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Voicing Contrast of Stops in the Palestinian Arabic Dialect

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Voicing Contrast of Stops in the Palestinian Arabic Dialect

Abstract

This study investigates the voicing contrast of stops in the Palestinian Arabic dialect by measuring Voice Onset Time (VOT) in both production and perception experiments using the program Praat. The results of the production experiment show that the Palestinian Arabic dialect has negative VOT for voiced stops and short positive VOT for voiceless stops. The VOT pattern for voiceless stops that was observed in eleven languages (Lisker & Abramson, 1964) regarding the relationship between VOT values and the place of articulation of the stop is retained in the Palestinian dialect. As the place of articulation moves back in the vocal tract, VOT for voiceless stops increases. In addition, stops preceding the high front vowel /iː/ are found to have longer VOT durations than those preceding the vowel /aː/. Results also show that VOT is shorter in intervocalic position than in initial position. The Palestinian Arabic dialect has regressive voicing assimilation in medial consonant clusters. In the perception experiment, it is found that VOT is the major acoustic cue in the identification of the homorganic stops /t/, /d/ and, /$t^ʕ$/, /$d^ʕ$/. Furthermore, the following vowel contains cues of the previous stop consonant where higher F0 occurred after voiceless stops and lower F0 occurred after voiced stops.

Key Words

Stop consonants, Voice Onset Time(VOT), Palestinian Arabic.

1. Introduction

Palestinian Arabic is a dialect spoken by people of Palestine, and it is part of the South Levantine Arabic dialect. The Palestinian dialect is a colloquial variety of Arabic which shares common features of Modern Standard Arabic, but also diverges from it. Table 1 provides an overview of the consonantal system of Modern Standard Arabic. There are differences between standard Arabic and different Arabic dialects which also differ from each other as Al-Ani (1970) indicated “The differences in the phonology, morphology, and syntax of theses dialects are often so great that verbal communication between an illiterate Egyptian and an illiterate Iraqi, whether they be townsmen or peasants, is difficult if not impossible” (p. 18).

Table 1. Consonantal system of Modern Standard Arabic (Embarki, M., 2013, p. 27)[1]:

	Bilabial	Labio-dental	Dental	Dento-alveolar	Post-alveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	b			t, d			k	q		ʔ
Nasal	m			n						
Trill				r						
Fricative		f	θ đ	s z	ʃ ʒ			x ɣ	ħ ʕ	h
Approximant						j	w			
Lateral approximant				l						
Pharyngealized plosive				tˤ dˤ						
Pharyngealized fricative			đˤ	sˤ						

Unfortunately, few studies investigated voicing contrast of stop consonants in Arabic. Many of these studies were unsystematic, and show different and often contradictory results. Alghamdi (1990) attributed this difference to three factors: the language, the informants, and the material. First, Arabic is spoken in many countries with different dialects. These dialects vary in phonology, morphology, and syntax (Al-Ani, 1970). Alghamdi (1990) criticized Port, et al.'s study (1980) because five informants were chosen with different dialects, and they were asked to speak Standard Arabic although there are differences between Standard Arabic and spoken dialects. Alghamdi indicated that it is inevitable that there would be a difference in VOT between Arabic dialects. Second, a few number of informants were recruited in studies on Arabic. For example, Hussain (1985) had two informants, one of the informants was the experimenter who was a phonetician and aware of what was measured. Al-Ani (1970) was the primary informant for his experiments. As for the third factor namely the material, Alghamdi also criticized the materials which were used by Hussain (1985), and Al-Ani (1970) because

[1] Transcriptions are adapted to IPA symbols. I changed the place of articulation of the stops /t/, /d/, /tˤ/, and /dˤ/ from dental to dento-alveolar in the chart.

they used isolated words which might influence the duration since isolated words are longer than words in context.

In this study, I investigated voicing contrast of stops in the Palestinian Arabic dialect both in production and in perception using Voice Onset Time(VOT). Modern Standard Arabic has eight stop consonants: /b/, /t/, /d/, /tˤ/, /dˤ/, /k/, /q/, /ʔ/. However, there are some phonemic differences between Modern Standard Arabic and the Palestinian Arabic dialect. For example, the glottal stop phoneme in many words in Modern Standard Arabic has disappeared in Palestinian Arabic as in رأس /raʔs/ 'head' which is pronounced as /raːs/ in the Palestinian dialect. Moreover, distinctive phonological features distinguish different sub-dialects of the Palestinian Arabic such as urban, rural, Bedouin, and Druze dialects. One of the prominent features that characterizes different sub-dialects is the pronunciation of the Modern Standard Arabic /q/ phoneme (corresponding to the letter ق). It is pronounced as [ʔ] in urban dialect, [k] in rural dialect, and [g] in Bedouin dialect whereas it remains [q] in Druze dialect (Jarrar, Habash, Alrimawi, Akra, & Zalmout, 2016). In the present study, I investigated the urban dialect spoken in Nablus city, where /q/ phoneme is pronounced as [ʔ]. Section 2 introduces a background about previous studies on voicing of stop consonants in different Arabic dialects. Three experiments were conducted: one production experiment (section 3), and two perception experiments (section 4). The conclusions are presented in section 5.

2. Theoretical background

Voice Onset Time (VOT) is the time when the voicing starts in relation to the release of the closure for stop consonants. 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 which results in an unaspirated voiceless stop (Alghamdi, 1990). Lisker and Abramson (1964) studied VOT in eleven languages. They divided languages with a two-way contrast in VOT in to two groups: languages which have long positive VOT for voiceless stops and short positive or zero VOT for voiced stops such as English; and languages which have short positive VOT for voiceless stops and negative VOT for voiced stops such as Dutch. They also differentiated between three categories of stops according to voice onset time: Negative VOT between -125 and -75 ms for voiced stops, positive VOT between 0 and 25 ms for voiceless unaspirated stops, and positive VOT between 60 and 100 ms for voiceless aspirated stops. In addition, they found that as the place of articulation moves back from the lips to the velum, the VOT for voiceless stops increases. In Arabic, voiced stops are produced with voicing lead (nearly fully voiced); however, there are significant differences between different Arabic dialects in the duration of voicing lag of voiceless stops (Alghamdi, 1990).

