (pharyngeal /ʕ/, epiglottal /ʡ/), as well as it being at the centre of debate by researchers on different languages. In fact, a more recent study by Alsiraih and Ali (2019) found /ʕ/ showing a prevalence of voicelessness across all three manners of articulation depending on its position in the word (with more being in final position). However, having a stop realisation, in particular, of the sound /ʕ/ in IA is identified as being: a voiceless stop in final position by Al-Ani (1970); a voiceless stop in both initial and final word-positions by Alsiraih (2013) (also see Mahdi, 1985); followed by a stop articulation in final position (Butcher and Ahmad, 1987: 170); or is an epiglottal stop [ʡ] (Esling, 1999; Esling, 2005; Edmondson et al, 2005; Edmondson et al, 2007; Hassan et al., 2011; Kattab et al., 2018). For these variations of /ʕ/, particularly that it being a stop is hitherto being disputed; the present study will not include it among the investigated stops. Therefore, researchers of IA agree on classifying stop consonants as being primary stop sounds: /b, t, d, k, g, q, ʔ/, and as follows.

Table 1: Classification of the Iraqi Arabic stop consonants

	Bilabial	Dental	Denti-alveolar	Alveolar	Velar	Uvular	Pharyngeal	Epiglottal	Glottal
Stops	(p) b	(t) (d)	(t) (d)	(t) (d)	k	q	(ʕ)	(ʡ)	ʔ

/b/ (ب): This phoneme is realised in two ways: as a voiced bilabial stop [b], e.g. [bɛ:ʕ] ‘selling’ of standard /beɪʕ/; and as a voiced pharyngealised bilabial stop [bˤ], e.g. [bʊqa:] ‘he stayed’ of standard /baqa:/. It is also produced as a realisation of the non-Arabic voiceless bilabial stop phoneme /p/ as [b] in loanwords from Persian, Turkish and European origin and borrowed into IA, which is mostly noted in the speech of urban Baghdadi speakers or are from Baghdadi origin living in other areas of Iraq;

whereas speakers living in rural Baghdadi, in northern cities or in Southern Iraqi cities (urban and rural) use [b], e.g. [pu:ʃi] 'veil' and [parda] 'curtain' which is also produced as [bu:ʃi] and [barda], respectively.(1)

/t/ (2) (ت): This consonant has been described as a voiceless denti-alveolar, alveolar and dental stop which is accordingly realised as [t] or [t̪], e.g. [ta:li] 'later' of standard /fi:ma baʕd/. According to the researcher's own pronunciation, being an IA speaker herself, /d/ requires touching the inner part of the teeth plus the beginning of the alveolar-ridge, which makes it denti-alveolar.

/d/ (د): This is described as a voiced denti-alveolar, alveolar and dental stop and accordingly realised as [d] or [d̪], e.g. [dixʌl] (as produced by Southern Iraqis) or [daxal] (as produced by Central Iraqis) meaning 'he entered' of the standard /daxala/. Similar to /t/, the researcher also pronounces this stop as denti-alveolar.

/k/ (ك): This is a voiceless velar stop. However, this phoneme is realised as both [k], a voiceless velar stop, and [tʃ], a voiceless palato-alveolar affricate, e.g. [ka:n] and [tʃa:n] of the standard /ka:na/ 'he was' (Blanc, 1964: 27). Speakers would produce both realisations interchangeably. In other words, speakers might use one or the other but never both, e.g. [kabis] which is used to mean 'stapling paper together', and [tʃabis] which is used to mean 'stacking stuff together, such as dates'; both of the standard /kabs/. However, according to Abdul-Hassan (1988: 173), /tʃ/ is a vernacular feature of IA associated with front vowels; while /k/ would be retained with back vowels.

/**q/ (ق):** This is usually described as a voiceless uvular stop, but considered by Al-Ani (1970) as a voiceless unaspirated uvular stop (also see: Abdul-Hassan, 1988: 172). This phoneme is one of the most studied phonological variables in Arabic due to its important phonetic distinguishing feature between Arabic dialects. In IA, it is preserved in the dialect spoken by Christians (see Abu-Haidar, 1991) but is mainly

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(1) The consonant /p/ does not belong to the Arabic inventory of phonemes and is only common in loanwords. It is realised as [p] by some speakers of urban areas mostly Baghdad. However, none of the 11 speakers participating in the present study uses [p] in their speech neither do they aim to target it, even in words of non-Arabic origin. Therefore, this sound was not included in the analysis of the data.

(2) This study adopts the view that emphatic consonants in IA are pharyngealised (Al-Ani, 1970; Hassan and Esling, 2007; Hassan et al, 2011), which is why the consonants /tˤ, dˤ/ have not been investigated.

realised as [g] [(3)] (a voiced velar stop) and sometimes [k] by dialects spoken by Muslims (see Blanc, 1964), though it is also common to preserve the standard /q/ in standard and religious words plus those of common nouns. Examples of words preserving [q] vs the realisation [g] is Christian [qa:l] 'he said' and Muslim [ga:l]; and of words with the realisation [k] is the Muslim Baghdadi [waket] and [ketal] of standard and Christian [waqet] 'time' and [qetal] 'he killed', respectively (Blanc, 1964; Abu-Haidar, 1991). From a personal viewpoint, the researcher uses (/waqıt/, /wakıt/) and (/qıtal/, /kıtal/) interchangeably despite her being a Muslim from Southern Iraq.

/ʔ/ (ˈ): This is a glottal stop, e.g. [ʔɛkıl] 'food' of standard /ʔakl/. In IA it is only realised as [ʔ] of standard Arabic /ʔ/. However, there are cases where speakers of IA would produce it even if the standard does not contain it, e.g. [ınkıtba] of standard /naktubuhu/ 'we write it'; whereby the [ʔ] is added to the beginning of the word.

4. Acoustic Properties of Iraqi Stops

The acoustic measurements carried out on consonants in general are: the duration of the consonant, $F1/F2$ formant frequencies of the adjacent vowels, and voicing. For stop consonants, voicing is measured depending on the start of voicing in relation to the closure/release phases of the consonant. This is called voice onset time (VOT for short). However, to the knowledge of the researcher no research has been done to address this feature in IA. The only detailed acoustic analysis of Arabic stop consonants is that of Standard Arabic by Al-Ani (1970). Al-Ani does not refer to VOT but measures it when determining the duration of voicing of stop consonants. This section will present Al-Ani's description of the first two acoustic measurements (duration and $F1/F2$), while VOT will be discussed in the next section. Al-Ani's results will be compared to the results of the present study. [(4)]

/b/: The most common allophone of /b/ is a voiced bilabial unaspirated stop (Al-Ani, 1970: 31). Its voicing appears on the spectrogram with a duration of 60 to 110 ms. In initial position, it influences onsets of vowel /i:/ by lowering their $F2$ to 1600-1700Hz; it only slightly lowers $F2$ of /a:/; and does not affect that of /u:/ at all (ibid).

/t/: The most common allophone of /t/ is a voiceless dental aspirated stop (Al-Ani, 1970: 44). On the spectrogram it appears as a burst seen as a vertical spike followed

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(3) Due to the fact that the realisation [g] is a common feature of IA and of the *gelet* dialectal group; therefore, this sound was included in the data selection and considered as one of the stop sounds of IA despite it not being a phoneme of Standard Arabic. It was not among the stop consonants investigated by Al-Ani (1970) which was on Standard Arabic.

(4) Although Al-Ani's (1970) work investigated the productions of Iraqi speakers but it was done on Standard Arabic; therefore /g/ was not included among the phonemes he investigated.

by a gap with weak noise; the duration of the burst is 40-60 msec. increasing near long vowels. In final position, the gap also increases before the release up to 150-200 ms. Initially, /t/ influences onsets of vowel /i:/ by lowering its *F*2 from 2200Hz (steady state) to 1900-2000Hz; onsets of *F*2 of vowel /u:/ rise sharply from 750-800Hz (steady state) to 1400Hz; and onsets of *F*2 of vowel /a:/ tend to be lower at about 1300-1350Hz (ibid).

/d/: The most common allophone of /d/ is a voiced dental unaspirated stop (Al-Ani, 1970: 46). For Al-Ani (ibid), /d/ has a similar appearance on the spectrogram as that of /t/ but with an addition of a voice bar and lack of aspiration. It tends to also have the same effect on formants of nearing vowels as that of /t/.

/k/: The most common allophone of /k/ is a voiceless velar aspirated stop, but with a palatalised allophone [k'] near vowel /i:/(Al-Ani, 1970: 32). On the spectrogram it appears as a burst in a form of a spike followed by friction noise. The burst also has a random noise with a duration from 60 to 80 ms. However, near vowel /i:/ that burst tends to concentrate at frequency ranges of 2500-3000Hz, with few lower than 2000; near vowel /u:/ the burst concentrates at 1000Hz but both burst and noise disappear above 1200Hz; while near vowel /a:/ the concentration of the burst is between 2000 and 2200Hz. Formant frequencies of these vowels are also affected and as follows: the onsets of *F*2 near /i:/ tend to be lowered to 2000Hz; but with the onsets of *F*2 of vowel /u:/ being unaffected.

/q/: The most common allophone of /q/ is a voiceless uvular unaspirated stop (Al-Ani, 1970: 32). It appears on the spectrogram as a strong burst in the form of a vertical spike starting weak at the baseline and rises up to 3000Hz. Following the burst is a silence gap with a duration of 30-40 ms. No noise follows the spike indicating lack of aspiration. Formant frequencies of vowels nearing /q/ tend to be affected as follows: onsets of *F*2 near vowel /i:/ tends to lower from 2200Hz to 1600Hz; onsets of *F*1 near /q/ are also affected with a slight rise; and onsets of *F*2 of vowel /u:/ tend to also rise to 900Hz.

/ʔ/: In initial position it appears in many forms and "seems to be very unstable and does not set any definite pattern", thus being in one of the following forms: as a burst followed by a silence gap with a duration of 15-20 ms; as a burst followed by a weak noise; as a short glide which starts the vowel formants of the neighbouring vowel (Al-Ani, 1970: 60-61). In the vowel /i:/, the concentration increases at 2000-2600Hz whereby formants *F*1, *F*2 are barely affected and within the ranges: 280-300Hz, 2000-21500Hz, respectively. In the vowel /u:/, there is no burst and only a weak glide starting the vowel formants as: *F*1 between 280-300Hz, *F*2 between 750-825Hz. In the vowel /a:/, consonant /ʔ/ is seen as a burst with a duration of 20-30 ms and a concentration of being in the region of *F*2 as 1350-1500Hz, with the measures: 600-675Hz, 1300-1400Hz, as *F*1and *F*2, respectively. In final position, /ʔ/ is noted as a burst in the form of a vertical line which may or may not be followed by a weak noise (ibid: 62). Before the burst, there is a silence gap with a duration of 180-200 ms. In this position, the formant frequencies of the neighbouring vowels are similar to those in initial position.

5. Voice Onset Time (VOT)

Voice Onset Time or what is commonly known as VOT for short is an acoustic measure applied to stop consonants in initial position before the onset of the vowel, as is indicated by its term. Lisker and Abramson (1964) were the first to propose an acoustic measure that differentiates stop consonants of different voicing categories. In that study, and in their later study of Abramson and Lisker (1972), they defined VOT as being "the temporal relation between the onset of glottal pulsing and acoustic features of supraglottal articulation." In other words, it is the time when the voicing starts in relation to the release of the closure for stop consonants (Tamim, 2017); or "the time from energy onset to the onset of the first detectable glottal pulse" (Repp and Lin, 1988: 26). It therefore measures the time span between the release of the sound and the beginning of the vibration of the vocal cords.

The purpose of Lisker and Abramson's (1964: 389) study was to investigate how well VOT "serves to separate the stop categories of a number of languages in which both the number and phonetic characteristics of such categories are said to differ"; whereby attention was limited to word-initial position before vowels. The 11 languages in their study show that the stop consonants are divided into three categories: 1- those which have a zero 0 VOT whereby the vibration occurs immediately after the release, this usually happens in voiced sounds; 2- those which have a positive +VOT whereby the vibration occurs after a short delay following the release, this usually happens in voiceless sounds; 3- the third category also includes voiced sounds but with the vibration occurring before the release of the sound, and therefore has a negative –VOT (also see: Abramson and Lisker, 1972; Alghamdi, 1990; Rifaat, 2003; Carroll, 2008; AlDahri and Alotaibi, 2010; Alotaibi and AlDahri, 2011; AlDahri, 2012; Tamim, 2017; Olson, 2017).

Lisker and Abramson's (1964) findings show that the different languages are similar for voiceless sounds, with all having positive VOTs, but differ in their voiced consonants. Therefore, they (ibid) divided languages into two groups depending on the type of VOT of voiced consonants: 1- those with all consonants having +VOT; 2- those with voiced consonants having –VOT. This result was further confirmed in

Abramson and Lisker (1972: 3) which they summarised by stating that "negative numbers are assigned to lead voicing and positive to lag, while the moment of stop release is labelled zero."

Lisker and Abramson (1964) also found that the VOTs of voiced consonants are always shorter than those of voiceless consonants whether the former were positive of negative. Voiced stops have negative VOT because the vocal folds vibrate during the closure interval before the release of the closure (voicing lead) whereas voiceless stops have positive VOT as the vibration of the vocal folds is delayed after the release of the stop closure (voicing lag). If the vibration of the vocal folds takes place at the time of the closure release, VOT is zero (Alghamdi, 1990; Tamim, 2017). Alghamdi's (1990: iii) results on Saudi Arabic also show that the closure intervals of the initial stops were found to be shorter than those of the voiceless ones. Accordingly, depending on the language under investigation, if the voiced stops have a negative –VOT, its length tends to be short; and that of voiceless stops of those languages is of medium-length positive. This is due to the fact that a voiced consonant has a glottal vibration during its entire production in addition to the period preceding the burst denoting its VOT. On the other hand, in other languages where both voiced and voiceless stops have positive +VOTs, the length of the VOT is shorter for voiced consonants than for voiceless ones.

As is earlier noted, previous studies investigated VOT in a number of Arabic dialects. These studies include Saudi Arabian in Alghamdi (1990), Egyptian in Rifaat (2003), Jordanian and Saudi in Alotaibi & AlDahri (2011), and Modern Standard and Classical Arabic in AlDahri & Alotaibi (2010) and AlDahri (2012). Phonetic categories of voicing in relation to VOT in Colloquial Egyptian Arabic show a pattern of long lead for the voiced stops versus short lag for the voiceless ones (Rifaat, 2003: 791). The results of the production experiment on the Palestinian Arabic dialect show it having negative VOT for voiced stops and short positive VOT for voiceless stops (Tamim, 2017). Their findings on these Arabic varieties showed them to be members of the first group, with mostly positive +VOTs. The only exceptions are: Lebanese Arabic, investigated by Yeni-Komshian et al. (1977), showing negative –VOTs for /b/ and /d/; and Palestinian Arabic, investigated by Tamim (2017), whereby all of its voiced stops showed a negative –VOT. This makes Lebanese belonging to both groups, while Palestinian belonging to the second. However, the only previous study up to date that has conducted to measure the voicing of stop consonants in IA is that of Al-Ani (1970), whereby he does not mention VOT and only refers to the length of the voicing. Therefore, the present study will investigate VOT in IA stop consonants.

