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## An Acoustic Analysis of Voice Onset Time in the Production of Voiceless Plosives in English and Iraqi Kurdish

**A B S T R A C T**

This paper is a study of voice onset time (VOT) in Iraqi Kurdish and English. The stops /t, k/ were used in initial position and were embedded in words which were presented to ten native speakers of Iraqi Kurdish and four English native speakers. Recordings were made and analyzed using a computer software that generated a spectrogram for each word (pratt). The results prove that stops in Iraqi Kurdish and in English occur at the same place along the VOT. The study also found that Place of articulation has a significant effect on VOT values and asserts the strong relationship between VOT values and place of articulation. Moreover vowel context has its significant effect on VOT values and asserts the strong relationship between VOT values and vowel context. Additionally, it is found that gender impact on VOT values varied from one language group to another, gender has no significant effect in the production of voiceless plosives in Iraqi Kurdish. Whereas English male speakers produce longer voice onset time than Female speakers.

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### دراسة لغوية لقياس زمن بدء الصوت في نطق الاصوات الانفجارية اللغة الانكليزية والكردية

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**الخلاصة:**

يدرس هذا البحث زمن بداية الجهر (VOT) في اللغة الكردية واللغة الانكليزية. لقد تم استخدام

الاصوات الانفجارية (t, k) في بداية مجموعة من الكلمات المفردة. وتم عرض هذه الكلمات على عشر

متحدثين من اللغة الكردية واربعة متحدثين من اللغة الانكليزية تم التسجيل والتحليل باستخدام برنامج (Praat) واثبتت النتائج بان الاصوات الانفجارية في اللغة الكردية واللغة الانكليزية لها نفس الموقع في لفظ زمن بداية الجهر (VOT). بالإضافة الى ذلك فقد اثبتت الدراسة بان لنوع وموقع صوت العلة تأثير قوي على زمن بداية الجهر (VOT). ولقد تم الاثبات ايضا بان تأثير الجنس على زمن بداية الجهر (VOT) يختلف من لغة الى اخرى. اذ انه في اللغة الكردية لا يؤثر الجنس على نطق الحروف الانفجارية بينما يكون التأثير واضح في اللغة الانكليزية اذ ان للذكور معدل اعلى من الاناث في زمن بداية الجهر (VOT).

**الكلمات المفتاحية:** النفس, زمن بداية الجهر, الاصوات الصحيحة, جنس المتحدث

## 1.Introduction

Beginning with Lisker and Abramson's (Lisker and Abramson 1964) study, VOT is one of the most important methods for studying the timing of voicing in stops (particularly in word-initial position). A large number of studies have dealt with voice onset time to investigate voicing contrasts in stops throughout the last few decades. However, only few studies examine VOT patterns in English and Iraqi Kurdish. This study deals with the concept of aspiration more specifically VOT, in English and Iraqi Kurdish. Moreover, the present study deals with variables that affect VOT which are: place of articulation, the linguistic contexts, age, vowel context, gender and number of syllables in a given word. It investigates the stop consonants production by Iraqi EFL learners. Simon (2011) states that English, is a language with positive short and long-lag plosives. Besides, Honeybone (2005) asserts that English is an aspiration language in the sense that phonologically it is also classified as voiced vs voiceless and phonetically by the (spread glottis) feature.

## 2. Research methodology

### 2.1 Subjects

14 speakers participated in this experiment from 4<sup>th</sup> year students and MA students (7 males and 7 females) are of two groups; the first group is the English native speakers group which consist of 4 speakers (2 female and 2 male) who were born in London. The second group is the Iraqi Kurdish group which consist of ten speakers of Iraqi Kurdish speakers (five females and five males). All were born in Erbil.

The criteria of selecting Iraqi EFL learners used in this study include: (1) a university education; (2) formal instruction in English; (3) using English as a foreign language; (4) the capacity to speak and read English fluently.

### 2.2 Data Collection

The voiceless plosives (t, k) in English and Iraqi Kurdish were used in the present study. All the words used are real words gathered from linguistic experts and native speakers of these language varieties. Each of these stops are followed by three long vowels, front, back and low /i:/, /u:/ and / a:/ respectively in initial (prevocalic) position. These stops are tested in a monosyllable and polysyllable words, placed in the initial position followed by long vowels. The long vowel was chosen because they have more obvious effects on VOT values of aspirated plosives than short vowels (Klatt, 1975; Weismer, 1979; port, and Rotunno, 1979 and Fischer & Goberman, 2010). The total number of tokens is 28 words, belong to Iraqi Kurdish and English language. 14 words for English and 14 for Iraqi Kurdish.

### 2.3 Procedures of The Study

Advertisement prompted potential participants to contact the experimenters via email or phone. Candidates recruited online were sent an email with a brief description of the study and were asked to either call the experimenter or to reply a few prescreening questions. Once contact was established by phone, a series of questions were asked in order to assess whether the potential subjects fit into the category of speakers the study aims to test. Each participant recorded individually. They were asked to read each list out loud at a normal speed. They put a pause with a natural length between items. Their speech is recorded at a 44.1 KHz sampling rate. They are required to speak as naturally as possible, speaking at a natural pace neither too quickly nor too slowly, but speaking clearly.

### 2.4 Measurement of VOT

Acoustic measurement of the speech material are made using praat software (Boersma and Weenink 2011) which is a Microsoft program proposed by Paul Boersma and David Weenink at the institute of phonetic science at the university of Amsterdam in 1992. This program is regarded as a comprehensive software that can be used in different ways. It is used in data recordings and data analysis. It is one of the most considerable and adopted programs. It gives the duration, formant, intensity, pitch, and prosodic features. The analysis involves displaying two panels (spectrogram and waveform) on separate portions of the screen, and using a manually controlled cursor for durational measurements. Measurement reliability is assessed by re-measuring three randomly selected stops in each group from duplicate spectrograms. In this study, 28 tokens are acoustically analyzed. All the tokens of this study in isolated words are segmented and saved as wave files by

each subject name, to examine the duration of VOT and avoiding confusion as much as possible.