There are very few studies on VOT in different Arabic dialects; however, there are no studies on the Palestinian Arabic dialect except for one study about the production of stops by agrammatic Palestinians with Broca's Aphasia (Adam, 2012). Adam investigated VOT of the alveolar stops /d/ and /t/ in initial position followed by the vowel /a/. He analyzed spontaneous speech samples for five Palestinian Broca's aphasics, and compared their VOT measurements with five normal Palestinian Arabic speakers. For the normal speakers, /t/ was produced with a voicing lag (VOT of 20 ms), and /d/ was produced with a voicing lead (VOT of -10 ms). He found no overlap between VOT values for /t/ and /d/. He concluded that VOT is a reliable acoustic cue for the distinction between these two stops.

As for other Arabic dialects, Al-Ani (1970) did the first experimental work in Arabic phonetics. He studied the phonology of standard Arabic as used in Iraq. Al-Ani was the primary informant for his experiments. Stops were investigated in isolated words. He found a VOT of 60-80 ms for/k/, and a range between -60 and -110 ms for /b/. In final position, /b/ found to be voiced or voiceless, released or unreleased. /ʔ/ had a VOT of 15-20 ms. Al-Ani also studied VOT in pharyngealized stop consonants. His results showed that the VOT of plain dental stops is longer than that of their pharyngealized counterparts. He found a VOT of 40-60 ms for /t/; whereas a shorter VOT of 20-30 ms for /$t^ʕ$/, and a VOT value range between -80 and -100 ms for both /d/, and /$d^ʕ$/.

Yeni-Komshian, Caramaza, & Preston (1977) investigated voicing in Lebanese Arabic. They investigated the production and perception of stop consonants. In the production experiment, participants were asked to read a text containing stop consonants in initial position. In their comparison between /t/ vs /d/, and their pharyngealized counterparts /$t^ʕ$ / vs /$d^ʕ$ /, they found an overlap in VOT values of 0 to 30 ms. They suggested that VOT is not the only acoustic cue used in distinguishing between homorganic stops due to the overlap in the production of these homorganic stops observed in their study. They also investigated initial stops in three different vowel environments where stop consonants were followed by /a/, /u/, and /i/. They found that VOT is longer for voiceless stops preceding front vowels than those preceding back vowels. They also reported that there was a slight sign for the tendency that the VOT for voiceless stops increases as the place of articulation moves back in the vocal tract.

In the perception experiment, Yeni-Komshian, et al. used an imitation response task where participants repeated manipulated synthetic stimuli, and the imitation were transcribed by two listeners. They found that not all stimuli were recognized by the participants as stops, some of them were repeated as /ha/, /za/, /ða/, / ħ/, or /a/. VOT durations were measured for the stimuli that were repeated as stops. They found that participants responded to the difference in VOT values, and there was consistency between the results of the production and the perception experiments.

Flege (1979) studied voicing contrast in the Saudi Arabian Najdi dialect as well as the voicing contrast of English stops produced by Saudi Arabians in his study of the interference in second language acquisition. In the Arabic experiment, he investigated stop consonants in initial and final positions. Six native Saudi Arabian speakers read the test words included in carrier sentences. The test words were of the form CV(V)C where the stop consonants were preceded or followed by the short vowel /a/ or the long vowel /aː/. He found a VOT of 36.8 ms for /t/, and 52.4 ms for /k/. In word- initial position /b/ and /d/ were produced with 100% voicing during the closure interval which had a VOT of -85ms and -82ms respectively. In their investigation of the closure duration, they found that voiceless stops were 10 ms longer than voiced stops.

Alghamdi (1990) investigated voicing distinction of Arabic stops in the Ghamidi dialect spoken in Saudi Arabia by conducting production and perception experiments. He used a reliable methodology; he relied on a large number of informants (22) who were homogeneous in terms of their dialect, age, education, and foreign language experience. In addition, test words were given in sentences, and stops were investigated in initial, intervocalic, and final positions. He found that for voiced stops, the vocal folds vibrate during almost the whole closure interval with a voicing percentage of 98% in word-initial and intervocalic positions, and 92% in word-final position. On the other hand, in voiceless stops the voicing was delayed after the release of the closure, and voiceless stops were aspirated in all positions. Alghamdi found that as the place of articulation moves back in the vocal tract, the voicing duration for voiced stops becomes shorter, and the VOT for voiceless stops becomes longer. He also found that before high vowels, stops show longer VOT duration. Finally, VOT was significantly shorter in intervocalic position than in word-initial and word-final positions.

In the perception experiment, Alghamdi (1990) used both natural and synthesized stimuli. Some acoustic cues were manipulated among them was VOT. Subjects listened to the stimuli and were asked to choose between two words: one with a voiced stop, and the other with a voiceless stop. He found that sounds were categorized as voiceless when VOT values were 10 ms or more; whereas, the number of voiced responses increased as VOT decreased. He suggested that other acoustic cues such as F1 transition play a role in the perception of voicing in Arabic stops.

Mitleb (2001) investigated VOT in Jordanian Arabic alveolar and velar stops. Four native speakers of the Jordanian dialect were asked to read isolated words where sop consonants were word initially followed by /a/ or /aː/. He found that VOT is shorter before short vowels which he attributed to the fact that vowel length is phonemic in Arabic. In addition, his results regarding the effect of place of articulation on VOT values differ from the tendency noticed in other languages. Lisker and Abramson (1964) noticed that VOT duration increases as the place of articulation moves back from the lips to the velum for voiceless stop consonants. However, Mitleb (2001) found no significant difference between VOT values of alveolar and velar stops in both vowel environments. Before short vowels, he found a VOT of 37 ms for /t/, and 39 ms for /k/; whereas before long vowels, the VOT for /t/ was 64 ms and 60 ms for /k/. A similar tendency was found for the difference between /d/, and /g/ where the VOT of /d/ was -10 ms, and for /g/ it was -15 ms before short vowels, and before long vowels there was a VOT of -23 ms for /d/, and -20 ms for /g/. He explained this difference as being due to language-specific tendency.