Journal of Basra Research for Human Sciences   No. : 2   Vol. : 45   Yr. August 2020

6. Participants

Eleven Iraqi male speakers, aged 30-55 years old, were recorded producing the test-words. Speakers were seated in front of a high-quality recorder (Type: Edirol R09) with an internal microphone. In front of the speaker was a computer screen showing the power-point slides. Because each slide only contains one sentence, the researcher controlled moving on to the next slide after making sure that the speaker had produced the target words in the proposed manner. Finally, the recordings were subject to acoustical analysis using PRAAT (version 6.0.30).

7. Data Collection

11٠ target words containing stop consonants were selected for the purposes of this study and distributed as follows: 6٤ words beginning with a stop, 66 words ending with a stop; among these words, 2 had stops in both word-positions. They are all real colloquial IA words of the CVC type syllable structure, where (V) is one of a set of long vowels / iː, ɛː, ɑː, uː, ɔː/, and the stop consonants /b, t, d, k, g, q, ʔ/ are either in initial, in final or in both word positions (table 2). The words were put in a carrier sentence '*guulu* ____ *sit marrat*' /gu:lu ____ sɪt marra:t/ (meaning: *say* _______ *six times*). Speakers were also asked to produce the vowels of the same words in isolation within the same carrier sentence for purpose of comparison with productions of the vowels within words.

Table 2: The list of target words

No	Item		Trans.	No	Item		Trans.	No	Item		Trans.	No	Item		Trans.
1	إيد	2iid	ʔi:d	33	قيس (امر)	qiis	qi:s	65	توب (امر)	tuub	tu:b	97	شيك	sheek	ʃɛ:k
2	عيب	3eeb	ʕɛ:b	34	شاب	shaab	ʃa:b	66	هيت	heet	hɛ:t	98	شيك	shiik	ʃi:k
3	عيد	3iid	ʕi:d	35	شيب	sheeb	ʃɛ:b	67	هيت (امر)	hiit	hi:t	99	شوگ	shoog	ʃɔ:g
4	حاد	7aad	ħa:d	36	تاب	taab	ta:b	68	كان	kaan	ka:n	100	شوك	shook	ʃɔ:k
5	حوك	7ook	ħɔ:k	37	توب	tuub	tu:b	69	كاس	kaas	ka:s	101	سوق	sooq	sɔ:q
6	باع	baa3	ba:ʕ	38	خاب	Xaab	xa:b	70	كيف	keef	kɛ:f	102	سوگ	suug	su:g
7	باب	baab	ba:b	39	زاد	zaad	za:d	71	كيك	keek	kɛ:k	103	سوق (امر)	suuq	su:q
8	بان	baan	ba:n	40	اخ	2aax	ʔa:x	72	كيل (امر)	keel	kɛ:l	104	تاء	taa2	ta:ʔ
9	بات	baat	ba:t	41	اوف	2oof	ʔɔ:f	73	كيت	keet	kɛ:t	105	ثاء	thaa2	θa:ʔ
10	بين	been	bɛ:n	42	حوك (امر)	7uuk	ħu:k	74	كيل (امر)	kiil	ki:l	106	تيه (امر)	tiih	ti:h
11	بيت	beet	bɛ:t	43	باء	baa2	ba:ʔ	75	كيس	kiis	ki:s	107	تيم	tiim	ti:m
12	بيع	bii3	bi:ʕ	44	باگ	baag	ba:g	76	كود	kood	kɔ:d	108	تين	tiin	ti:n
13	بوش	boosh	bɔ:ʃ	45	بوگ	boog	bɔ:g	77	كوم	koom	kɔ:m	109	توب	toob	tɔ:b
14	بوم	buum	bu:m	46	بوء	buu2	bu:ʔ	78	كون	koon	kɔ:n	110	توم	toom	tɔ:m
15	بوت	buut	bu:t	47	بوگ (امر)	buug	bu:g	79	كوب	kuub	ku:b				
16	بوز	buuz	bu:z	48	بوق	buuq	bu:q	80	كوس	kuus	ku:s				
17	داس	daas	da:s	49	چيك	cheek	tʃɛ:k	81	لاء	laa2	la:ʔ				
18	داخ	daaX	da:x	50	ضاء	dhaa2	dˤa:ʔ	82	ليق (امر)	liiq	li:q				
19	ذيب	dhiib	ði:b	51	ضيء (امر)	dhii2	dˤi:ʔ	83	لوگ (امر)	luug	lu:g				
20	دين	diin	di:n	52	ضوء	dhoo2	dˤɔ:ʔ	84	موگ	muug	mu:g				
21	دوم	doom	dɔ:m	53	فاق	faaq	fa:q	85	نوء (امر)	nuu2	nu:ʔ				
22	دوب	duub	du:b	54	فوگ	foog	fɔ:g	86	قاف	qaaf	qa:f				
23	دود	duud	du:d	55	گال	gaal	ga:l	87	قاس	qaas	qa:s				
24	دون	duun	du:n	56	گام	gaam	ga:m	88	قيد	qeed	qɛ:d				
25	دوش	duush	du:ʃ	57	گير	geer	gɛ:r	89	قير	qiir	qi:r				
26	دوس	duus	du:s	58	غاگ	ghaag	ɣa:g	90	غيب (امر)	qiis	ɣi:b				
27	غاب	ghaab	ɣa:b	59	گير	giir	gi:r	91	قوس	qoos	qɔ:s				
28	غيب	gheeb	ɣɛ:b	60	گول	gool	gɔ:l	92	قود (امر)	quud	qu:d				
29	مات	maat	ma:t	61	گوم	goom	gɔ:m	93	راگ	raag	ra:g				
30	موت	moot	mɔ:t	62	گول (امر)	guul	gu:l	94	ريت	reet	rɛ:t				
31	نوب	nuub	nu:b	63	گوم (امر)	guum	gu:m	95	ريگ	riig	ri:g				
32	قاس	qaas	qa:s	64	هاك	haak	ha:k	96	ساق	saaq	sa:q				

Journal of Basra Research for Human Sciences No. : 2 Vol. : 45 Yr. August 2020

Measurements were carried out on three vowel portions (onset, midpoint, offset) to track changes at different positions, and for the following reasons: 1- at midpoint to reduce consonant influence (Trittin and Lleo, 1995) during what is presumed to be the most steady-state portion of the vowel whereby reducing the influence of voicing of neighbouring consonants (Klatt and Klatt, 1990: 829); 2- midpoint is also where the formants of vowels undergo “the least frequency shift between surrounding consonants” (Dickson, 1962: 105); 3- at onset and offset to examine the amount and direction of influence of the neighbouring consonants.

8. Segmentation

Before applying any acoustical analysis, recordings were manually segmented. Both auditory and visual information were taken into account when deciding segmental boundaries, and as follows. When the stop consonant is in initial position, the transitional portions were considered to belong to the following vowel and not the consonant, but not including any aspiration or friction of that consonant. Therefore, the beginning of a vowel would be from the first pulse of vibration indicating the start of voicing, in addition to the change of intensity which at that portion of the vowel tends to ascend to a certain level and stays stable until the end of the vowel. Accordingly, the end of the vowel would be where intensity decreases and voicing ends.

9. Analysis of Results

The analysis of the acoustic results will be presented as follows: the realisations of the stop consonants in both initial and final positions; VOT in initial position; *F*1/*F*2 changes at (onset, midpoint and offset) of the adjacent vowel in both (initial and final) positions of the stop consonants, in comparison to those of isolated vowels.

9.1 Realisation of Stop consonants (Initial Position)

/b/: In this position, /b/ is realised as having vibration starting before the closure and release phases, which are in turn immediately followed by the voicing of the adjacent vowel with no aspiration or friction in between (fig. 1).

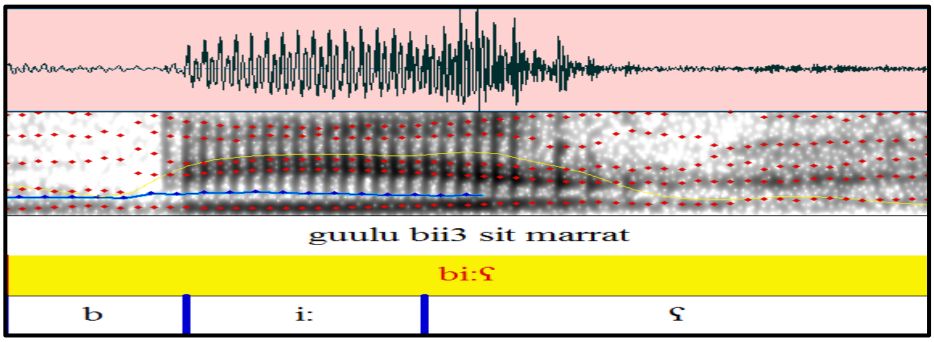


Fig. 1: The stop consonant /b/ in initial position in the word /bi:ʕ/ ‘sell’ produced with a long closure followed by a release; voicing is noted throughout the entire sound and continues into the adjacent vowel.

/t/: The realisation of /t/ shows a burst or a number of bursts released into aspiration and/or friction before the start of the adjacent vowel. Voicing does not occur during these phases and is only noted with the start of the vowel (fig. 2).

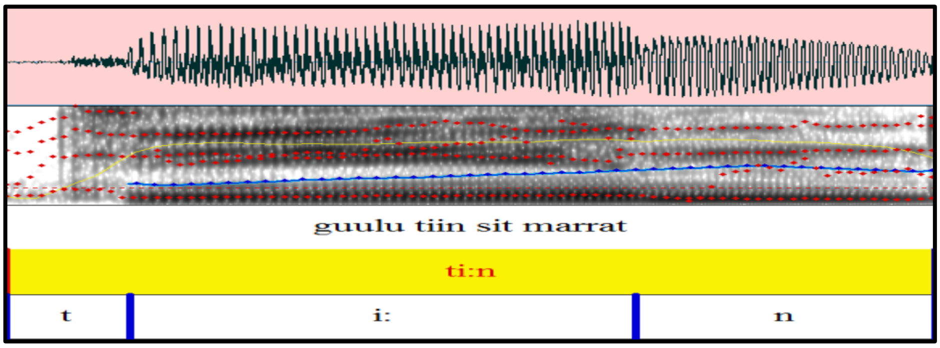


Fig. 2: The stop consonant /t/ in initial position in the word /ti:n/ 'fig' produced with a release followed by aspiration; as noted there is no voicing during the entire sound which does not start until the beginning of the adjacent vowel.

/d/: In this position, /d/ is realised similar to /b/ as having vibration starting before the closure and release phases and continues into the vowel. However, some productions of /d/ included slight aspiration following the release and before the start of the vowel (fig. 3).

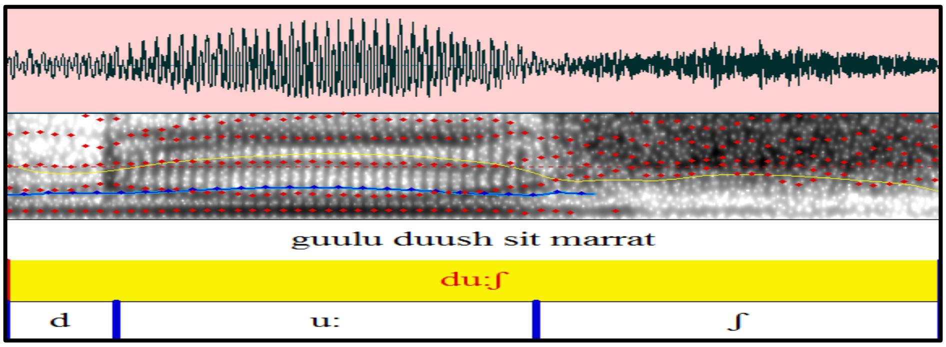


Fig. 3: The stop consonant /d/ in initial position in the word /du:ʃ/ 'shower' produced with a long closure followed by a release; voicing is noted throughout the entire sound and continues into the adjacent vowel.

/k/: The realisation of /k/ shows one or more releases (bursts) followed by a long aspiration and/or friction before the start of the adjacent vowel. Voicing does not occur during these phases and is only noted with the start of the vowel (fig. 4).

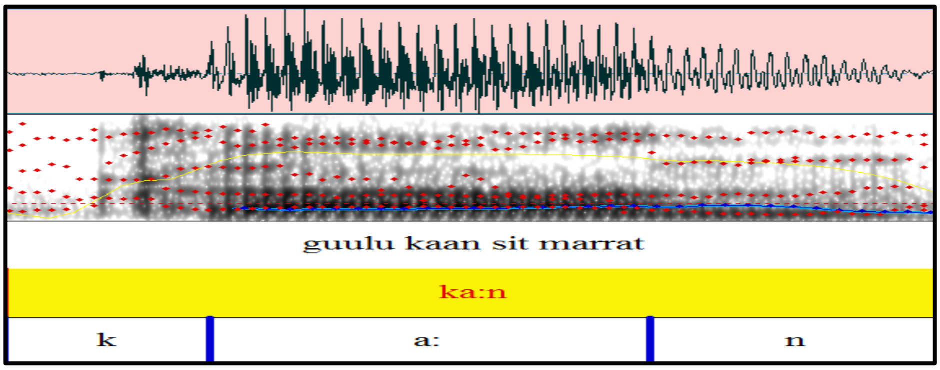


Fig. 4: The stop consonant /k/ in initial position in the word /ka:n/ 'was' produced with a closure followed by two bursts released into aspiration; there is no voicing during the entire sound which does not start until the beginning of the adjacent vowel.

Journal of Basra Research for Human Sciences No .: 2 Vol.: 45 Yr. August 2020

/g/: In this position, /g/ is realised with a number of closures (bursts) and releases, which are followed by the voicing of the adjacent vowel. However, although voicing starts before the closure and continues into the vowel, there are instances of aspiration and friction between bursts and before the start of the vowel (fig. 5).

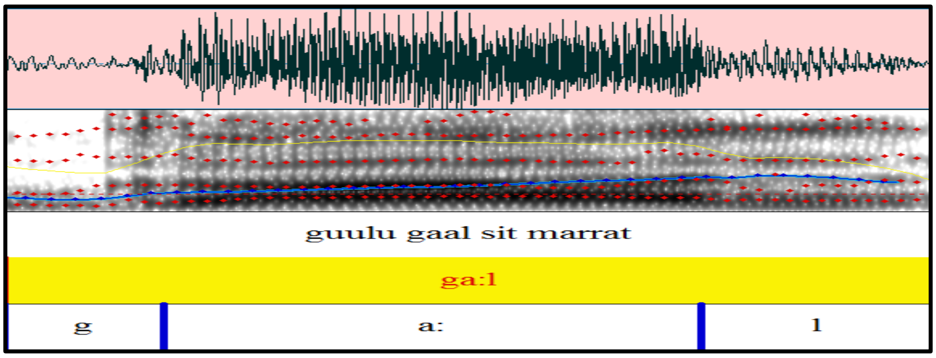


Fig. 5: The stop consonant /g/ in initial position in the word /ga:l/ 'he said' produced with a closure followed by two bursts released into aspiration before the adjacent vowel; there is voicing during the entire sound which continues during the aspiration and into the adjacent vowel.