## 2.5 Adopted Model

The present study adopts Lisker & Abramson (1964) model. They define Voice Onset Time as the interval between the beginning of vocal-fold vibration and the release of the oral constriction for plosive production and examine word-initial stops in 11 different languages. VOT is usually measured in milliseconds (ms). According to Lisker and Abramson (1964) VOT has either a negative value, -VOT, when voicing begins before the release, i.e. during the closure, and is referred to as "voicing lead", or positive value. The term "short lag" refers to VOT that begins voicing up to 25 milliseconds after the release. When voice begins more than 25ms after the release, it is referred to as "long lag". VOT has a value of zero when voicing begins at the time of release. Figure (1) below illustrates the three VOT conditions.

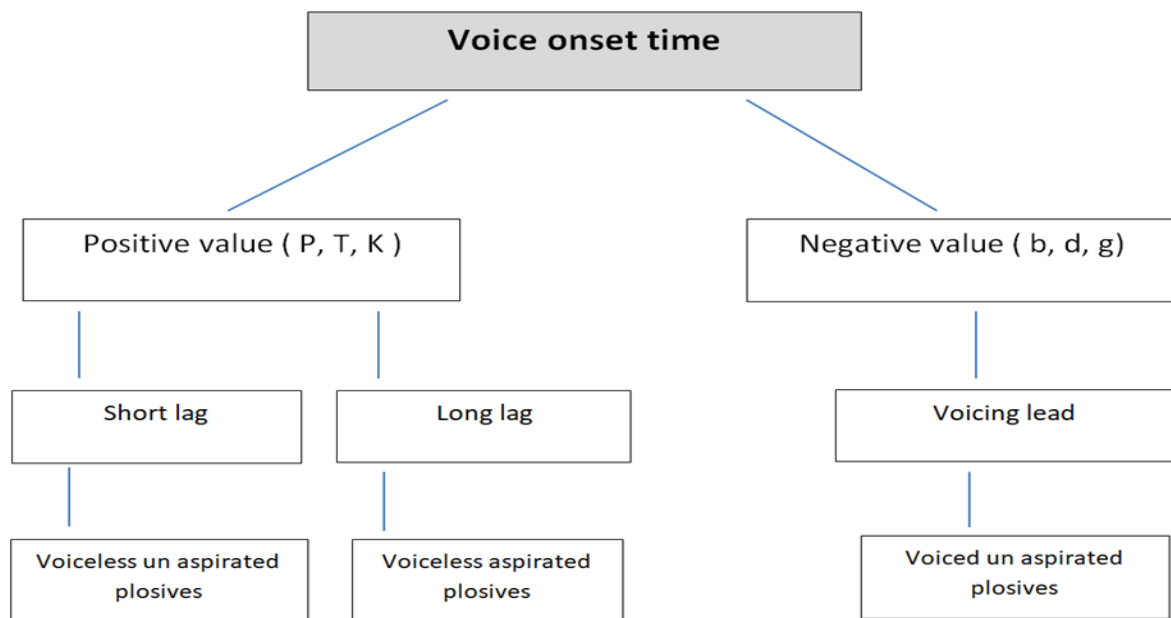


Figure (1): The Three Conditions of Voice Onset Time According to (Lisker and Abramson,1964)

### 3 Data Analysis

#### 3.1 English VOT

This section outlines, the acoustic analysis and the production of VOT for voiceless stops (t, k) in isolated words in British English in relation to the three long vowels (/i:, u:, a:/), and in relation to initial position. Each sub section includes a table which clarifies the mean and the range of VOT values of voiceless aspirated plosives followed by long vowels in the initial position in isolation.

##### 3.1.1 VOT Measurement of Voiceless Aspirated Plosive /t<sup>h</sup>/

As to the VOT average, it is found that in initial position the English native speakers produce /t<sup>h</sup>/ before the long vowel /i:/ with a mean (89.25) ms and range (78-96) while before the long vowel/u:/ the mean is (90.75) ms and range (76-104) whereas the mean is (95.25) ms and the range (85-112) is for /t<sup>h</sup>/ before long /a:/. See table (1) below.

Table (1): Voiceless Aspirated Plosive /t/ Followed by /i:, u:, a:/'

Stop Consonant and Position	Type of long vowel					
	/i: /		/u: /		/a: /	
	Mean	Range	mean	Range	Mean	Range
Initial/t/	89.25	78-96	90.75	76-104	95.25	85-112

The following Praat images illustrate the acoustic waveforms of English Native speakers production :

i. Wave Form of Initial /t<sup>h</sup>/ with Long Vowels / i:, u:, a: /

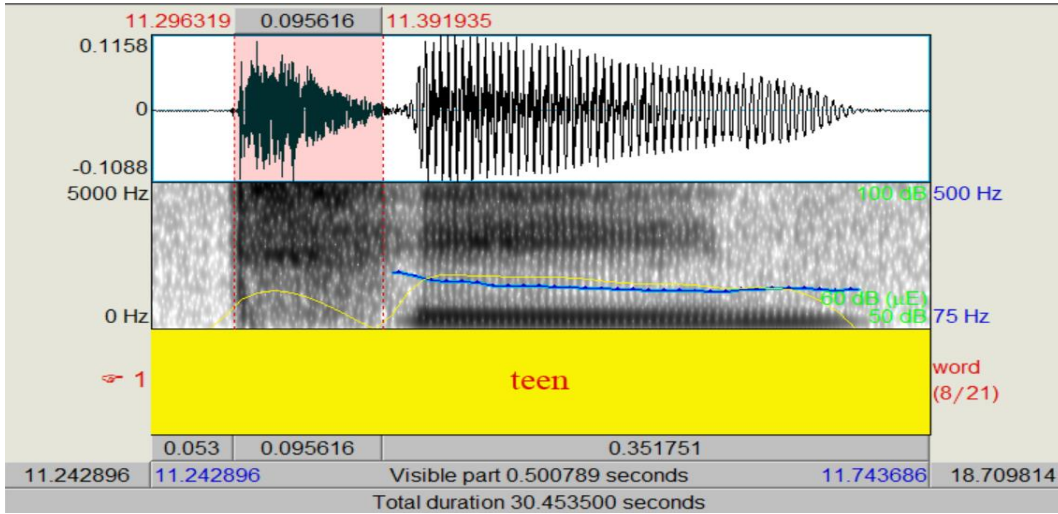


Figure (2): Wave Form of Initial [t<sup>h</sup>] with VOT Value 96 ms of 'teen'.