In a study on Cairene Arabic, Kabrah (2008) found that in this dialect there is regressive voicing assimilation. First, she found that there is regressive devoicing in intervocalic and word-final obstruent clusters. When an underlyingly voiced obstruent precedes a voiceless obstruent, the former is devoiced. For example, the word /ʃabka/ 'jewelry' becomes [ʃapka], and the word /kabt/ 'oppression' becomes [kapt]. Second, there is regressive voicing assimilation in intervocalic and word-final obstruent clusters where an underlyingly voiceless obstruent precedes a voiced obstruent, the former becomes voiced. For instance, the word /yisbaħ/ 'he swims' becomes [yizbaħ], and the word /nasˤb/ 'cheating' becomes [nazˤb]. Voicing assimilation was also observed by Mabrouk (1981) in his study of the Kuwaiti Arabic dialect. He argued that fully voiced stops become partially devoiced before voiceless stops as in [ʔɪb̥talaʃ] 'he got involved'. In addition, in a previous study I conducted on the Palestinian Arabic dialect to find whether it has an allophone [p] in native Arabic words where /b/ precedes a voiceless consonant, I found that [p] is not an allophone of the Arabic phoneme /b/. I found that like the Kuwaiti Arabic dialect, /b/ in the Palestinian Arabic dialect is partially devoiced [b̥] before voiceless consonants (Tamim, 2017). The present study investigated the voicing assimilation in detail for all the stops in the Palestinian Arabic dialect.

3.The production experiment

The research questions, hypotheses, and predictions are discussed in section 3.1. Section 3. 2 is dedicated to the methodology. The results of the production experiment are given in section 3. 3.

3. 1. Research questions, hypotheses, and predictions

In this study, I addressed three research questions in the production experiment. First, I investigated whether the observed pattern of VOT values for voiceless stops in relation to the place of articulation of the stop is retained in the Palestinian dialect. Based on studies on eleven languages (Lisker & Abramson, 1964), I expected that VOT values would increase as the place of articulation moves back in the vocal tract. Second, I examined the effect of the following vowel on VOT in the Palestinian Arabic dialect. I expected longer VOT values before the high front vowel /i/ in the Palestinian Arabic dialect as has been observed in both the Lebanese, and the Saudi Arabic dialects. Third, voicing assimilation in consonant clusters was investigated to see whether the Palestinian Arabic dialect has voicing assimilation as observed in both the Egyptian and the Kuwaiti Arabic dialects.

3. 2. Methodology

3. 2. 1. Participants

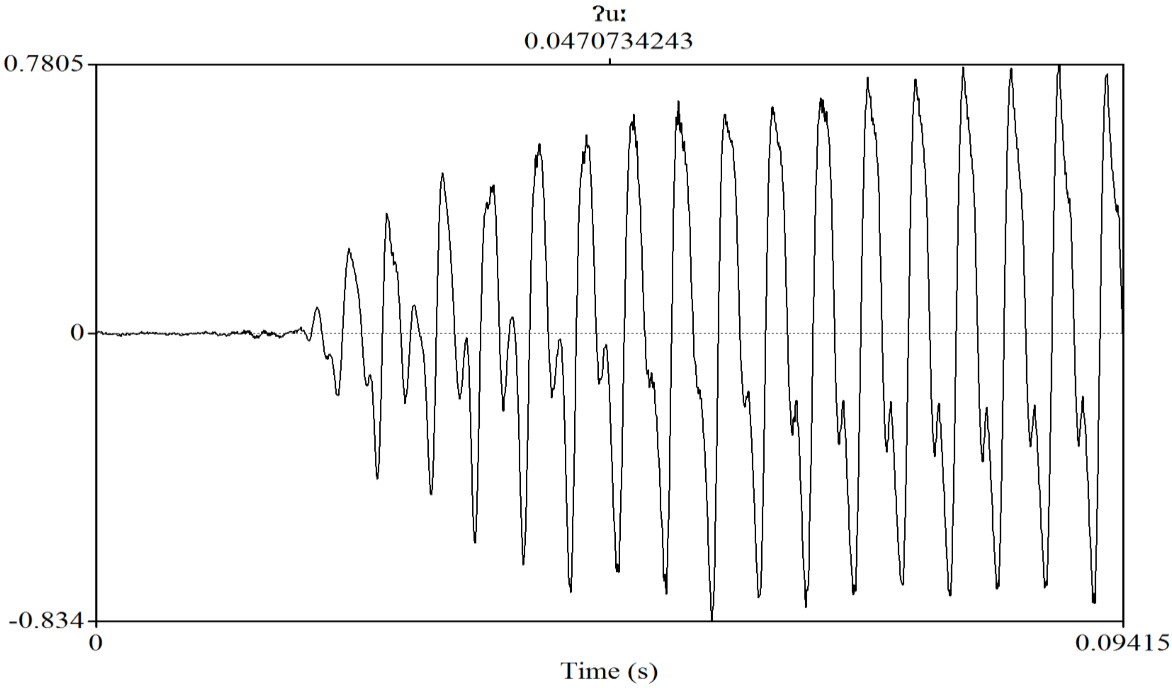
Eight native Palestinian Arabic speakers participated in the study (four males of 22, 27, 29, 31 years, and four females of 23, 24, 28, 29 years). All the subjects speak English as a second language, and they are holders of bachelor degrees in different specializations. All the participants reported having normal speech and hearing. To insure dialect homogeneity, all informants were from Nablus city. Two informants (one female and one male) were excluded and replaced by other participants because one was stuttering, and the other showed a very fast tempo in his speech.

3. 2. 2. Material

The voiced stops /b/, /d/, /d^{ʕ}/, and voiceless stops: /t/, /k/, /t^{ʕ}/were investigated in word-initial position followed by /aː/, /uː/, and /iː/ respectively as illustrated in appendix 1. In addition, these stops were investigated in intervocalic position preceded by /u/, and followed by /aː/ as shown in appendix 2. Stops in final position were not investigated in this study because I found in a previous study on the Palestinian dialect that stops in final position are not always released which makes it difficult to measure VOT (Tamim, 2017).

At first, the glottal stop /ʔ/ was included in the investigation; however, it was excluded after analyzing the first repetition of the eight speakers. It was found that /ʔ/ word initially was not always pronounced by the participants as illustrated in figure 1. In the instances where the /ʔ/ was uttered word initially, it was found that it had a short VOT between 10-15 ms which is similar to that observed by Al-Ani (1970). In his investigation of the Iraqi dialect, Al-Ani measured a VOT of 15-20 ms for /ʔ/.

Figure 1. The deletion of /ʔ/ word initially.