/q/: In this position, /q/ is realised with a release or a number of releases with no voicing preceding or during its production until the start of the adjacent vowel. The release is also followed by aspiration and/or friction which vary in length. It is also noted that there is a slight creak at the onset of the adjacent vowel in effect of the production of /q/ (fig. 6).

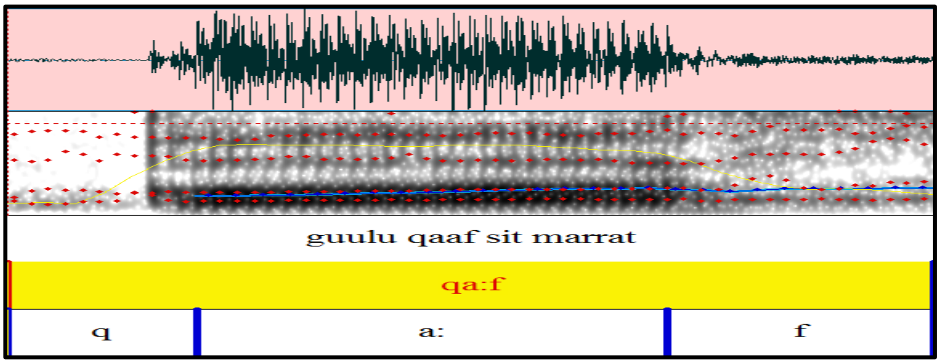


Fig. 6: The stop consonant /q/ in initial position in the word /qa:f/ 'the letter q' produced with a closure followed by two bursts released into the adjacent vowel; there is no voicing during the sound but also no aspiration or friction and voicing starts with the start of the adjacent vowel.

/ʔ/: In this position, /ʔ/ is similarly realised as voiced sounds /b/ and /d/with a closure and release which is immediately followed by the voicing of the adjacent vowel. However, there is no voicing before the closure (fig. 7).

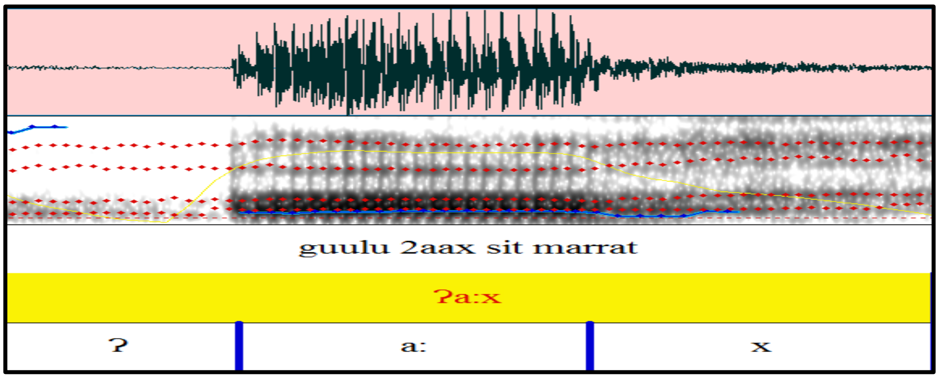


Fig. 7: The stop consonant /ʔ/ in initial position in the word /ʔa:x/ 'ouch' produced with a long closure followed by a release into the adjacent vowel; there is no voicing during the entire sound which does not start until the beginning of the adjacent vowel.

9.2 Realisation of Stop consonants (Final Position)

/b/: In this final position, /b/ is mostly produced with no heard or visible burst/release but where the voice bars of the preceding vowel suddenly disappear leaving only the voicing bar in the bottom which continues until the end of the production of the consonant. When a speaker starts producing /b/ there is a gap which represents the stop or hold phase which continues the voicing. There is no visible or heard friction or aspiration but there is a burst or release at the end which is heard as a click (fig. 8).

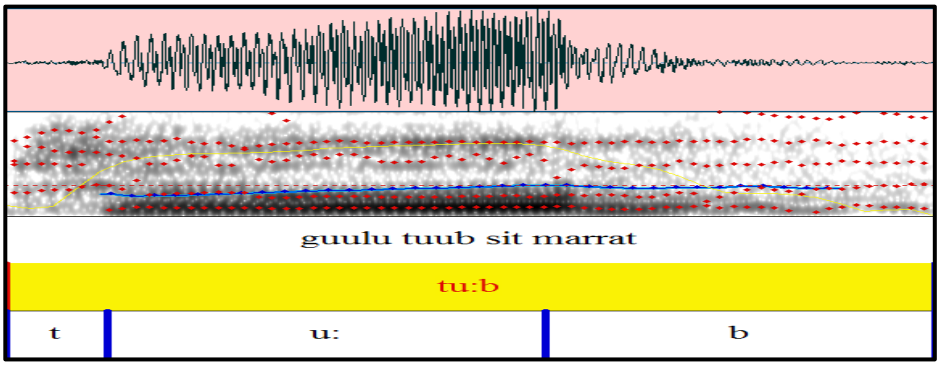


Fig.8: The stop consonant /b/ in final position in the word /tuub/ 'repent' produced with a closure followed by two heard but non-visible bursts; there is voicing during the consonant which continues that of the preceding vowel.

/t/: In this final position, when the closure of /t/ is produced the voice bars of the preceding vowel suddenly disappear leaving a gap representing the stop or hold phase of the closure which is usually longer than it is in initial position and showing no voicing. There is a burst/release or more after the gap followed by aspiration and/or friction (fig. 9).

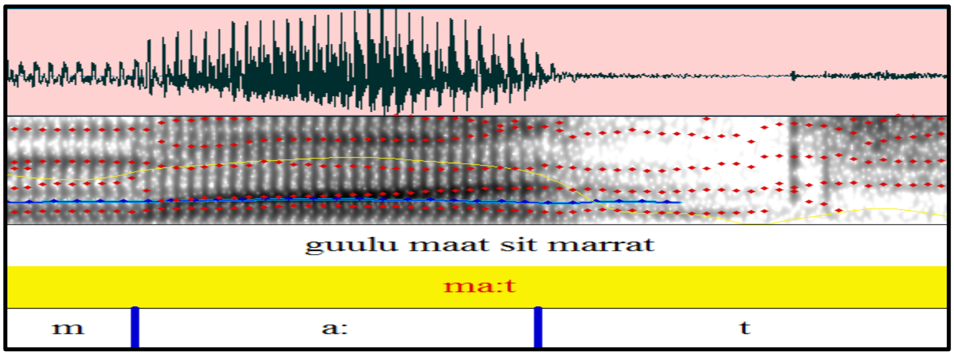


Fig.9: The stop consonant /t/ in final position in the word /ma:t/ ‘he died’ produced with a long closure followed by two bursts released into friction; there is no voicing during the sound.

/d/: In this position, /d/ is produced similar to /t/ with the addition of a voice bar at the bottom during the closure phase. This is a long gap where the air is held where the voice bars of the preceding vowel suddenly disappear leaving only one voicing bar at the bottom. However, differing from the voiced /b/, /d/ is similar to the voiceless /t/ in its release having a burst/release or more after the gap followed by aspiration or/and friction. This indicates that the voiced stops in final position are released similarly to their voiceless counterparts. This is due to it being at the end of the word and not followed by a vowel (fig. 10).

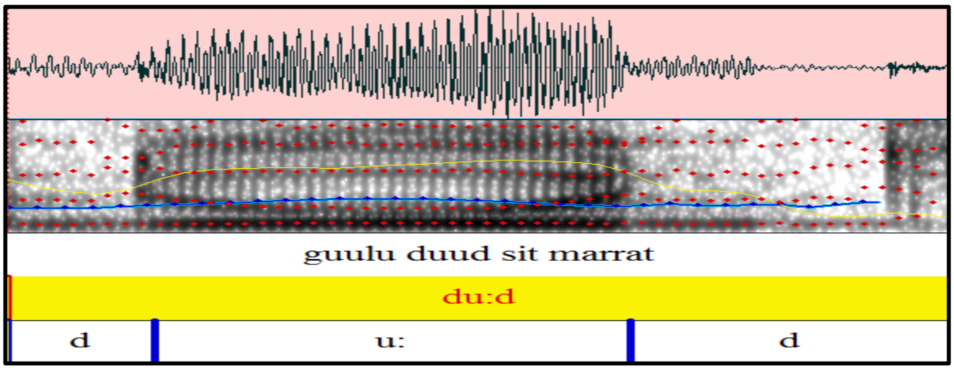


Fig.10: The stop consonant /d/ in final position in the word /du:d/ ‘ants’ produced with a closure followed by two bursts released into a slight friction; there is voicing during the sound which continues until the end of its production even through the friction.

/k/: In this final position, /k/ is produced similarly to /t/ with the voice bars of the preceding vowel suddenly disappearing leaving a gap representing the closure phase of the stop which is usually longer than it is in initial position and showing no voicing. There could be a burst/release or more after the gap followed by aspiration or/and friction (fig. 11).

Journal of Basra Research for Human Sciences No. : 2 Vol. : 45 Yr. August 2020

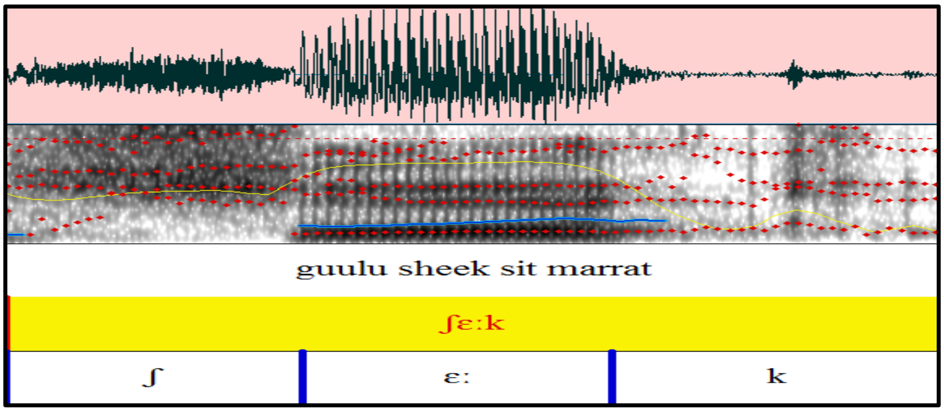


Fig.11: The stop consonant /d/ in final position in the word /ʃɛ:k/ 'a cheque' produced with a closure followed by a burst released into another short closure followed by another release into a slight aspiration and another closure/release; there is no voicing during the entire sound.

/g/: In final position, /g/ is realised similar to /k/ whereby the voice bars of the preceding vowel suddenly disappear leaving a gap representing the closure phase of the stop, which is usually longer than it is in initial position. There is also a burst/release or more after the gap followed by aspiration and/or friction. However, /g/ differs from /k/ in that the former continues the voicing of the preceding vowel until the end of its production. In certain instances where there is aspiration/friction, there are short instances of devoicing (fig. 12).

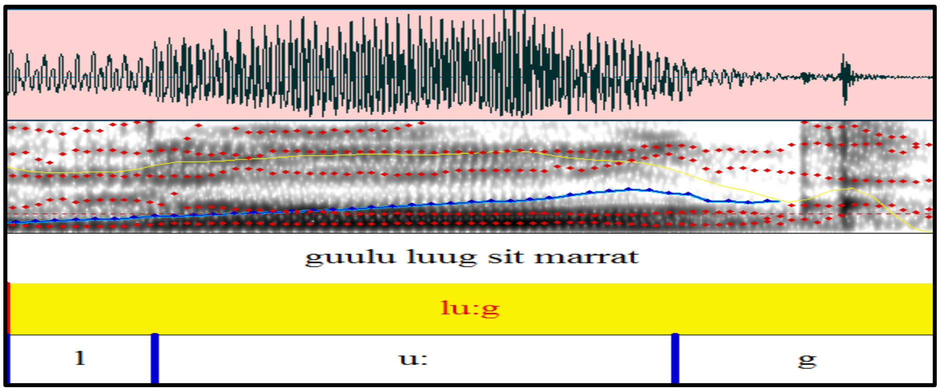


Fig.12: The stop consonant /g/ in final position in the word /lu:g/ 'it suits' produced with a closure followed by a burst released into aspiration and another burst released into friction; there is voicing during the entire sound which fades slightly in some instances during the second release.

/q/: In final position, /q/ is realised with the voice bars of the preceding vowel suddenly disappearing and having a number of bursts at the start of the consonant and/or at its end. The closure phase of the stop is usually longer than it is in initial position and there is aspiration and/or friction at the start of the consonant and/or following the releases (fig. 13).

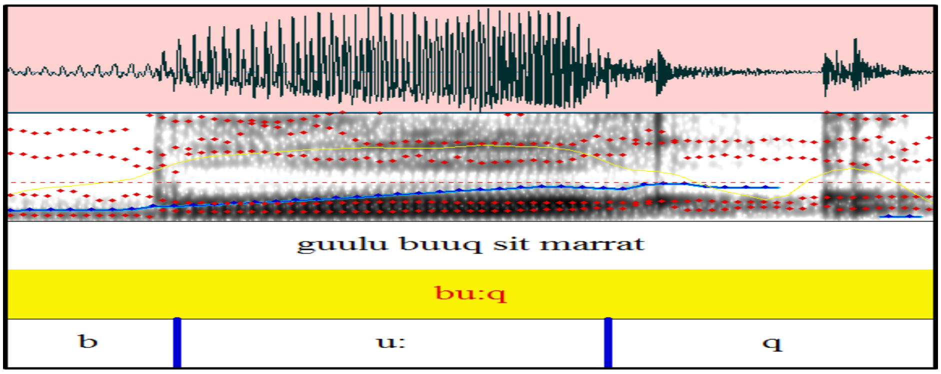


Fig.13: The stop consonant /q/ in final position in the word /bu:q/ 'trumpet' produced firstly with aspiration followed by a closure followed by a burst released into slight aspiration; then a long gap followed by a number of bursts released into faint aspiration; there is no voicing during the entire sound.

/ʔ/: In final position, /ʔ/ is realised similar to /k/ whereby it has the voice bars of the preceding vowel suddenly disappear leaving a gap representing the closure phase of the stop, which is usually longer than it is in initial position. There is a burst/release, or more, immediately after the vowel before the gap, which is followed by another number of bursts/releases. The closure being made by the glottis itself affects the production of the end of the preceding vowel, which is usually produced with a creaky voice (fig. 14).