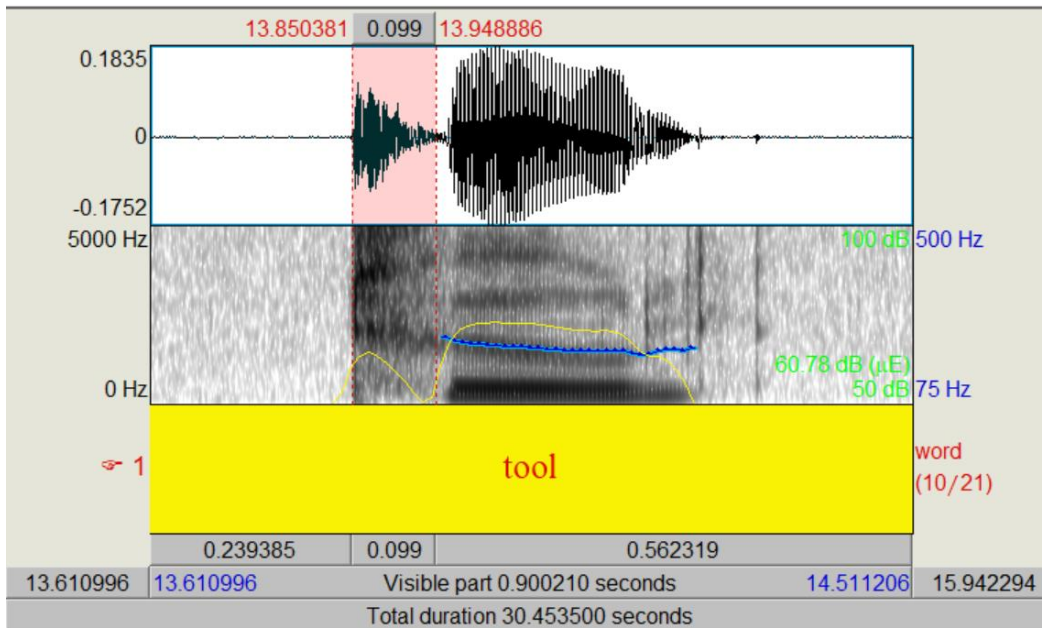


Figure (3): Wave Form of Initial [t<sup>h</sup>] with VOT Value 99ms of ‘tool’.

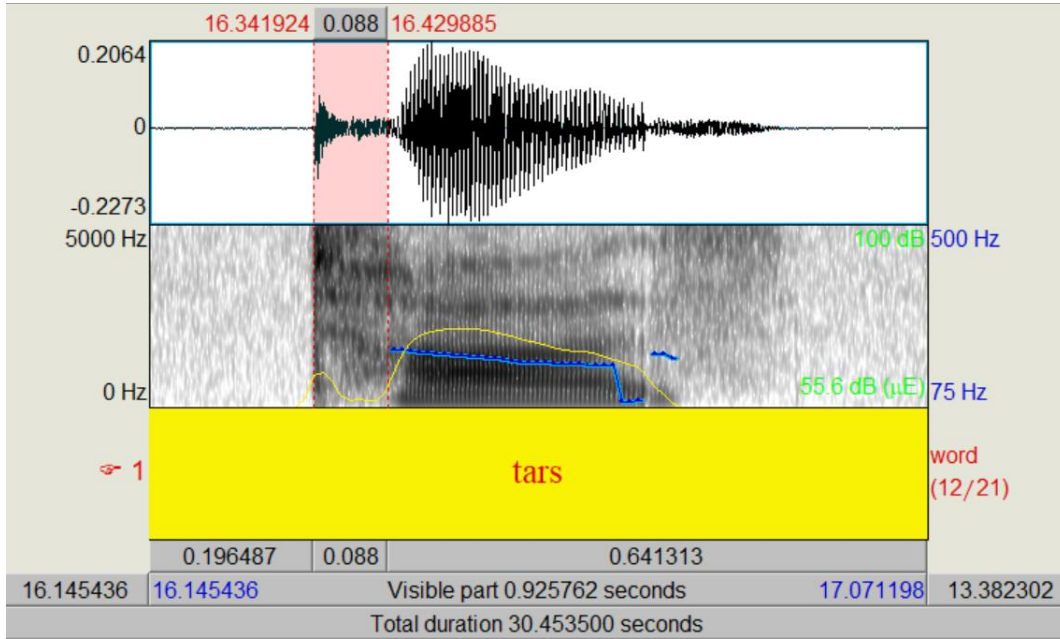


Figure (4): Wave Form of Initial [t<sup>h</sup>] with VOT Value 88 ms of ‘tars’.

### 3.1.2 VOT Measurement of Voiceless Aspirated Plosive /k<sup>h</sup>/

As to the VOT average, it is found that in initial position English Native speakers produce /k<sup>h</sup>/ before the long vowel /i:/ with a mean (105) ms and range (80-131) while before long /u:/ the mean is (102) ms and range (79-122) whereas the mean is (83.25) ms and the range (61-102) is for /k<sup>h</sup>/ before the long vowel /a:/. See table (2) below.