To investigate voicing assimilation, test words with medial consonant clusters were used. Voiced stops were followed by voiceless obstruents, and voiceless stops were followed by voiced obstruents as illustrated in appendix 3. (The meanings and the average VOT measurements of the test words are in Appendices 1, 2 and 3 respectively).

3. 2. 3 Procedure

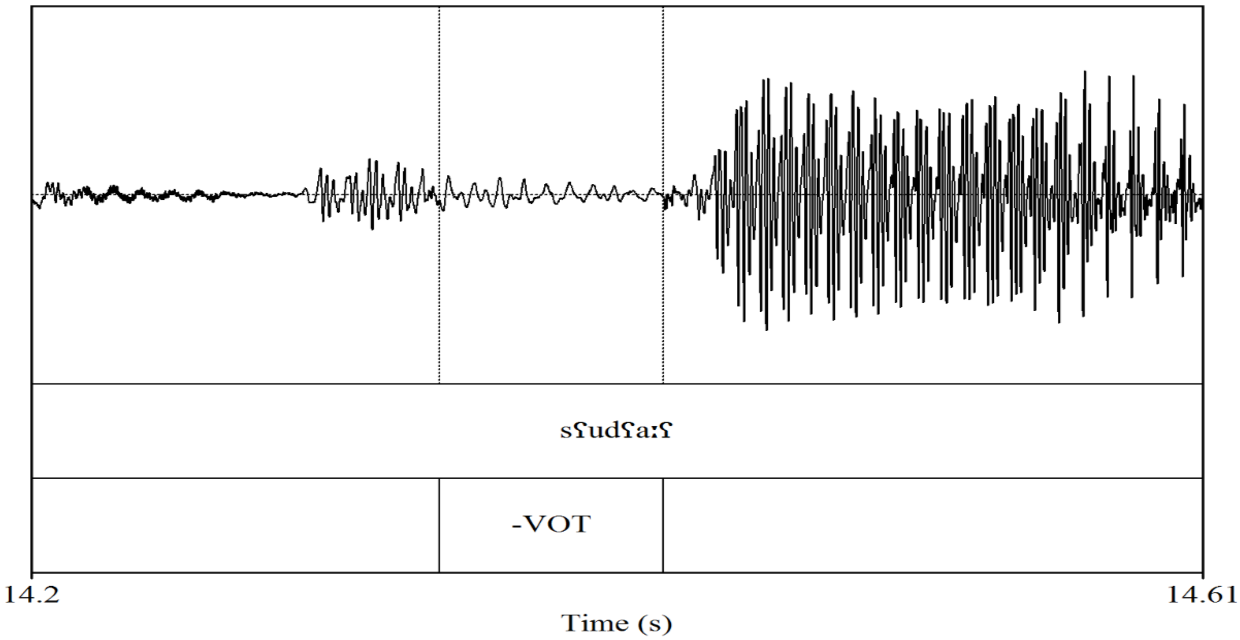
To avoid the problem associated with eliciting dialectical data where the written form is usually associated with Standard Arabic, the procedure adopted by Flege (1979) was used in the present study. It was made clear to the participants that the aim of the study is investigating the Palestinian Arabic dialect rather than Standard Arabic. Participants were asked to read each test word three times inserted in the carrier sentence which is a dialectal expression: /ʒiːt ʔaqraʔ ___

w ʔruːħ/ "I came to read ___ and go". The test words were written in Arabic scripts. The data were collected in Nablus city, Palestine. One of the participants acted as the experimenter. She introduced the test to the participants, and gave instructions in the Palestinian Arabic dialect to read the sentences at a normal tempo in the Palestinian dialect. The sentences were recorded in a quiet room by a laptop with an in-built microphone using the program Praat.

3. 2. 4. Segmentation

720 words were segmented (30 test words * 8 speakers *3 repetitions). In spectrograms, voicing appears as vertical striations which represent the vibrations of the vocal folds. The vocal folds vibrate during the whole closure interval for voiced stops /b/, /d/, /dˤ/. For voiced stops in intervocalic position, the start of voicing in relation to the release of the stop closure was not taken as a reference point in measuring VOT since the vocal folds were already vibrating during the preceding vowel. Therefore, the start of the stop closure was taken as a reference point for the voicing lead of voiced stop in intervocalic position as illustrated in figure 2. The partial devoicing due to voicing assimilation was measured from the beginning of the closure interval where the vocal folds start vibrating to the end of the vibrations within the closure interval. Percentage of voicing duration to the closure duration was calculated.

Figure 2. The negative VOT of the voiced stop /dˤ/ in intervocalic position.