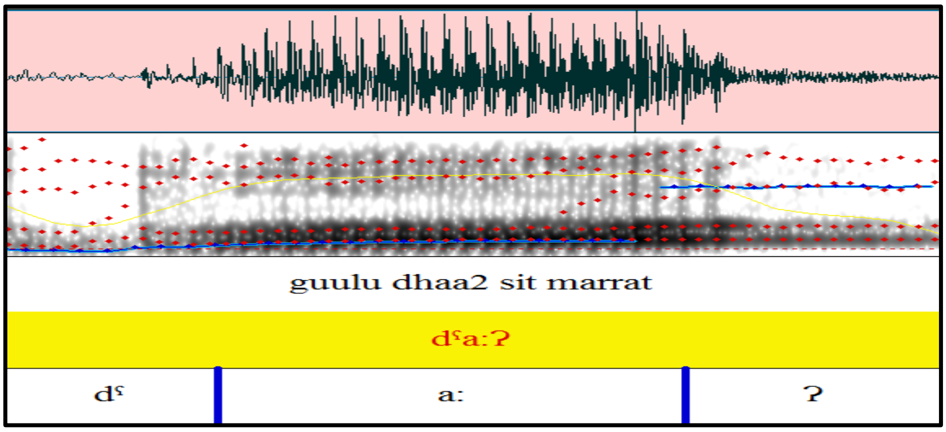


Fig.14: The stop consonant /ʔ/ in final position in the word /dˤa:ʔ/ 'it lighted up' produced firstly with a burst followed by a closure; there is no voicing during the entire sound but it being a glottal stop affected the offset of the vowel which is produced with a creaky voice.

9.3 VOT

In this section, VOT of the stop consonant in initial position is presented in relation to each of the long vowels adjacent to them. Results show that the range of VOT for each consonant differs, with some being very wide. This is due to how close/open - front/back the adjacent vowels are when following the consonants; or are speaker specific. The present study aims to investigate to which group of languages IA belongs, depending on the position of VOT as being: whether 0/negative, in voiced stops; or positive, in voiceless stops. Other details require further and thorough investigations which could be addressed in future research. Overall results show that IA has a negative VOT in voiced stops and a positive one in voiceless stops. This makes it similar to Palestinian Arabic.

/b/: The stop consonant /b/ has a negative –VOT ranging between -62ms and -76ms where vibration of the stop starts before the release of the stop denoting it to being voiced (fig. 15).

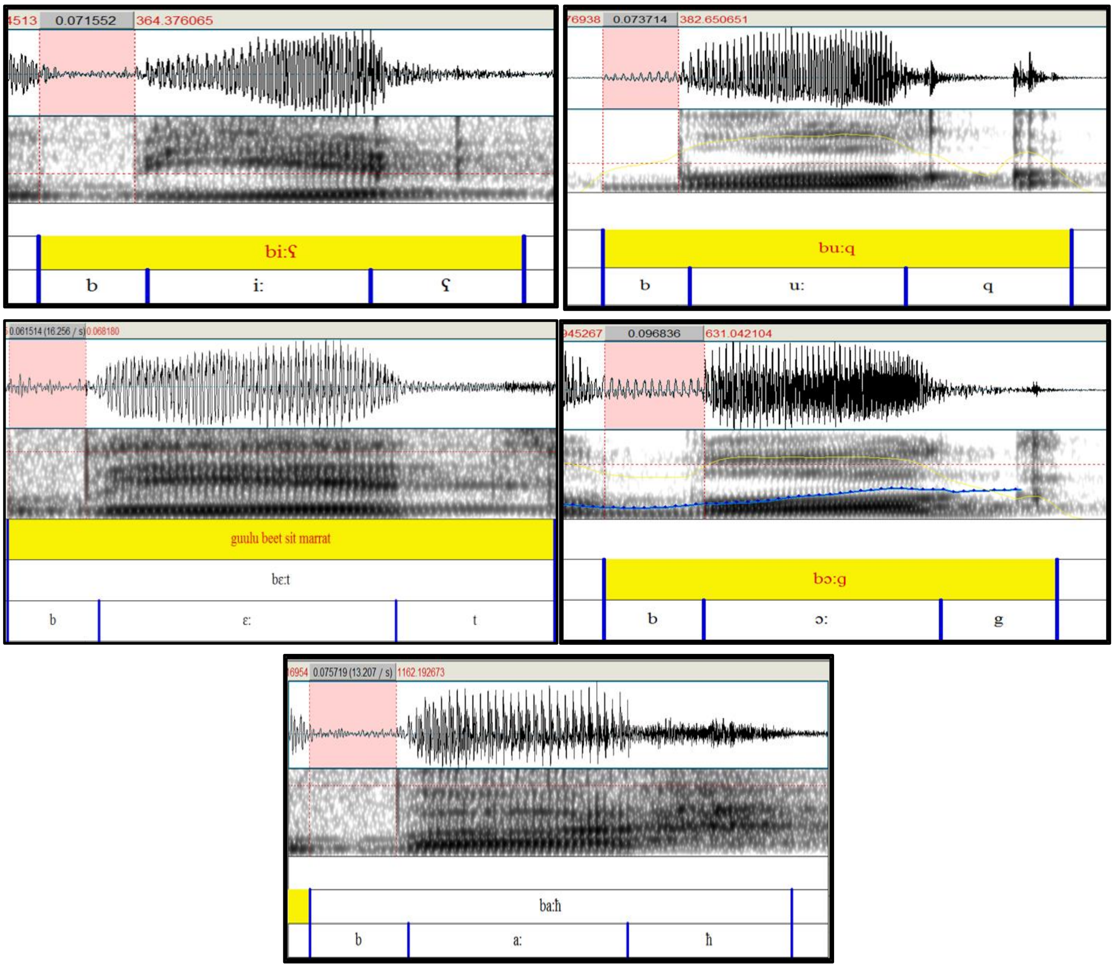


Fig. 15: VOT (negative/prevoiced) for /b/= [-71ms adjacent to /i:/]; [-62ms adjacent to /ɛ:/]; [-74ms adjacent to /u:/]; [-96ms adjacent to /ɔ:/]; [-76ms adjacent to /a:/]

/t/: The stop consonant /t/ has a positive +VOT ranging between +31ms and +58ms from the release of the stop up to the start of the vibration of the adjacent vowel, showing it as voiceless (fig. 16).

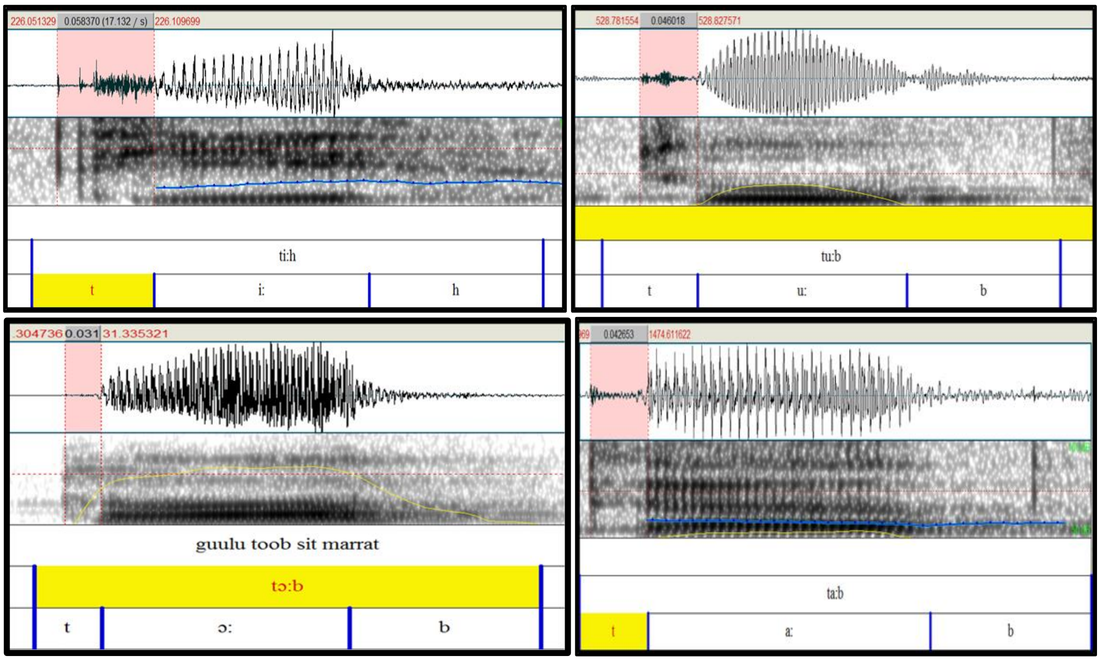


Fig. 16: VOT for /t/= [+58ms adjacent to /i:/]; [+46ms adjacent to /u:/]; [+31ms adjacent to /ɔ:/]; [+43ms adjacent to /a:/]

/d/: The stop consonant /d/ has a negative –VOT ranging between -60ms and -76ms where vibration of the stop starts before the release of the stop denoting it to being voiced (fig. 17).

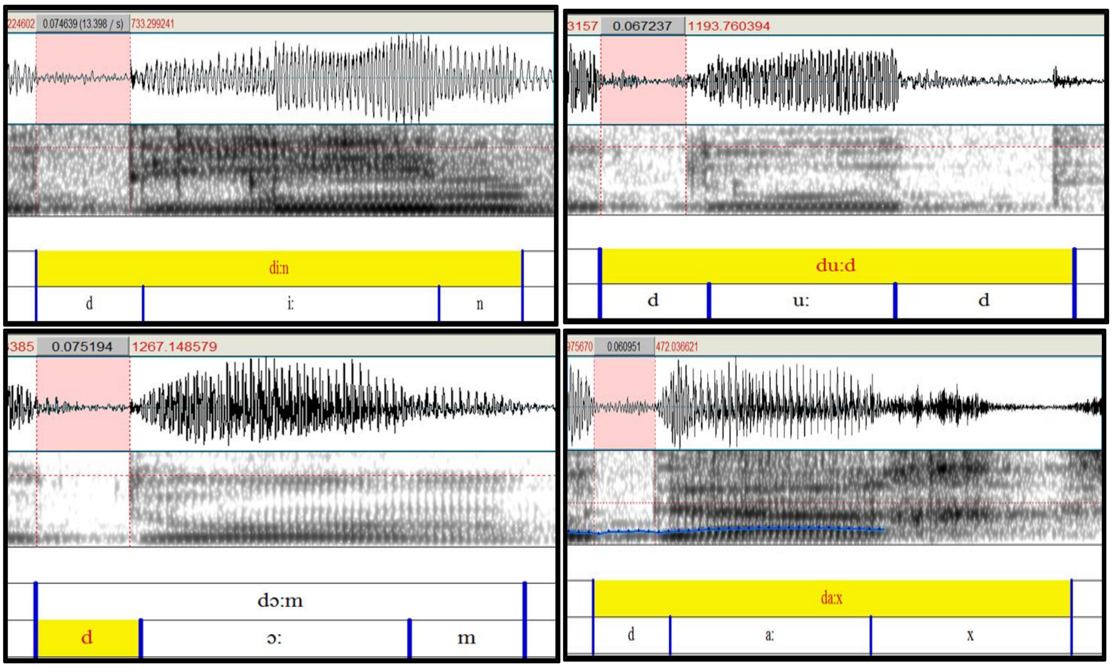


Fig. 17: VOT (negative/prevoiced) for /d/= [-76ms adjacent to /i:/]; [-67ms adjacent to /u:/]; [-75ms adjacent to /ɔ:/]; [-60ms adjacent to /a:/]

/k/: The stop consonant /k/ has a positive +VOT ranging between +48ms and +75ms from the release of the stop up to the start of the vibration of the adjacent vowel, showing it to being voiceless (fig. 18).

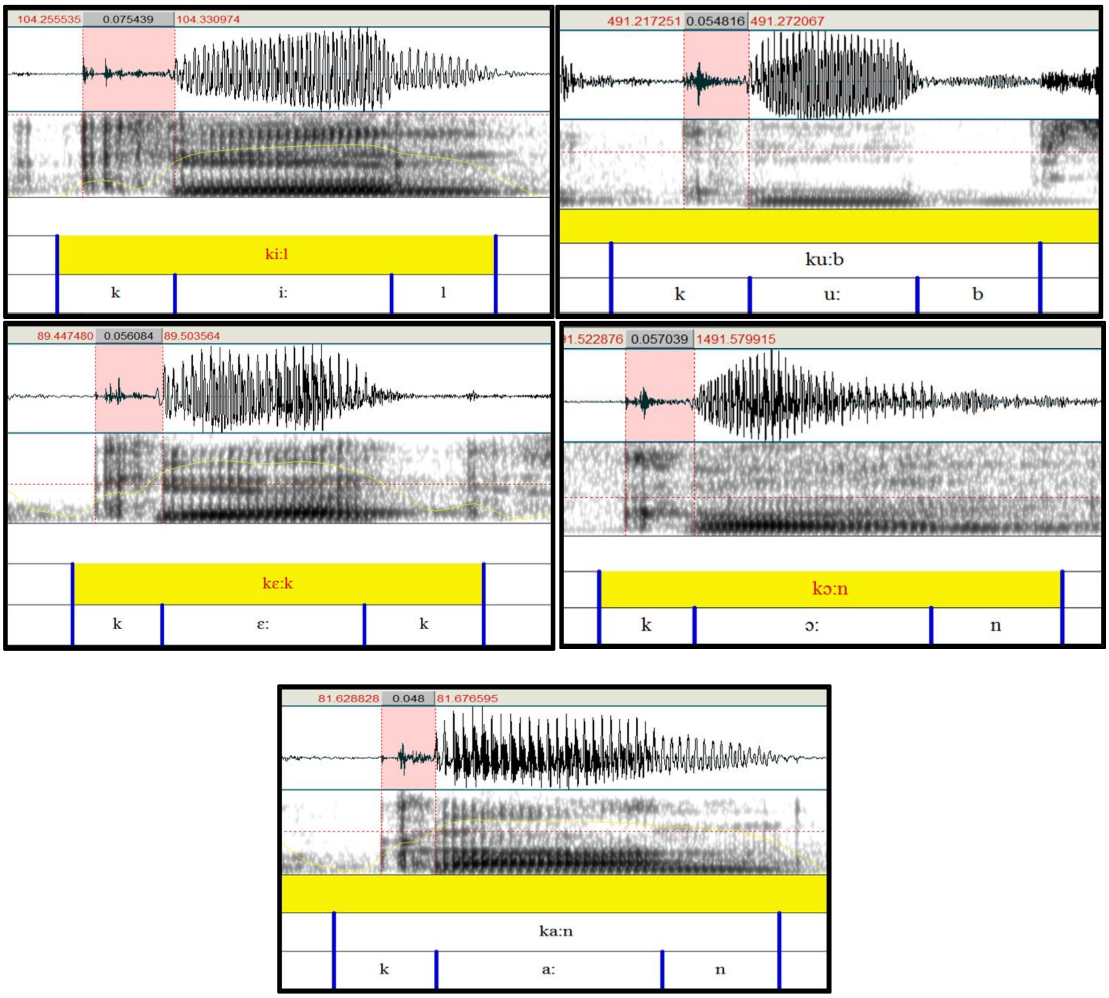
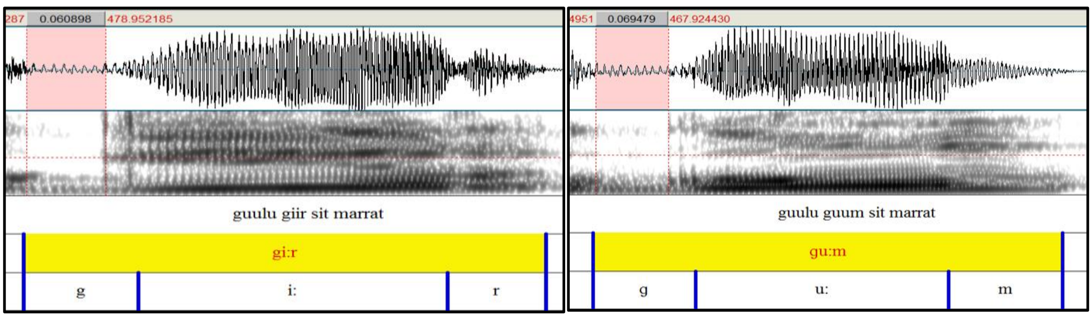


Fig. 18: VOT for /k/= [+75ms adjacent to /i:/]; [+55ms adjacent to /u:/]; [+56ms adjacent to /ɛ:/]; [+57ms adjacent to /ɔ:/]; [+48ms adjacent to /a:/]

/g/: The stop consonant /g/ has a negative –VOT ranging between -55ms and -85ms where the vibration of the stop starts before its release denoting it to being voiced (fig. 19).