Table (2):Voiceless Aspirated Plosive /k/ Followed by /i:, u:, a:/

Stop Consonant and Position	Type of long vowel					
	/i: /		/u: /		/a: /	
	mean	range	mean	range	mean	range
Initial/k/	105	80-114	102	79-122	83.25	61-102

The following Praat images illustrate the acoustic waveforms of English native speakers production:

i. Wave Form of Initial /k<sup>h</sup>/ with Long Vowels / i:, u:, a: /

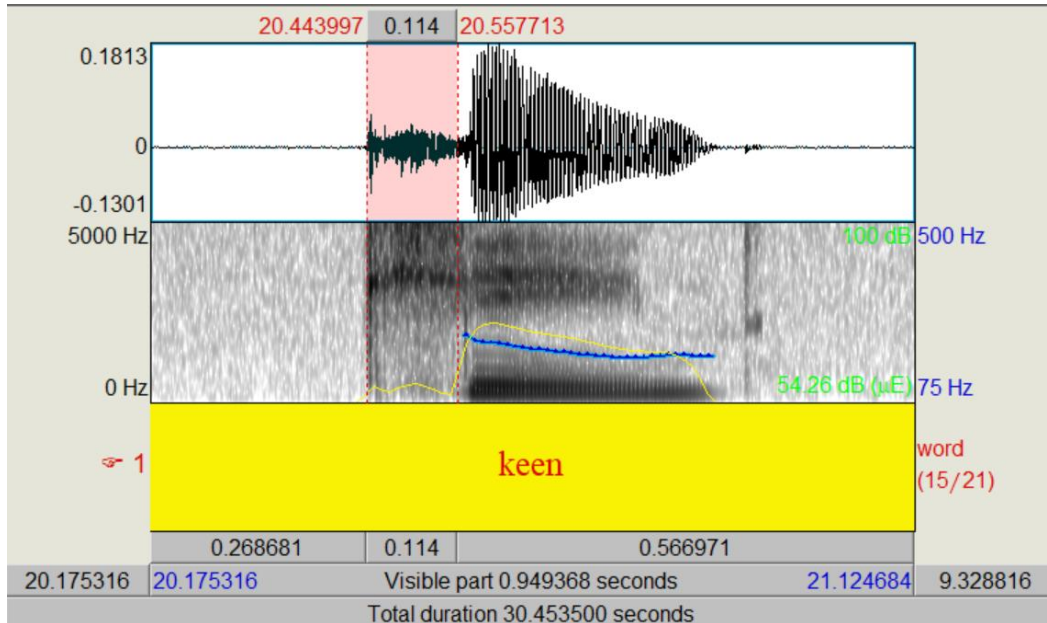


Figure (5): Wave Form of Initial [k<sup>h</sup>] with VOT Value 114 ms of ‘keen’.

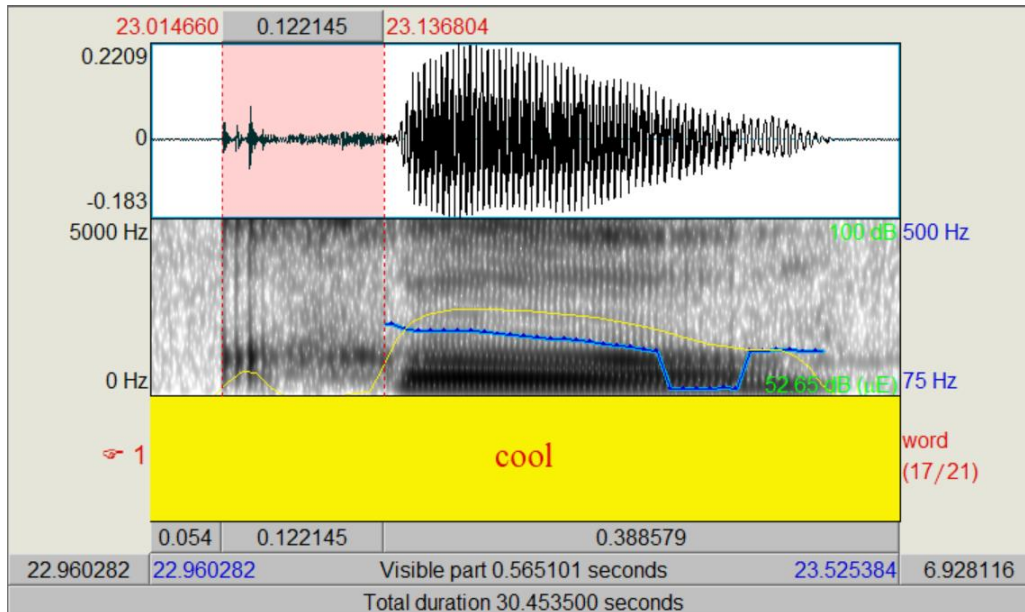


Figure (6): Wave Form of Initial [k<sup>h</sup>] with VOT Value 122 ms of ‘cool’.

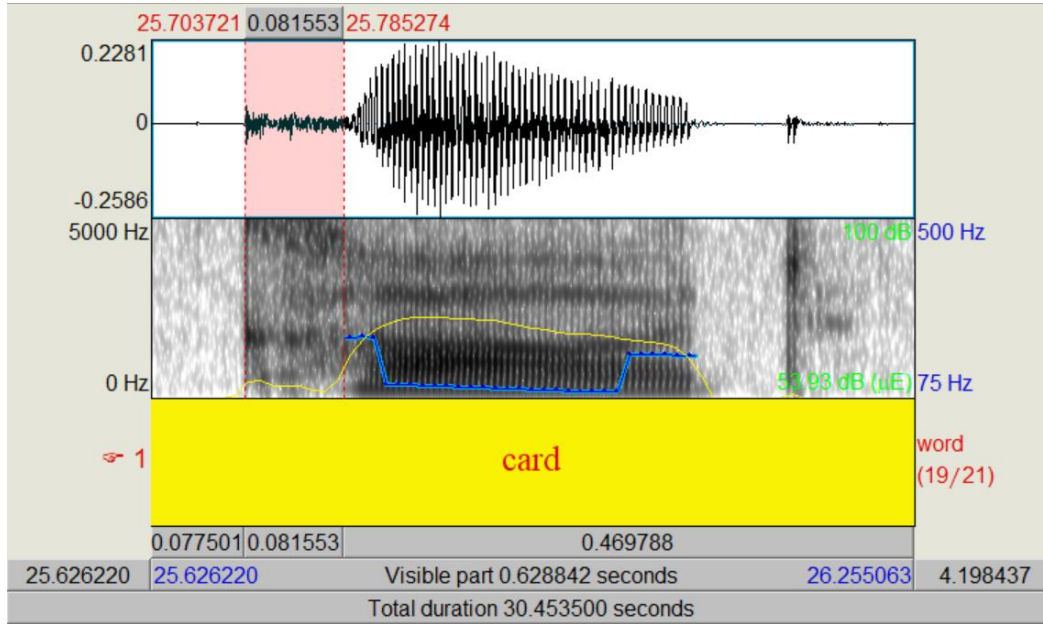


Figure (7): Wave Form of Initial [k<sup>h</sup>] with VOT Value 81 ms of ‘card’.