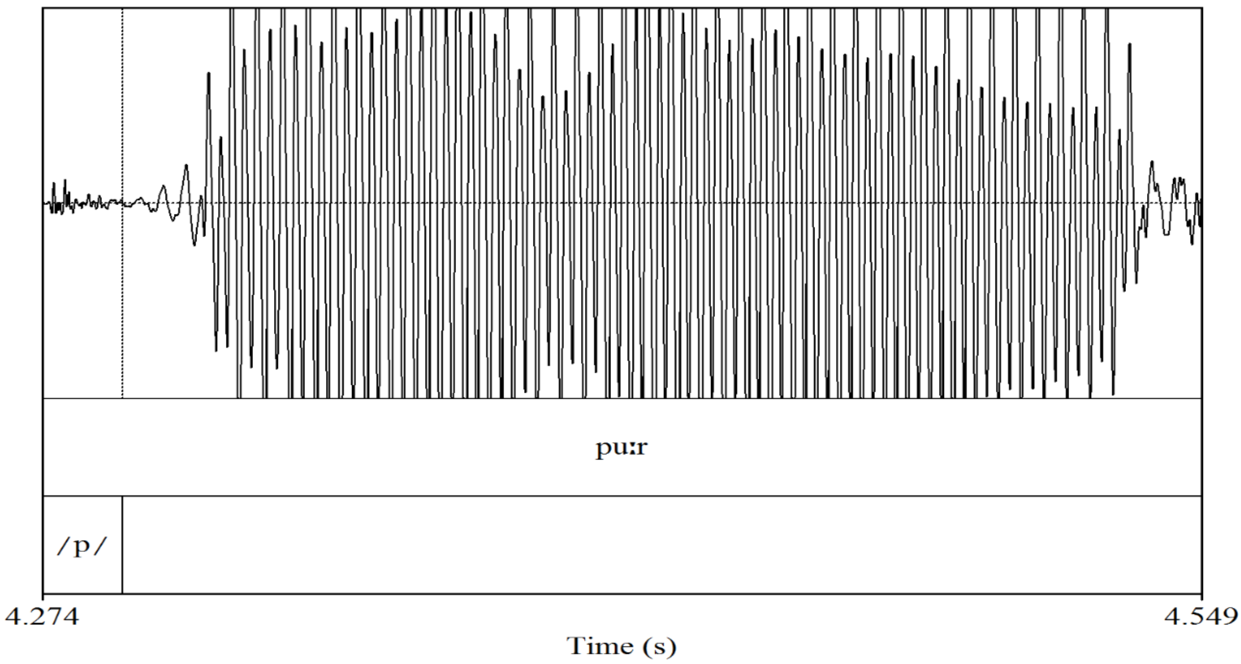
3. 2. 5. Analysis

A Praat script that calculates the durations of the VOT of stops in word-initial and intervocalic positions was used, this script is given in appendix 4. In addition, another Praat script was used to calculate the voicing percentage of stops in medial consonant clusters to investigate the voicing assimilation in the Palestinian Arabic dialect, this scripts can be found in appendix 5. For statistical analysis, a t-test was used where a probability that is lower than 0.05 was considered significant.

3. 3. Results and discussion

The results of the production experiment show that the Palestinian Arabic dialect has negative VOT for voiced stops and short positive VOT for voiceless stops. One VOT measurement was excluded from the average VOT durations for /b/ in /buːr/ because the speaker pronounced /b/ as [p] as illustrated in figure 3; however, the same speaker pronounced the /b/ with prevoicing in the other two repetitions of the same word. /p/ is not a phoneme of Arabic, and since /b/ was pronounces as [p] once out of the 24 repetitions of the word by eight speakers who repeated this word three times, the chance that [p] is an allophone of the Arabic phoneme /b/ is very low. This conclusion is supported by the results of a previous study I conducted on the pronunciation of the English phoneme /p/ in loanwords used by Palestinian Arabic speakers (Tamim, 2017). It was found that the English phoneme /p/ was pronounced as the nearest Arabic phoneme /b/.

Figure 3. The pronunciation of the test word /buːr/ as [puːr] by one of the participants.



The results of average VOT durations in ms for voiceless stops in word-initial position are shown in table 5 and in intervocalic position are given in table 6. The average VOT for /t/, /k/, /tˤ/ before long vowels are 25 ms, 41 ms, 22 ms respectively.

Table 5. Average durations (in ms) of VOT for voiceless stops in the word-initial position with different following vowels.

Following Vowel	t	k	tˤ
aː	16	31	18
uː	23	48	24
iː	35	43	24

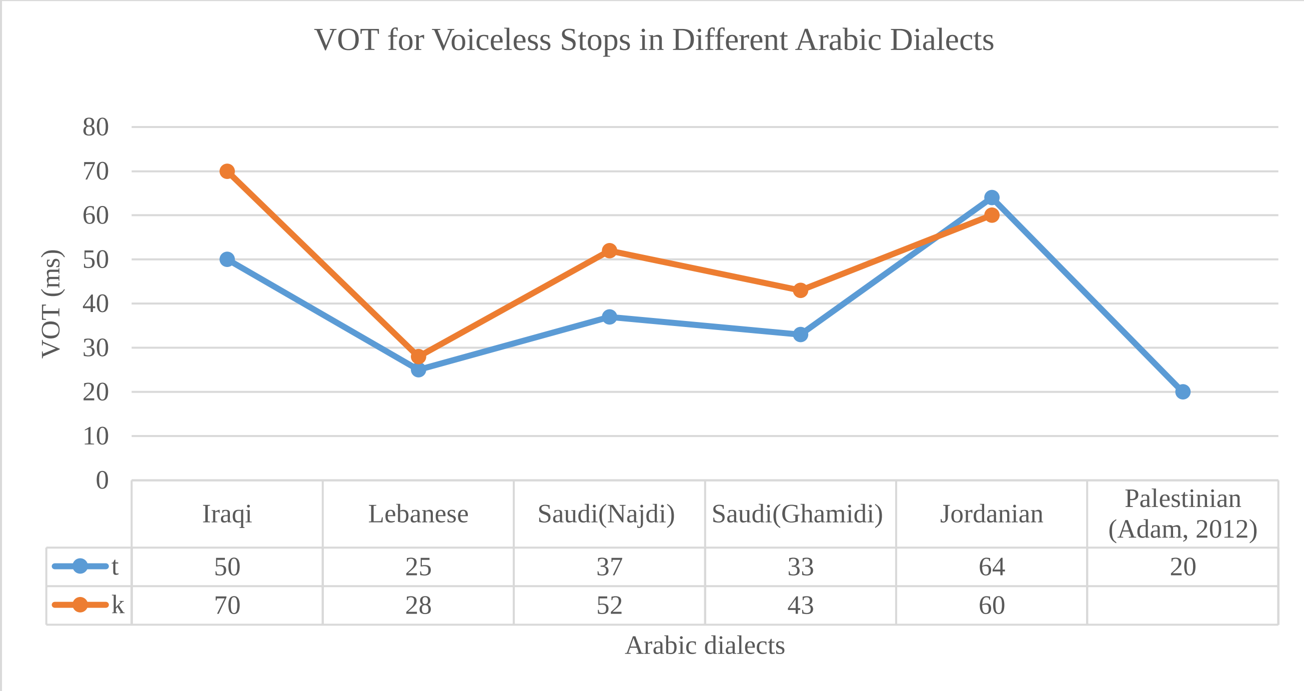
Table 6. Average durations (in ms) of VOT for voiceless stops in the intervocalic position.