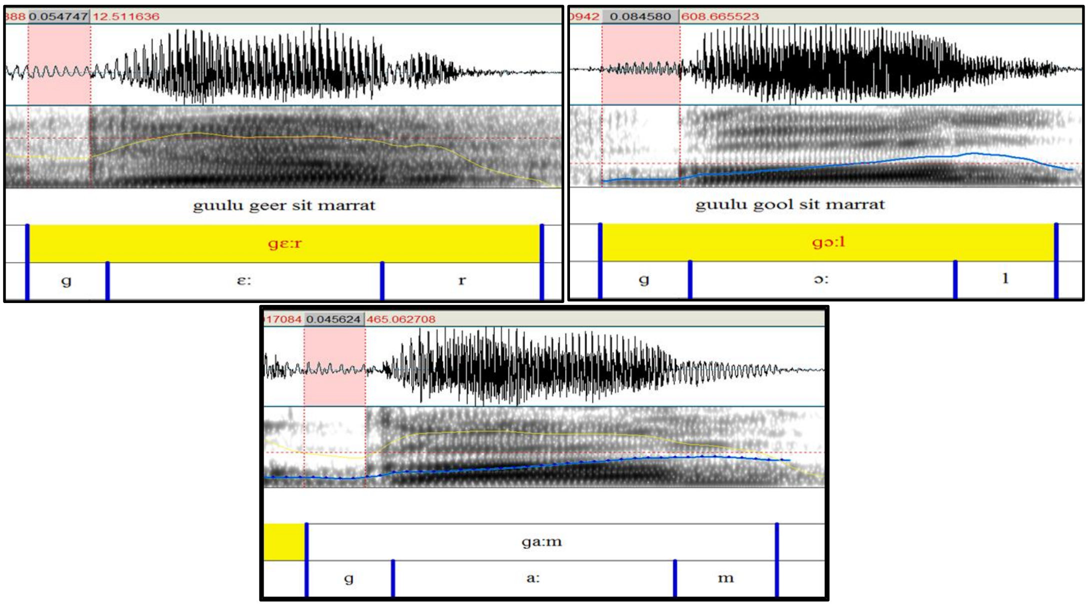


Fig. 19: VOT (negative/prevoiced) for /g/= [-61ms adjacent to /i:/]; [-69ms adjacent to /u:/]; [-55ms adjacent to /ɛ:/]; [-85ms adjacent to /ɔ:/]; [-45ms adjacent to /a:/]

/q/: The stop consonant /q/ has a positive +VOT ranging between +16ms and +47ms from the release of the stop up to the start of the vibration of the adjacent vowel, showing it to being voiceless (fig.20).

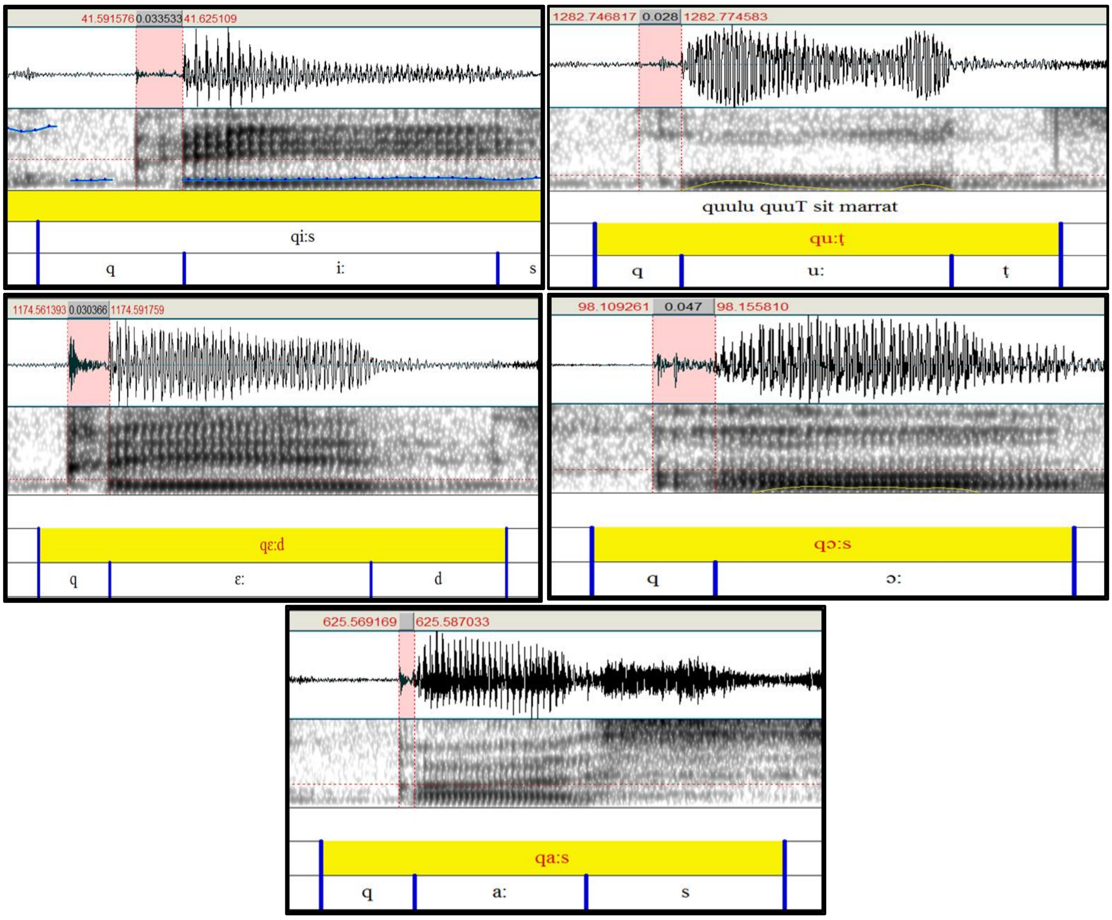


Fig. 20: VOT for /q/= [+34ms adjacent to /i:/]; [+28ms adjacent to /u:/]; [+30ms adjacent to /ɛ:/]; [+47ms adjacent to /ɔ:/]; [+16ms adjacent to /a:/]

/ʔ/: The stop consonant /ʔ/ has a positive +VOT ranging between +12ms and +17ms from the release of the stop up to the start of the vibration of the adjacent vowel. Since this consonant is a glottal stop whereby the vocal cords make the closure, therefore there is usually slight or no vibration denoting it to be voiceless (fig. 21).

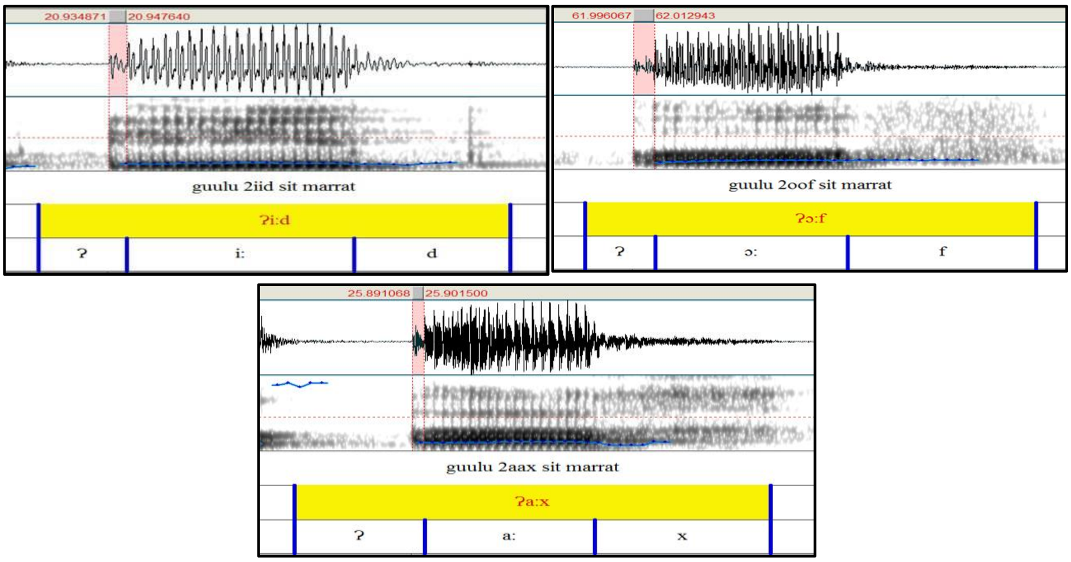


Fig. 21: VOT for /ʔ/= [+13ms adjacent to /i:/]; [+17ms adjacent to /ɔ:/]; [+12ms adjacent to /a:/]

9.4 Formant Frequency of Neighbouring Vowels

This section compares formant frequencies of vowels neighbouring the stop consonants with the same vowels in isolation contexts. Comparisons are made at onset (near an initial stop), midpoint (irrespective of stop position), and offset (preceding a final stop). Overall results show that the direction of *F*1/*F*2 frequency changes depends on the quality of vowels neighbouring stop consonants.

9.4.1 *F*1/*F*2 at Onset

In this section, onset portions of the long vowels which are near an initial stop are compared with those in isolation contexts (fig. 22–29). Overall results at onset show that all stop consonants have a lowering effect on *F*1 values of adjacent vowels, suggesting a more close quality. However, only the stops /b, q, ʔ/ have a lowering effect on *F*2 values suggesting a more back quality, while the stops /d, t, k, g/ have a rising effect on *F*2 suggesting a more front quality.

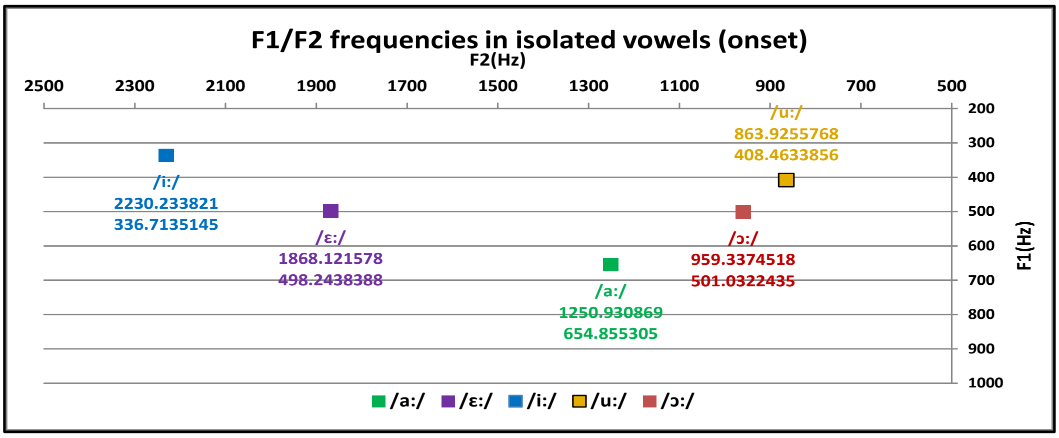


Fig. 22: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ in isolation contexts measured at onset

/b/: In contexts where vowels are adjacent to the initial stop consonant /b/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 23). For the vowels /i:, ɛ:, a:, ɔ:/ *F*2 lowers suggesting a more back quality, but rises for the vowel /u:/ suggesting a more front quality. As for the effects on *F*1 values, in the vowels /ɛ:, a:, ɔ:/ they are also lowered suggesting a more close quality; and only in the vowels /i:, u:/ that they rise showing a more open quality.

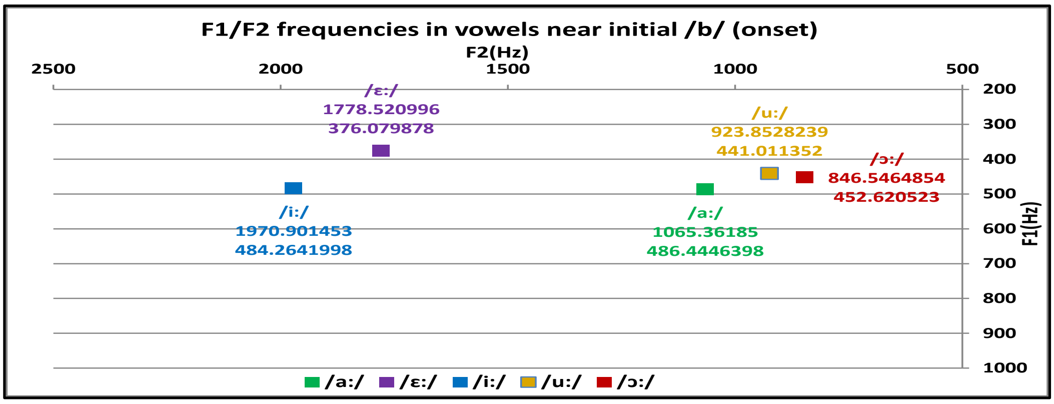


Fig. 23: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /b/ stop consonant measured at onset

/d/: In contexts where vowels are adjacent to the initial stop consonant /d/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 24). For the close front vowel /i:/, *F*1 and *F*2 values are lowered suggesting a more close and more back quality. As for the vowels /a:, u:, ɔ:/, *F*2 rises and *F*1 lowers suggesting a more front more close quality.