### 3.2 Iraqi Kurdish VOT

This section outlines the acoustic analysis and the production of VOT for voiceless stops (t, k) in initial position of isolated words in Iraqi Tikrity Arabic in relation to the three long vowels (/i:/, u:/, a/). Each sub section includes a table which clarifies the mean and the range of VOT values of voiceless aspirated plosives followed by long vowels in the initial position in isolation.

#### 3.2.1 VOT Measurement of Voiceless Aspirated Plosive /t<sup>h</sup>/

As to the VOT average, It is found that in initial position the Iraqi Kurdish EFL learners produce /t<sup>h</sup>/ before long /i:/ with a mean (73.8) ms and range (59-112) while before long /u:/ the mean is (64) ms and range (26-82) whereas the mean is (42.3) ms and the range (23-50) is for /t<sup>h</sup>/ before long /a:/. See table (3) below.

Table (3): Voiceless Aspirated Plosive /t/ Followed by /i:, u:, a:/

The Voiceless Stop Consonant and Position	/i: /		/u: /		/a: /	
	mean	range	mean	range	mean	range
Initial/t/	73.8	59-112	64	26-82	42.3	23-50

The following praat images illustrate the acoustic waveforms of Iraqi Kurdish EFL learners speakers production.

i. Wave Form of Initial /t<sup>h</sup>/ with Long Vowels / i:, u:, a: /

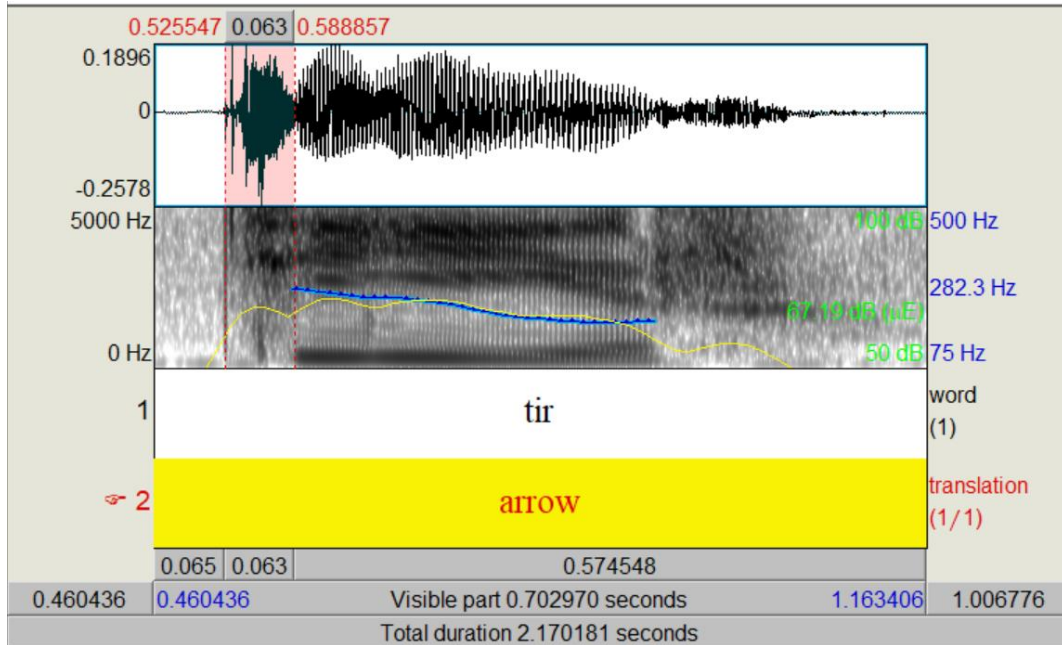


Figure (8): Wave form of Initial [t<sup>h</sup>] with VOT value 63 ms of ‘tir’

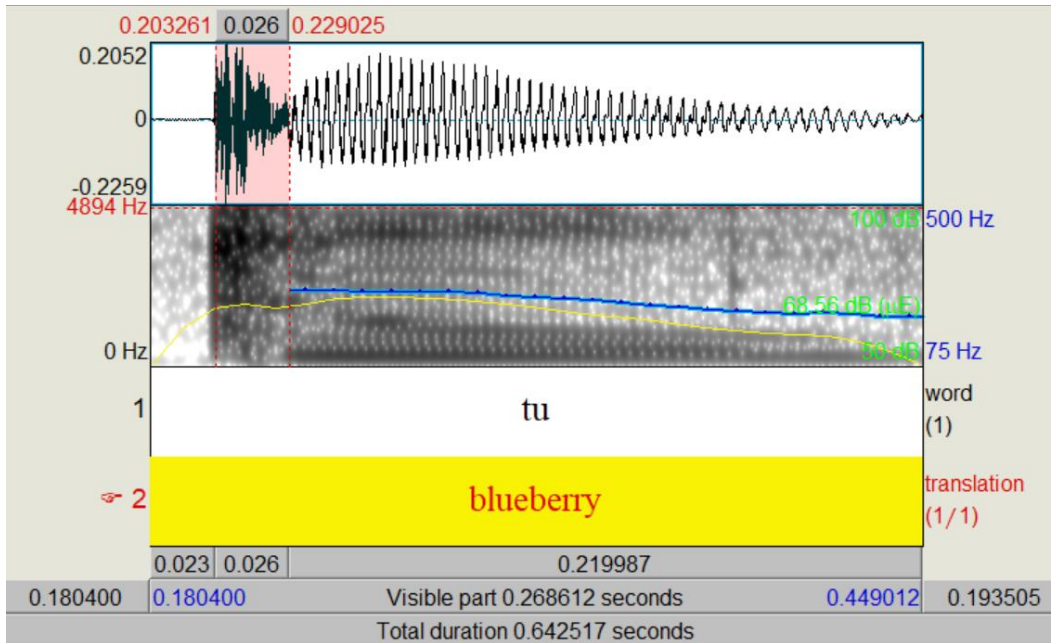


Figure (9): Wave form of Initial [t<sup>h</sup>] with VOT value 26 ms of ‘tu’