Stop	t	k	tˤ
Duration	17	28	18

VOT measurements of the voiceless stops /t/ and /k/ in word-initial position in the present study resemble the results of previous studies on other Arabic dialects except for the studies on the Iraqi dialect (Al-Ani, 1970) and the Jordanian dialect (Mitleb, 2001) which show much longer VOT durations, see figure 4 for VOT durations of the voiceless stops /t/ and /k/ in different Arabic dialects. Al-Ani and Mitleb used isolated words in their study whereas studies on other Arabic dialects used test words in sentences (Alghamdi, 1990; Flege, 1979), a text with test words (Yeni-Komshian et al., 1977), or spontaneous speech (Adam, 2012) which makes it difficult to compare these studies because it has been found that VOT is shorter in sentences than in isolated words (Lisker & Abramson, 1967). In the Jordanian and in the Lebanese dialects, no difference between the VOT of /t/ and /k/ was found; however, the VOT of the voiceless velar stop /k/ is significantly longer than the VOT of the voiceless alveolar stop /t/ in the present study which is similar to the observed pattern in eleven languages (Lisker & Abramson, 1964).

The average VOT for the voiceless pharyngealized stop /tˤ/ in the present study (22 ms) is similar to that in the Iraqi dialect (Al-Ani, 1970), and the Lebanese dialect (Yeni-Komshian et al., 1977) which had a VOT of 25 ms and 23 ms respectively.

Figure 4. VOT (in ms) for voiceless stops in different Arabic dialect. Figures are adapted from Al-Ani (1970), Yeni-Komshian et al. (1977), Flege (1979), Alghamdi (1990), Mitleb (2001), and Adam (2012).



The results of average VOT durations in ms for voiced stops in word-initial position are shown in table 7 and in intervocalic position are given in table 8. The average VOT for /b/, /d/, /$d^{ʕ}$/ before long vowels are -91 ms, -93 ms, -94 ms respectively.

Table 7. Average durations (in ms) of the negative VOT for voiced stops in the word-initial position with different following vowels.

Following Vowel	B	d	$d^{ʕ}$
aː	-93	-76	-93
uː	-83	-99	-94
iː	-98	-103	-94

Table 8. Average durations (in ms) of the negative VOT for voiced stops in the intervocalic position.

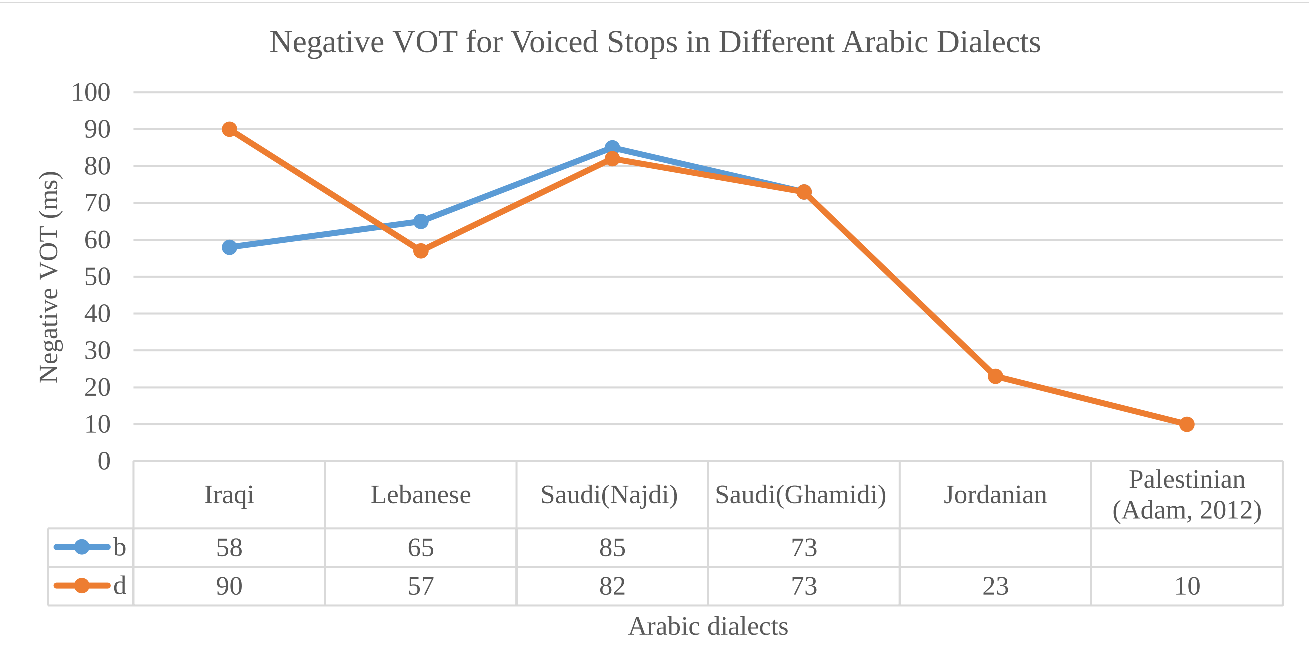
Stop	b	d	$d^{ʕ}$
Duration	-64	-55	-57

The results show that the prevoicing for the voiced stops /b/ and /d/ is longer in the Palestinian Arabic dialect than that for other Arabic dialects, as shown in figure 5. However, the difference is striking between the results of this study and the results of the study on the Jordanian dialect

(Mitleb, 2001), and the previous study on the Palestinian dialect (Adam, 2012). The negative VOT of /d/ -10 ms for the five participants (the control group in Adam's investigation of the VOT characteristics of the Palestinian Broca's aphasics) are questionable. It is not only much shorter than the negative VOT of /d/ in this study (-92 ms), but it is also much shorter than the negative VOT of /d/ in other Arabic dialects.