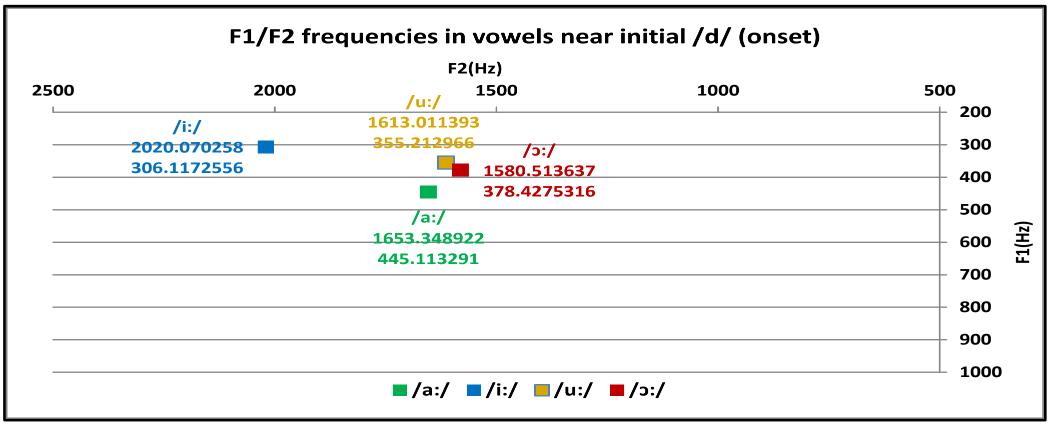


Fig. 24: Plotted *F*1/*F*2 frequencies in vowels /i:, a:, u:, ɔ:/ neighbouring the /d/ stop consonant measured at onset

/t/: In contexts where vowels are adjacent to the initial stop consonant /t/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 25). For all the vowels /i:, a:, u:, ɔ:/, *F*2 rises and *F*1 lowers suggesting a more front and more close quality.

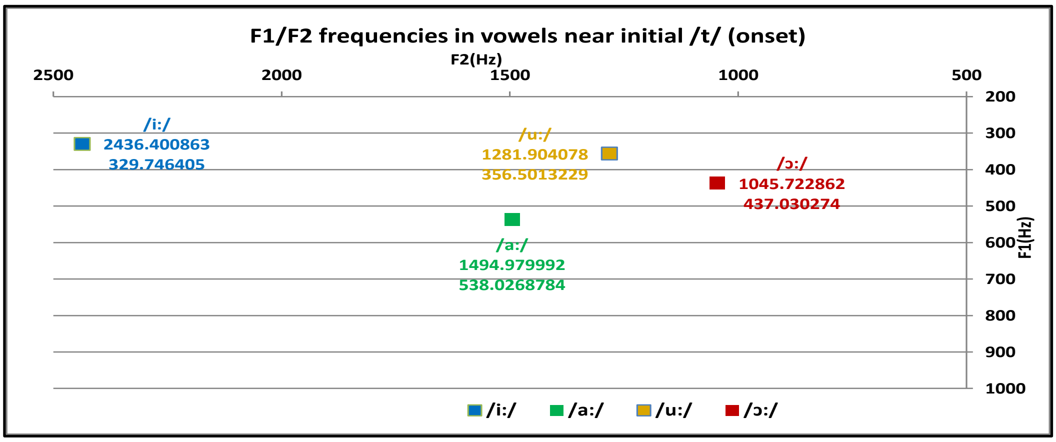


Fig. 25: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, u:, ɔ:/ neighbouring the /t/ stop consonant measured at onset [(5)]

/k/: In contexts where vowels are adjacent to the initial stop consonant /k/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 26). For the vowels /i:, ɛ:, ɔ:, u:/, *F*2 slightly rises and *F*1 slightly lowers suggesting a more front and more close quality; only for the vowel /a:/ that both *F*2and *F*1 slightly lower suggesting a more back and more close quality.

[(5)] No proper Iraqi or commonly used Arabic words containing /ɛ:/ were found; therefore, there is no measure for this vowel neighbouring /t/ at onset. This was also noted for other stop contexts at onset, midpoint and offset.

Journal of Basra Research for Human Sciences No .: 2 Vol.: 45 Yr. August 2020

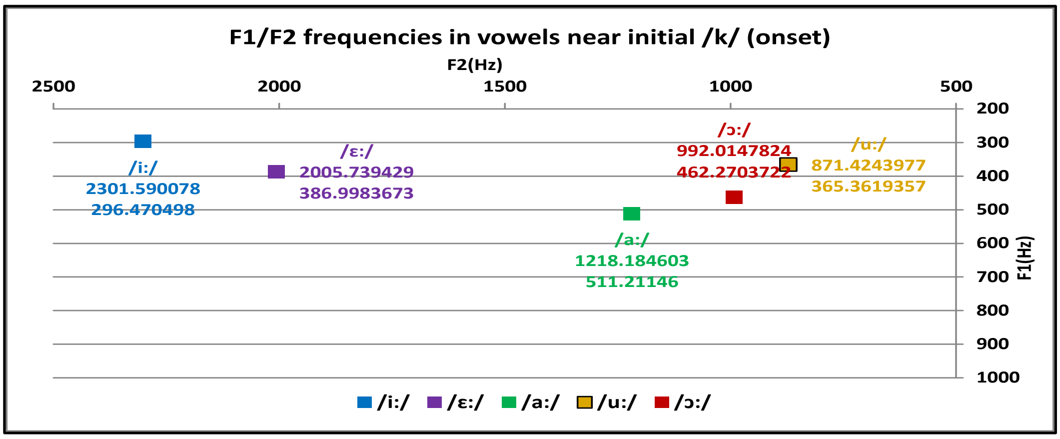


Fig. 26: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /k/ stop consonant measured at onset

/q/: In contexts where vowels are adjacent to the initial stop consonant /q/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 27). For all the vowels /i:, ɛ:, a:, ɔ:, u:/, *F*2 lowers suggesting a more back quality; while *F*1 slightly lowers in the vowels /ɛ:, a:, u:/ and slightly rises in the vowels /i:, u:/ suggesting a more close and more open quality, respectively.

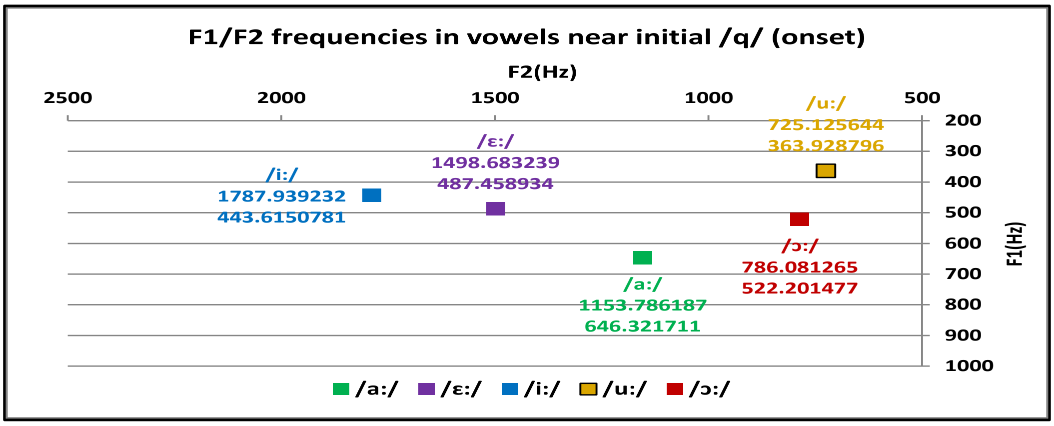


Fig. 27: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /q/ stop consonant measured at onset

/ʔ/: In contexts where vowels are adjacent to the initial stop consonant /ʔ/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 28). For the three vowels /i:, a:, ɔ:/ adjacent to the consonant /ʔ/, *F*2 lowers suggesting a more back quality. However, *F*1 only slightly lowers near the vowel /a:/ suggesting a slightly more close quality, while it does not show any changes near the vowels /i:, ɔ:/.

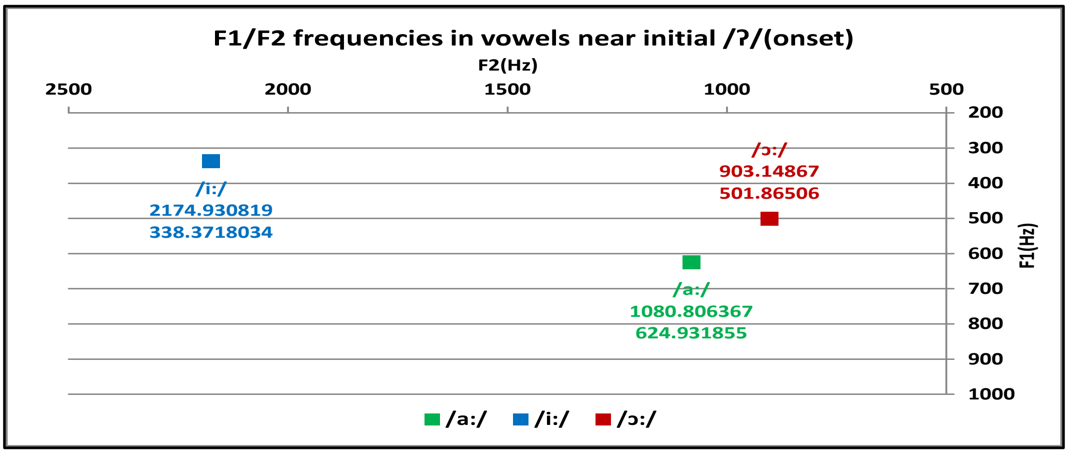


Fig. 28: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, ɔ:/ neighbouring the /ʔ/ stop consonant measured at onset

/g/: In contexts where vowels are adjacent to the initial stop consonant /g/, the results of the changes in *F*1/*F*2 at onset are as follows (fig. 29). For the vowels /i:, ɛ:, ɔ:/, *F*2 rises suggesting a more front quality with a special high rise in the vowel /ɛ:/; while it lowers in the vowels /a:, u:/ suggesting a more back quality. As for *F*1, it lowers in all the vowels, suggesting a more close quality.

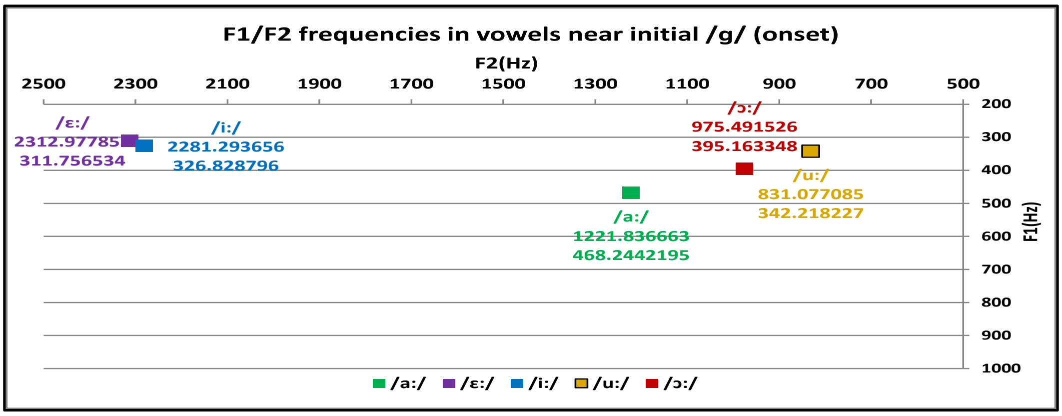


Fig. 29: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /g/ stop consonant measured at onset

10.4.2 *F1*/*F2* at Midpoint

In this section, midpoint portions of the long vowels which are adjacent to initial or/and final stop consonants are compared with those in isolation contexts (fig. 30 – 37). Overall results at midpoint show that the stop consonants /b, d, t/ have a rising effect on the *F*2 values of adjacent vowels, suggesting a more front quality; while the stops /k, q, ʔ, g/ show a lowering effect on the *F*2, suggesting a more back quality. However, only the stops /k, ʔ/ have a lowering effect on the *F*1 values, suggesting a more close quality; while the stops /b, d, t, q, g/ have a rising effect on the *F*1, suggesting a more open quality.

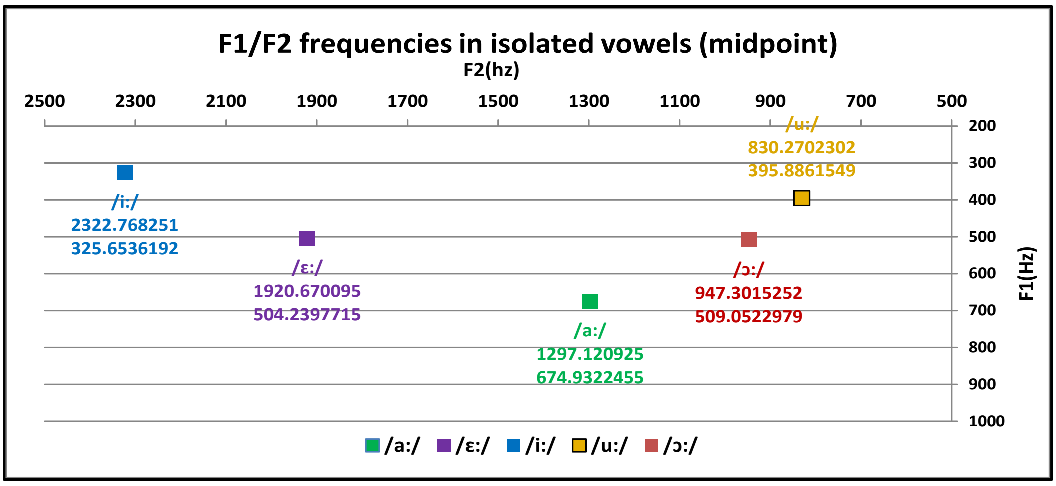


Fig. 30: Plotted *F*1/*F*2 frequencies in the vowels /i:, ε:, a:, u:, ɔ:/ in isolation contexts measured at midpoint

/b/: In contexts where vowels are adjacent to initial and/or final stop consonant /b/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 31). For the vowel /i:/, *F*2 slightly lowers suggesting a more back quality; for the vowels /ε:, ɔ:, u:/, *F*2 rises suggesting a more front quality; but for the vowel /a:/ no changes occur. As for *F*1, it lowers in the vowel /ε:/ suggesting a more close quality, but rises in the vowels /ɔ:, u:/ suggesting a more open quality; while no changes occur in the vowels /i:, a:/.