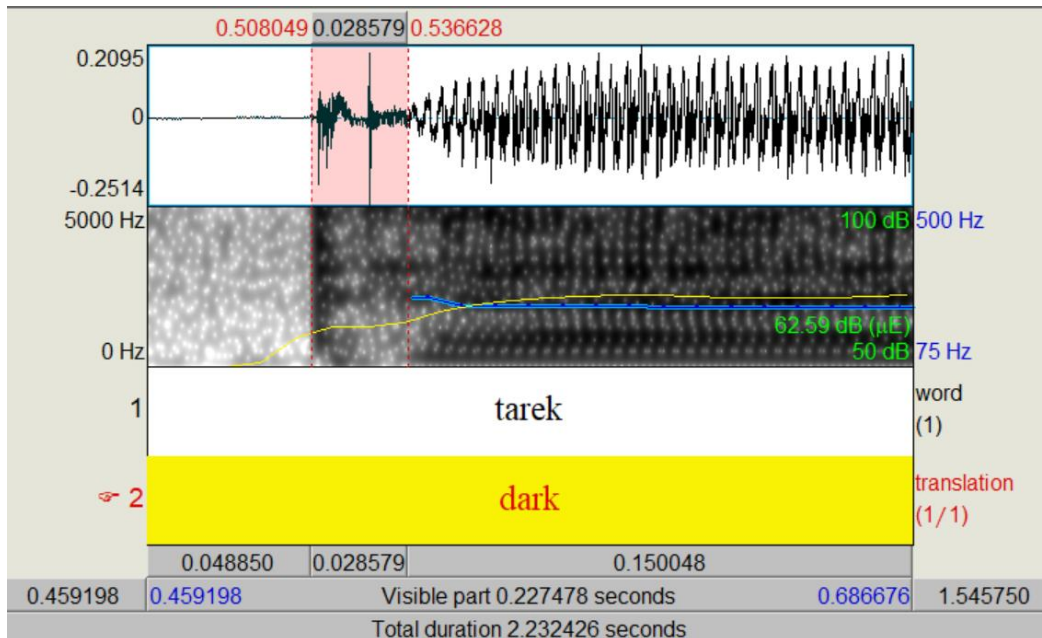


Figure (10): Wave form of Initial [t<sup>h</sup>] with VOT value 28 ms of ‘tarek’

### 3.2.2 VOT Measurement of Voiceless Aspirated Plosive /k<sup>h</sup>/

As to the VOT average, it is found that in initial position the Iraqi Kurdish EFL learners produce /k<sup>h</sup>/ before long /i:/ with a mean (70.1) ms and range (43-88) while before long /u:/ the mean is (55.8) ms and range (36-72) whereas the mean is (63) ms and the range (37-102) is for /k<sup>h</sup>/ before long /a:/. See table (4) below.

Table (4 ):Voiceless Aspirated Plosive /k/ Followed by /i:, u:, a: /

The Voiceless top Consonant and Position	/i: /		/u: /		/a: /	
	mean	range	mean	range	mean	Range
Initial/k/	70.1	43-88	55.8	36-72	63	37-102

The following praat images illustrate the acoustic waveforms of Iraqi Kurdish EFL learners speakers production:

i. Wave Form of Initial /k<sup>h</sup>/ with Long Vowels / i:, u:, a: /

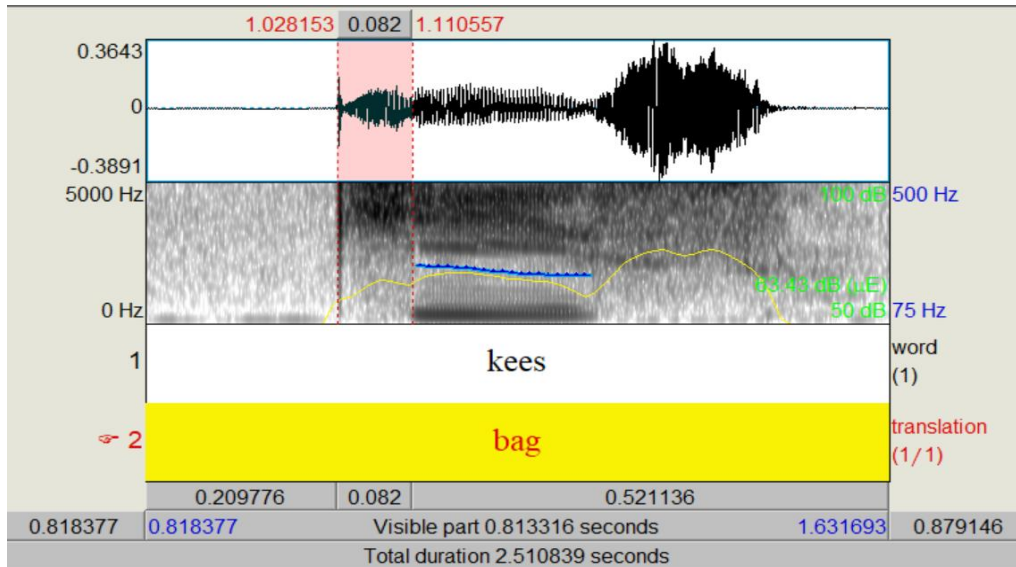


Figure (11): Wave Form of Initial [k<sup>h</sup>] with VOT Value 82 ms of ‘kees’.