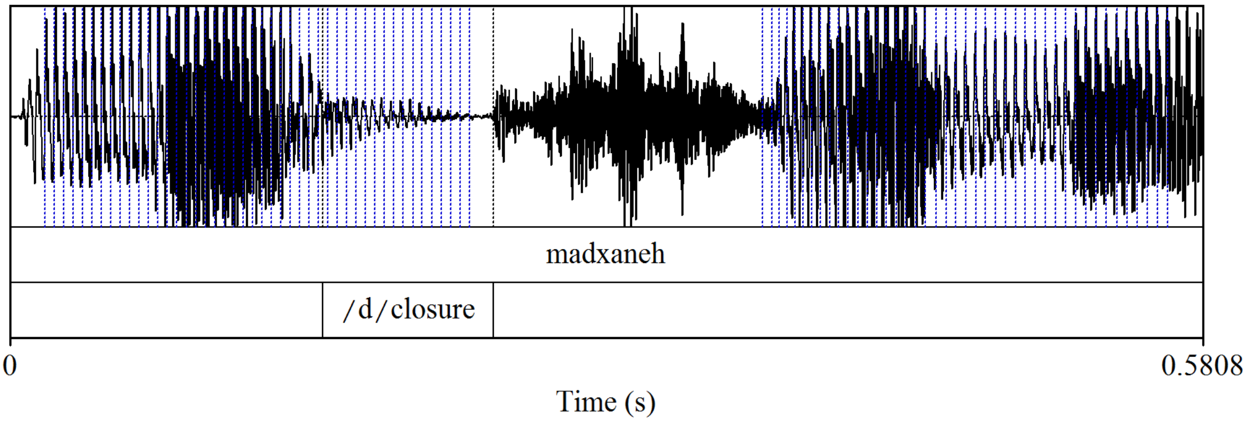
The average negative VOT for the voiced pharyngealized stop /dˁ/ in this study (-94 ms) resembles that of the Iraqi dialect (Al-Ani, 1970) with a negative VOT of -90 ms, and it is longer than that of the Lebanese dialect (Yeni-Komshian et al., 1977) with a negative VOT of -60 ms.

Figure 5. The average negative VOT (in ms) for voiced stops in different Arabic dialects. Figures are adapted from Al-Ani (1970), Yeni-Komshian et al. (1977), Flege (1979), Alghamdi (1990), Mitleb (2001), and Adam (2012).



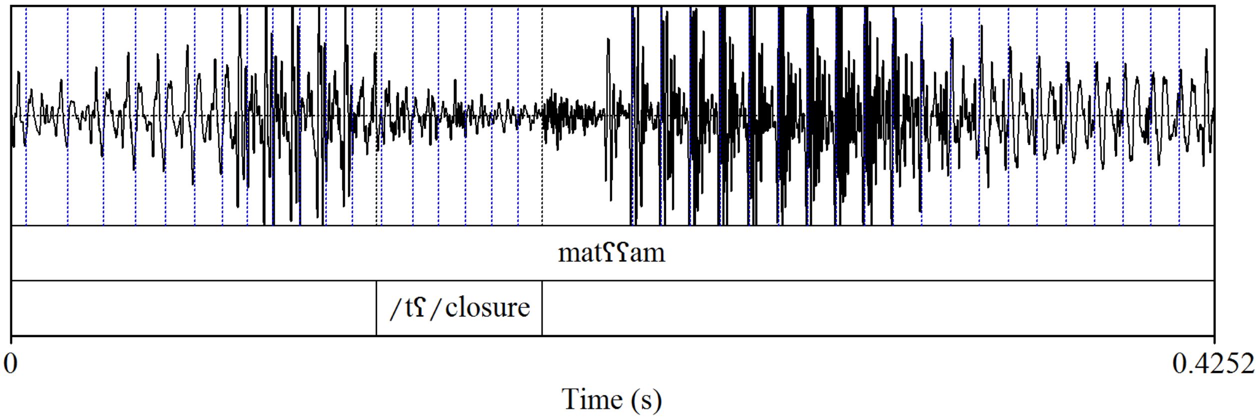
As for voicing assimilation, it was found that the Palestinian Arabic dialect has regressive voicing assimilation. Minimal regressive devoicing in intervocalic position was found where the three voiced tops /b/, /d/, /dˁ/ were minimally devoiced with a voicing percentage of 94%, 92%, 94% respectively. Figure 6 demonstrates the minimal devoicing of /d/ in the test word /madxaneh/. The Palestinian dialect is like the Kuwaiti Arabic dialect in that fully voiced stops become partially devoiced before voiceless consonants (Mabrouk, 1981). In the Egyptian Arabic dialect, the preceding voiced consonant becomes fully devoiced as in /ʃabka/ 'jewelry' becomes [ʃapka] (Kabrah, 2008) which is not the case in the Palestinian Arabic dialect, where the same word is pronounced as [ʃabkeh] with minimal devoicing of the /b/.

Figure 6. Minimal devoicing during the closure of /d/ in the test word /madxaneh/. The blue striations represent the vibrations of the vocal folds.



The results show regressive voicing assimilation in intervocalic position. The voiceless stops /k/, /t/, /tˤ/ become voiced to a high percentage namely 84%, 97%, 88% respectively. Figure 7 shows the voicing during the closure of the underlyingly voiceless stop /tˤ/ in the test word /matˤʕam/. like the Egyptian Arabic dialect (Kabrah, 2008), the Palestinian Arabic dialect has regressive voicing assimilation. In the Egyptian Arabic dialect, voiceless fricatives become fully voiced before voiced obstruents /yisbaħ/ 'he swims' becomes [yizbaħ]. In the Palestinian Arabic dialect, the voiceless stops become voiced to a high percentage but not fully voiced. Further research is recommended on the Palestinian Arabic dialect for regressive voicing assimilation on fricatives and other sounds before reaching final conclusions.

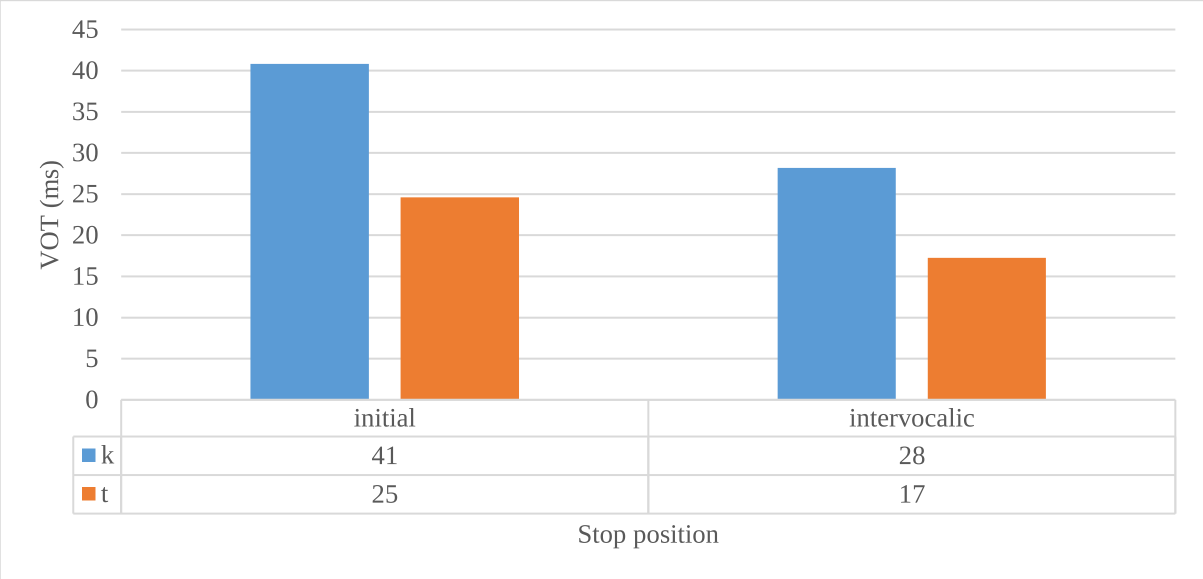
Figure 7. Voicing during the closure of the underlyingly voiceless stop /tˤ/ in the test word /matˤʕam/. The blue striations represent the vibrations of the vocal folds.