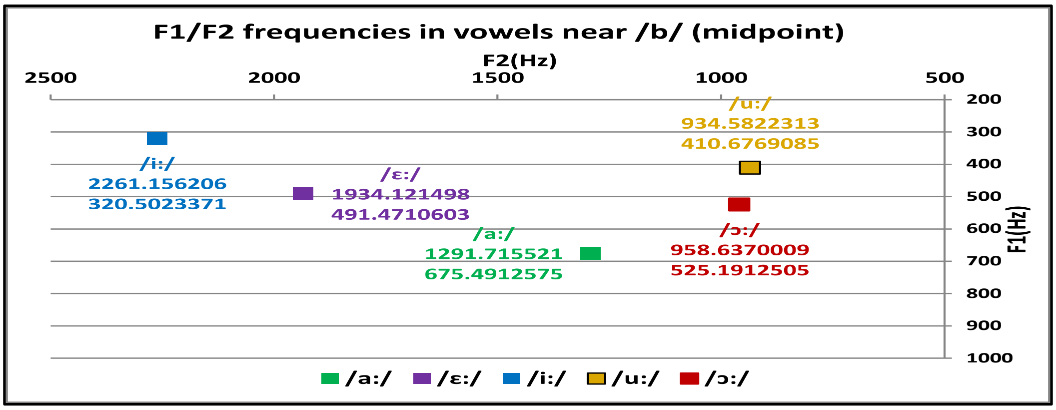


Fig. 31: Plotted *F*1/*F*2 frequencies in the vowels /i:, ε:, a:, u:, ɔ:/ neighbouring the /b/ stop consonant measured at midpoint

/d/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /d/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 32). *F*2 lowers only in the vowel /ε:/ suggesting a more back quality; while it rises in the vowels /i:, a:, ɔ:, u:/ suggesting a more front quality. Slight changes occur in the values of *F*1 of the vowels /i:, a:, ɔ:/ which show a rise suggesting a more open quality; while no changes occur in those of the vowels /ε:, u:/.

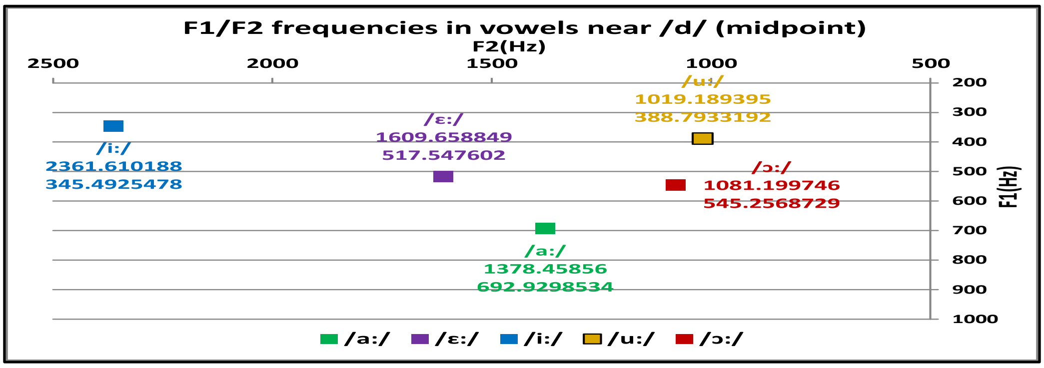


Fig. 32: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /d/ stop consonant measured at midpoint

/t/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /t/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 33). *F*2 values rise in the vowels /i:, ɛ:, a:, ɔ:/ suggesting a more front quality; while no changes occur for that of the vowel /u:/. As for *F*1, slight changes occur, with a slight rise in the vowels /i:, ɔ:/ suggesting a more open quality; a slight lowering in the vowel /ɛ:/; while no changes occur in the vowels /a:, u:/.

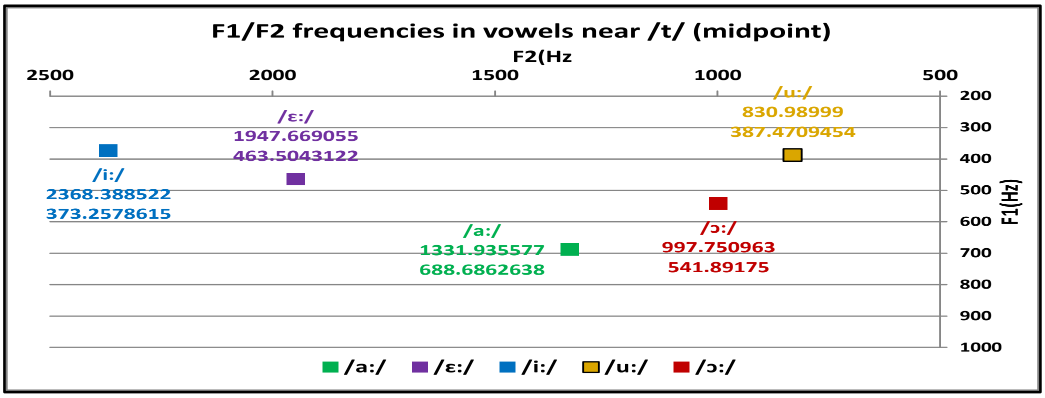


Fig. 33: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /t/ stop consonant measured at midpoint

/k/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /k/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 34). *F*2 values lower in the vowels /i:, ɛ:, a:/, suggesting a more back quality; while values rise in the vowels /ɔ:, u:/, suggesting a more front quality. As for *F*1 values, they lower in the vowels /ɛ:, a:, u:/, suggesting a more close quality; and they rise in the vowel /ɛ:/, suggesting a more open quality; but no changes occur in the vowel /i:/.

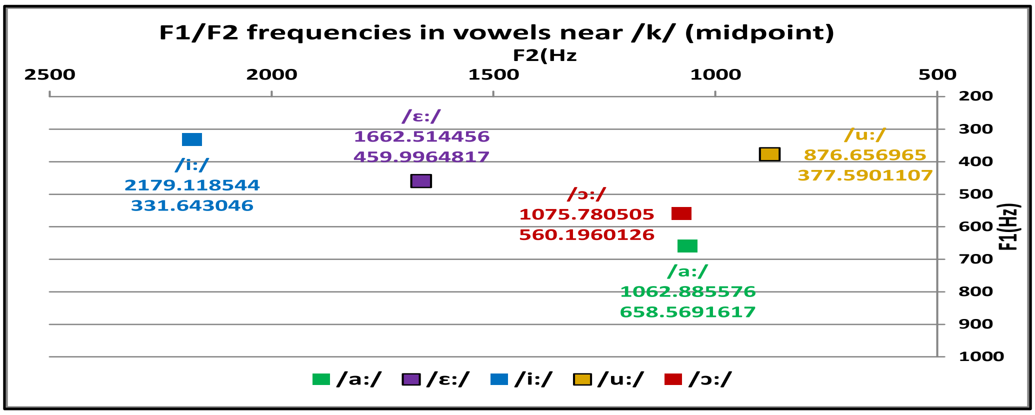


Fig. 34: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /k/ stop consonant measured at midpoint

/ʔ/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /ʔ/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 35). *F*2 lowers in the vowels /a:, ɔ:, u:/, suggesting a more back quality; while it slightly rises in the vowel /i:/, suggesting a more front quality. As for *F*1, it lowers in the vowels /a:, ɔ:/, suggesting a more close quality; but does not change in the vowels /i:, u:/

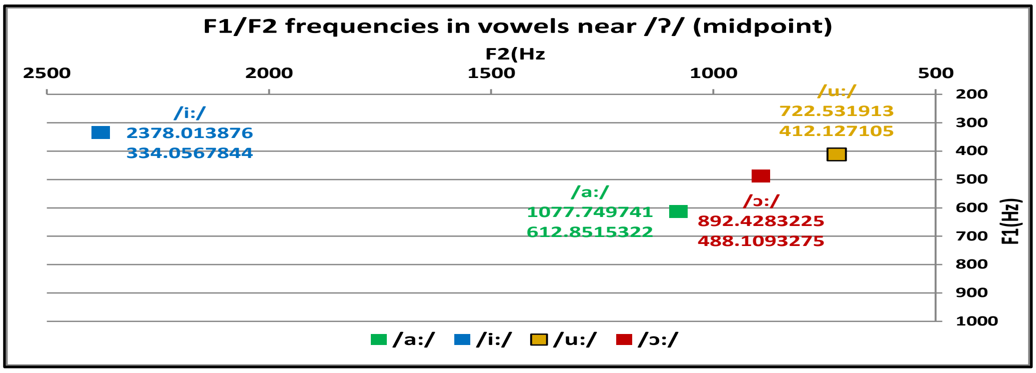


Fig. 35: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, u:, ɔ:/ neighbouring the /ʔ/ stop consonant measured at midpoint

/q/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /q/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 36). *F*2 values in all the vowels lower but with a very slight lowering in the vowels /ɔ:, u:/, suggesting a more back quality. As for *F*1 values, they rise in the vowels /i:, a:, ɔ:/ but show a slight rise in the vowel /ɛ:/, all suggesting a more open quality; but no changes occur in the vowel /u:/.

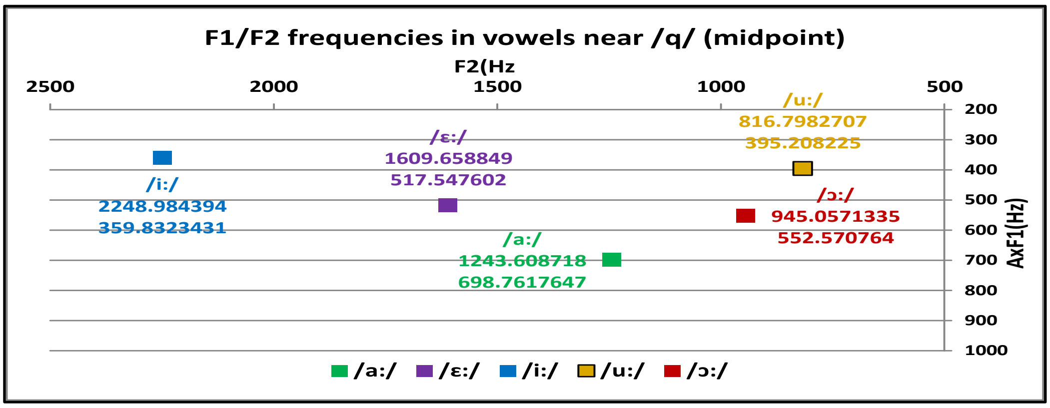


Fig. 36: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /q/ stop consonant measured at midpoint

/g/: In contexts where vowels are adjacent to the initial and/or the final stop consonant /g/, the results of the changes in *F*1/*F*2 at midpoint are as follows (fig. 37). *F*2 values lower in the vowels /i:, ɛ:, a:/, suggesting a more front quality; while it rises in the vowel /ɔ:/, suggesting a more back quality. As for *F*1 values, they rise in the vowels /i:, a:, ɔ:, u:/, suggesting a more open quality; with that in the vowel /ɛ:/ not changing.

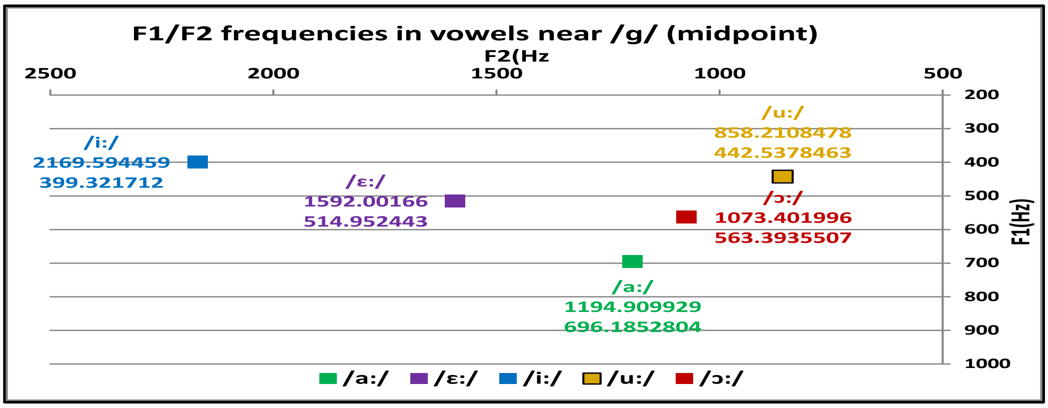


Fig. 37: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /ʔ/ stop consonant measured at midpoint

10.4.3 *F*1/*F*2 at Offset

In this section, offset portions of the long vowels which are adjacent to final stop consonants are compared with those in isolation contexts (fig. 38 – 45). Overall results at offset show that the stop consonants /b, k, q, ʔ, g/ have a lowering effect on *F*2 values of adjacent vowels, suggesting a more back quality; while the stops /d, t/ show a rising effect on *F*2, suggesting a more front quality. However, only the stops /b, d, t, g/ have a lowering effect on *F*1 values, suggesting a more close quality; while the stops /k, q, ʔ/ have a rising effect on *F*1 suggesting a more open quality.

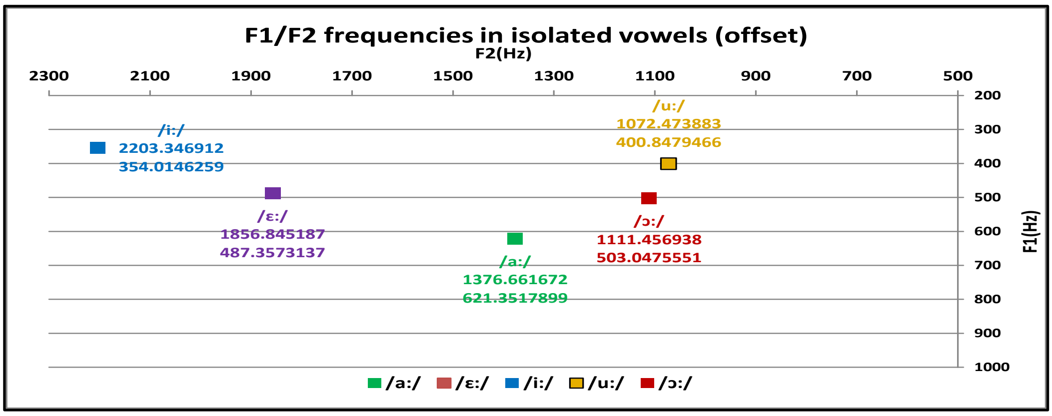


Fig. 38: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ in isolated contexts measured at offset

/b/: In contexts where vowels are adjacent to the final stop consonant /b/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 39). *F*2 values lower in all the vowels, suggesting a more back quality. *F*1 also lowers in all the vowels, suggesting a more close quality.