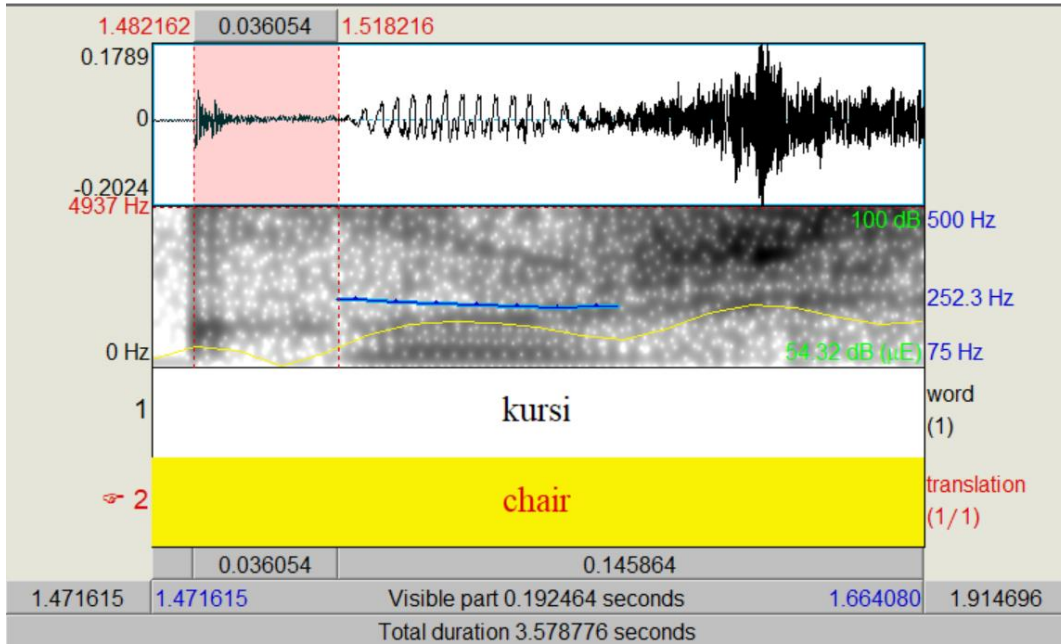


Figure (12): Wave Form of Initial [k<sup>h</sup>] with VOT Value 54 ms of ‘kursi’.

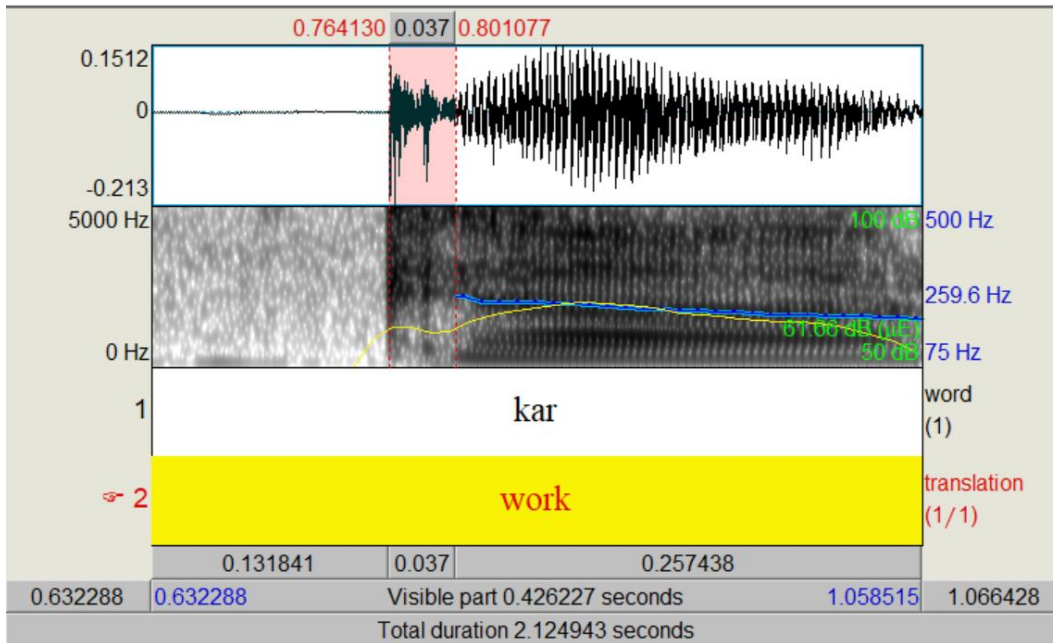


Figure (13): Wave Form of Initial [k<sup>h</sup>] with VOT Value 37 ms of ‘kar’.

#### 4. Discussion

The present study has demonstrated that the three stages of stop production; hold, release and post release were used to form the Kurdish voiceless stops (/t, k/), as well as English voiceless stops (/ t, k/). It has been noted that after the release of voiceless stops, the following voiced sounds began voicing. This indicates that vocal fold vibration began after the release burst in the production of all voiceless stops (i.e. they were all released with a positive VOT). It is important to mention that VOT has either a negative value or a positive value. A negative value ( -VOT) is the case when voicing begins before the release of stop consonants, i.e. during the closure, and is referred to as "voicing lead". On the other hand, the positive value (+VOT) is the case when voicing began after the release. When it is (+VOT) the value will be either: short lag (short VOT value) when voicing starts up to (25) ms after the release, or long lag ( long VOT value) when voicing starts up to more than (25) ms after the release. Therefore, for some plosives ( t, k) voicing starts directly after the release burst, while for other plosives ( t<sup>h</sup>, k<sup>h</sup> ) voicing starts much later after the release. It is worth noting that neither pre-voicing nor voicing lead have appeared in the current study.

- 1) The acoustic analysis of Iraqi Kurdish and English; they have generally long VOT value. However, time length varied depending on several number of variables, as follows:
  - i. The place of articulation: according to Cho and Ladefoged's (1999) viewpoint there is a relationship between the place of articulation and the length of the VOT. They have linked it to physiological and aerodynamic factors like the extended contact between active and passive articulators, movement of articulators, and to the near back of the mouth (back closure). VOT is longer when plosives occur near the back of the mouth because of

different reasons: firstly, the cavity behind the velar plosive is smaller than that behind the bilabial and alveolar plosives. Velar plosives have higher VOT values than bilabial and alveolar plosives because they produce more pressure when the breath is released. As a result, voicing starts later with velar plosives because vocal cord vibration starts later with velar plosives burst. Secondly, Lips and the tongue's tip move much faster than the tongue's back. Velars have longer VOT values than alveolar and bilabial plosives because the tongue tip moves faster than the lower lip. Thirdly, because of their passive and active contact areas, plosives have a longer VOT generally and more extended articulatory contact. According to all the previous reasons, velars have greater VOT values than bilabials and alveolars. In the present study, in all contexts, the velar voiceless plosive has the highest value. So, the result of the present study is consistent with Lisker and Abramson (1964); Crystal & House (1988); Byrd (1993); Cho and Ladefoged (1999); Mitleb (2009); Rahim & Kasim (2009); Mahran & Kasim (2021) point of view.