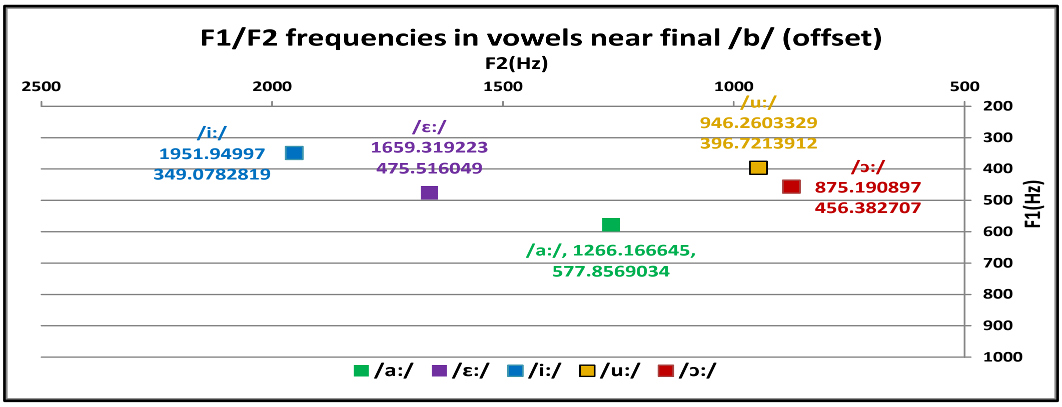


Fig. 39: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /b/ stop consonant measured at offset

/d/: In contexts where vowels are adjacent to the final stop consonant /d/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 40). *F*2 values lower in the vowels /i:, ɛ:/, suggesting a more back quality; while they rise in the vowels /a:, ɔ:, u:/, suggesting a more front quality. *F*1 values lower in all five vowels, suggesting a more close quality.

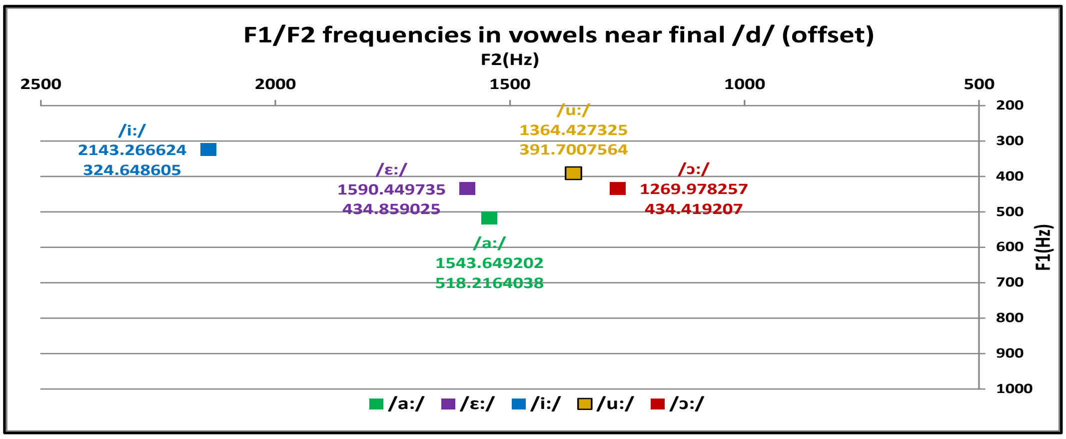


Fig. 40: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /d/ stop consonant measured at offset

/t/: In contexts where vowels are adjacent to the final stop consonant /t/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 41). *F*2 values lower in the vowels /i:, ɛ:/, suggesting a more back quality; while they rise in the vowels /a:, ɔ:, u:/, suggesting a more front quality. *F*1 values lower in the vowels /i:, ɛ:, a:, u:/, suggesting a more close quality; while they rise in the vowels /i:, ɔ:/, suggesting a more open quality.

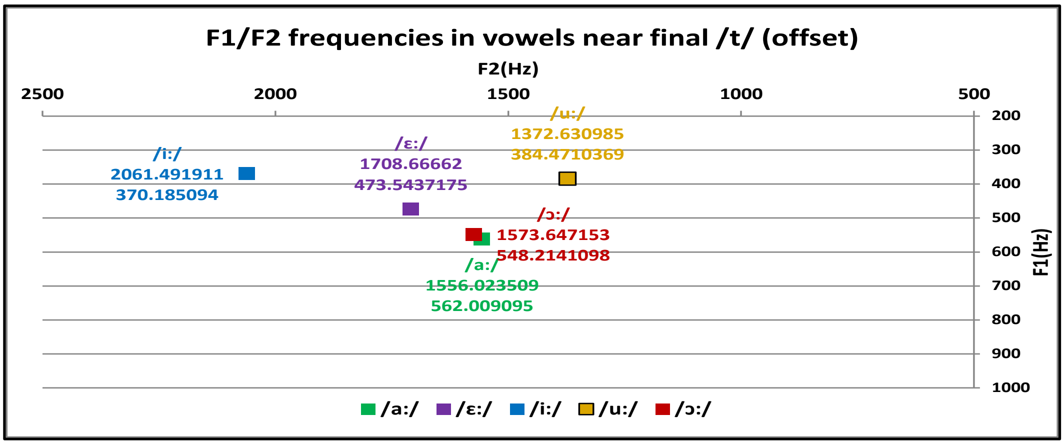


Fig. 41: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, u:, ɔ:/ neighbouring the /t/ stop consonant measured at offset

/k/: In contexts where vowels are adjacent to the final stop consonant /k/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 42). *F*2 values lower in the vowels /ɛ:, a:, ɔ:/, suggesting a more back quality; while in the vowel /i:/ it slightly rises suggesting a more front quality. As for *F*1, values rise in the vowels /i:, a:, ɔ:/ suggesting a more open quality; while no changes occur in the vowel /ɛ:/.

Journal of Basra Research for Human Sciences No . : 2 Vol. : 45 Yr. August 2020

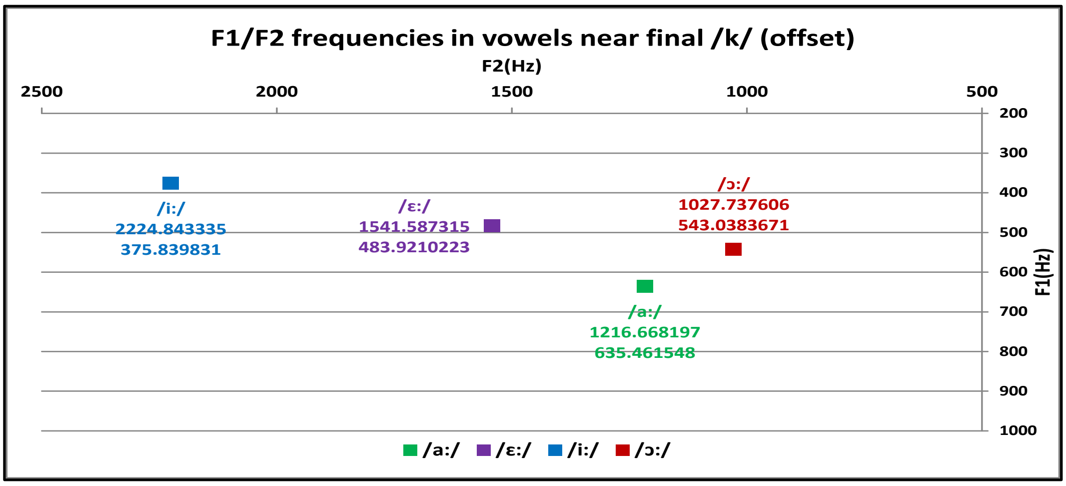


Fig. 42: Plotted *F*1/*F*2 frequencies in the vowels /i:, ɛ:, a:, ɔ:/ neighbouring the /k/ stop consonant measured at offset

/q/: In contexts where vowels are adjacent to the final stop consonant /q/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 43). *F*2 values lower in all the vowels /i:, a:, ɔ:, u:/ in this context, suggesting a more back quality. As for *F*1 values, they rise in all these vowels, suggesting a more close quality.

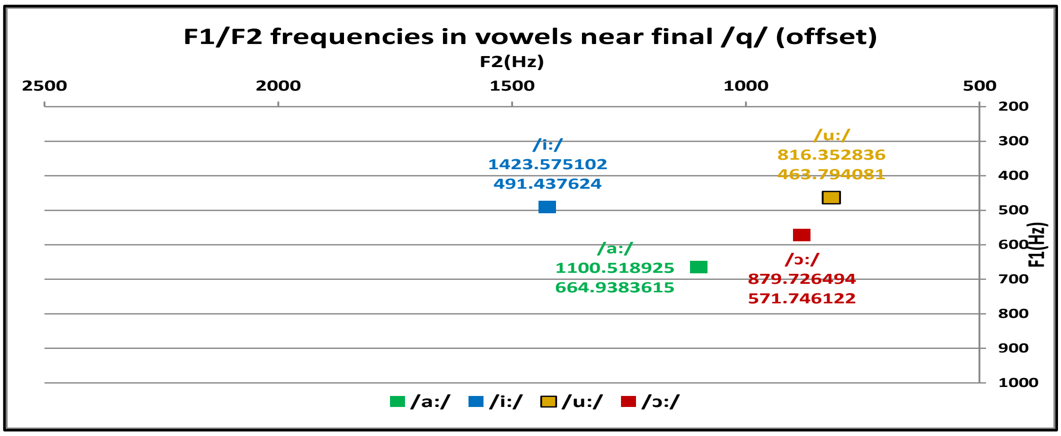


Fig. 43: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, u:, ɔ:/ neighbouring the /q/ stop consonant measured at offset

/ʔ/: In contexts where vowels are adjacent to the final stop consonant /ʔ/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 44). Results for this stop are similar to those of the stop /q/, except for one case whereby *F*2 values for the vowel /ɔ:/ do not show any change.

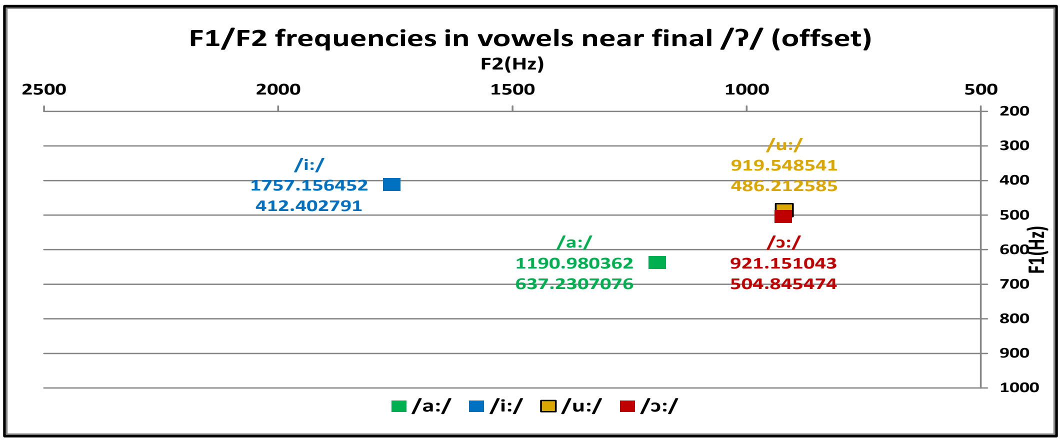


Fig. 44: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, u:, ɔ:/ neighbouring the /ʔ/ stop consonant measured at offset

/g/: In contexts where vowels are adjacent to the final stop consonant /g/, the results of the changes in *F*1/*F*2 at offset are as follows (fig. 45). *F*2 values lower for the vowels /a:, ɔ:, u:/, suggesting a more back quality; but slightly rise in the vowel /i:/, suggesting a more front quality. As for *F*1, values lower in the vowels /a:, ɔ:/, suggesting a more close quality; but rise in the vowels /i:, u:/, suggesting a more open quality.

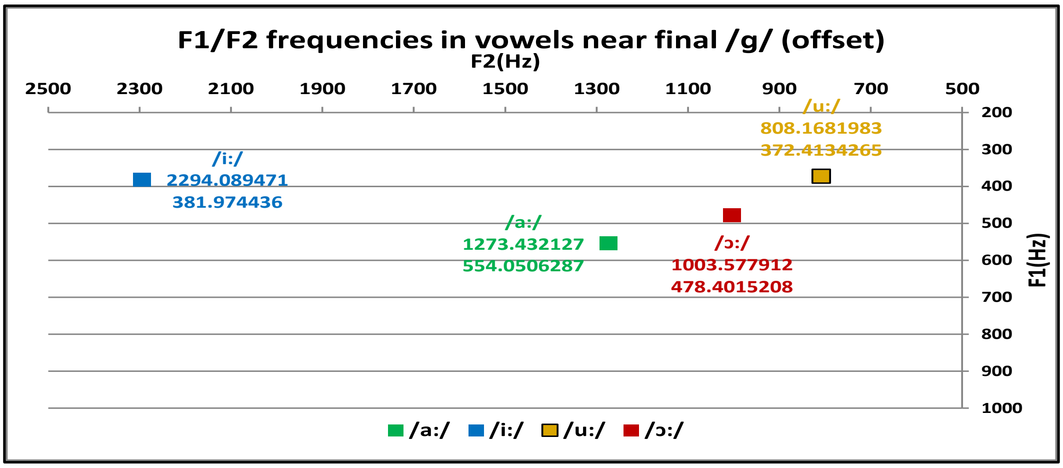


Fig. 45: Plotted *F*1/*F*2 frequencies in the vowels /i:, a:, u:, ɔ:/ neighbouring the /g/ stop consonant measured at offset

10 Discussion and Conclusions

The present study investigated the realisations of stop consonants as produced by 11 Iraqi speakers. In as far as the realisations of these stop consonants are concerned, results revealed the following. In initial position, all stops are realised by a burst or a number of bursts, but with the voiceless stops being released into aspiration and/or friction before the start of the adjacent vowel and with the voiced ones being followed by the voicing of the vowel. In final position, the stop consonants start with the end of the voice bars of the previous vowel and having a longer gap (closure) than that in initial position, followed by voicing in the voiced stops or aspiration/friction in the voiceless ones.

The present study is one of the first attempts to date at measuring the VOT of IA stop consonants. Results have categorised IA to be among those dialects which show a negative VOT for voiced consonants whereby voicing starts before the release, and a positive VOT for voiceless stops whereby the voicing of the following adjacent vowel starts after the release and aspiration/friction of the stop.

It should also be noted that it was beyond the scope of this study to investigate more deeply the other features of VOT, particularly that of their lengths. These length measures would be affected by many factors such as the surrounding sounds and whether the investigated words/items are in isolation or embedded in a carrier sentence/spontaneous speech. If the investigated initial voiced stop is preceded by a word containing a final voiced consonant, the vibration of the latter would continue despite having a closure resulting in having longer periods of –VOTs than those in voiceless stops. Therefore, it is recommended that this factor be controlled in future studies of VOT.

In as far as the effect of stop consonants on *F*1/*F*2 values is concerned, results showed varying effects. However, overall results showed *F*1/*F*2 values lowering at both onset and offset portions suggesting a more close-back effect. At midpoint, an interesting opposite effect with rising *F*1 values suggesting a more open quality; but with only two stops /d, t/ showing a rising effect on *F*2 of adjacent vowels at this portion, suggesting a front quality.

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