- ii. Vowel contexts: it is well known that the VOT of stops in different positions, is influenced by vowel context which is linked to vowel height. Vowel height has an effect on VOT values, Higgins et al. (1998) propose that this may be because vocal fold tension and airflow can both delay the onset of vocal fold vibration, which lengthens VOT. A measurement of the timing of all initial stops, such as /t/ in Iraqi Kurdish reveals that the VOT before the low vowel /a:/ is (42) ms and comparatively shorter than that before the high vowel /i:/ which is (73) ms and /u:/ which is (64) ms. This means that the VOT is shorter when there is a following low vowel, and longer when there is a following high vowel. This result is consistent with

the previous studies results which recorded longer VOTs for high vowels than for following low vowels, Klatt (1975), Weismer (1979), port and Rotunno (1979); Rochet and Yanmei (1991); Higgins et al. (1998); Chao et al (2006) and Fischer & Goberman (2010). But it is inconsistent with Lisker and Abramson (1967), who clarifies that the following vowel does not affect the VOT values of the preceding plosives.

- 2) Gender influence: one of the present study main goals is to examine whether gender has an influence on the VOT values of voiceless aspirated plosives ( t<sup>h</sup>, k<sup>h</sup> ) or not. Some researches indicate that gender has a significant effect on VOT ( Swartz, 1992; Ryalls et al, 1999; Karlsson et al. 2004 and Thomas, 2012). While others as (Sweeting and Baken, 1982; Morris et al. 2008; Yu, De Nil, and Pang, 2015) report no differences in VOT production between adult males and females. In the current study, statistical analysis shows that gender has no significant influence on VOT values for Iraqi Kurdish. These results are consistent with previous studies, Sweeting and Baken (1982), Morris et al. (2008) and Yu, De Nil, and Pang, (2015). But the results are inconsistent with previous studies e.g. Swartz (1992), Ryalls et al (1997), Koenig (2000); Whiteside and Marshall (2001) and Al-Malwi (2017). Meanwhile, English native speakers production of VOT shows that gender has a significant influence on VOT values, in which male speakers produce longer VOT value than female speakers do in the production of voiceless aspirated plosive / t<sup>h</sup>, k<sup>h</sup>/. This result shows consistency with Smith (1978) results. He concludes that adult males have higher VOT values than adult female. The reason behind gender differences related to different factors. But these factors have not been fully established yet. Gender differences in VOT production could be explained by these

explanations: firstly, speaking rate; Whiteside (1995, 1996), Swarts (1992), Oh (2011); Byrd (1992, 1994) Ali (2009) and Ali (2022) suggest that in spontaneous speech female's speaking rate is slower than that of male's. Secondly, physiological differences; Smith (1978) and Swarts (1992) state that supra glottal cavity, the length of vocal folds, the air flow rate and the pressure of sub glottal are different in females and males. All these differences might be the reason behind VOT differences.

- 3) With respect to the comparison of VOT patterns in Iraqi Kurdish and English native speakers. Independent T-Test results show that there is a significant difference between English and Iraqi Kurdish language. The results corroborate the claim that there is significant differences exist between these two languages. It is noted that English voiceless plosives ( $t^h$ ,  $k^h$ ) often have higher VOT values than Iraqi Kurdish. Iraqi Kurdish speakers produce the voiceless aspirated plosive  $/t^h/$  with a mean (57.18) ms. Whereas English native speakers produced it with a mean (84.33) ms. And Iraqi Kurdish speakers produce the voiceless aspirated plosive  $/k^h/$  with a mean (62) ms. Whereas English native speakers produce it with a mean (88.83) ms. The findings show higher mean of VOTs in English than Iraqi Kurdish.

## 5. Conclusions

Through the acoustic analysis of the VOT values of voiceless aspirated plosives  $/p^h$ ,  $t^h$ ,  $k^h/$  in the production of Iraqi EFL learners and English, the following conclusions can be drawn:

- 1- Place of articulation has a significant effect on VOT values which asserts the strong interaction between VOT values and place of articulation. The length of the

VOT could be explained by the extended contact between active and passive articulators, articulator movement, and proximity to the near back of the mouth (back closure). The cavity behind the velar plosive is smaller than that behind the bilabial and alveolar plosives, VOT is longer when plosives occur near the back of the mouth. Thus, velar plosives /k/ and /g/ have greater VOT values than bilabials /p/ and /b/ and alveolar plosives /t/ and /d/, because velar plosives develop more pressure when airflow is released, and as a result, voicing starts later after the velars plosives burst because vocal cord vibration begins after the plosive burst.

2- Vowel context has its significant effect on VOT values and asserts the strong interaction between VOT values and vowel context that is voiceless plosives have longer VOTs when they are followed by tense high vowels such as /i:/, /eɪ/ and /u:/ and shorter VOTs when they are followed by tense low and mid vowels /ɪ/, /æ/ and /ɛ/.

3- The influence of gender on VOT values is different from one language to another. Female and male speakers speak differently in English. An independent T-Test result show that gender has no influence on the production of voiceless plosives for Iraqi EFL learners VOT values. Test results provided evidence that the differences in VOT values between the female group and the male group was not statistically significant except for the voiceless plosive /p/ in intervocalic position when it is followed by the long vowel /a:/ .

4- There is a significant difference between English native speakers and Iraqi EFL learners in the production of VOT. An independent T-Test results provided evidence that the differences in VOT values between English native speakers and Iraqi EFL learners language groups was statistically significant. English native speakers produce longer VOT than Iraqi Kurdish.

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