There are three factors that affect VOT in the present study: First, the place of articulation. For voiceless stops, alveolar stops show shorter VOT durations than velar stops. Second, the following vowel affects VOT. VOT is significantly longer before the high vowel /iː/ than before the vowel /aː/. Third, the stop position in the word influences VOT. Shorter VOT is found in intervocalic position than in word-initial position.

First, the place of articulation of the stop affects VOT. Lisker and Abramson (1964) in their study of VOT in eleven languages found that as the place of articulation moves back from the lips to the velum, the VOT for voiceless stops increases. The same pattern was observed in different Arabic dialects (Figure 4). This pattern is found in the present study as well. The VOT for the voiceless velar stop /k/ is significantly longer than the VOT for the voiceless alveolar stop /t/ ($p < 0.001$) in word-initial and intervocalic positions as shown in figure 8.

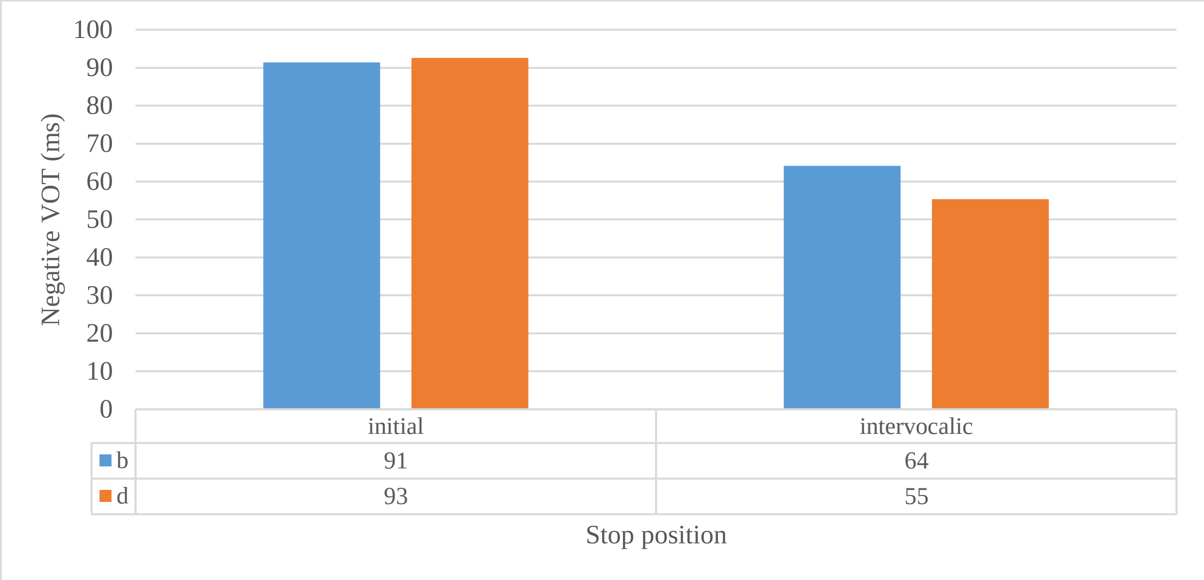
Figure 8. The average VOT (ms) of voiceless stops in word-initial and intervocalic positions.



Cho & Ladefoged (1999) cited different explanations from the literature for the increase of the VOT for voiceless stops as the place of articulation moves back in the vocal tract. Some of the explanations were based on general laws of aerodynamics. For instance, the size of the supralaryngeal cavity behind the velar constriction is smaller than that behind the alveolar constriction which causes higher pressure. This high pressure takes a longer time to fall and produce an adequate transglottal pressure difference necessary for the beginning of the vibration of the vocal folds.

For voiced stops, the average negative VOT of /b/ (-91 ms) is slightly shorter than the average negative VOT of /d/ (-93 ms) in word-initial position; however, the pattern is reversed in intervocalic position. The average negative VOT of /b/ in intervocalic position (-64 ms) is longer than that of /d/ (-55 ms) as illustrated in figure 9. Nevertheless, statistics show that the negative VOT for /b/ is not significantly longer than that for /d/ ($p > 0.05$) in intervocalic position. Alghamdi (1990) in his study on the Saudi (Ghamidi) dialect found a tendency towards having longer negative VOT for the bilabial voiced stop /b/ than for the alveolar voiced stop /d/. The reason is that the size of the supraglottal cavity behind the bilabial constriction is larger than that behind the alveolar constriction that keeps the difference between the sub-glottal and supraglottal air pressure large which is favorable for voicing (Alghamdi, 1990).

Figure 9. The average negative VOT (ms) of voiced stops in word-initial and intervocalic positions.



The second factor that affects VOT is the following vowel. It was observed in the Saudi-Ghamidi dialect (Alghamdi, 1990) that the high front vowel /i:/is preceded by longer VOT durations for both voiced and voiceless stops. However, in the Lebanese dialect, Yeni-Komshian et al., (1977) found a tendency for longer VOT for voiceless stops and shorter negative VOT for voiced stops before the high front vowel /i:/. The results of the present study are in agreement with the previous study on the Saudi-Ghamidi dialect in that the stops preceding the high front vowel /i:/ have longer VOT durations for both voiceless and voiced stops than those preceding vowel /a:/ ($p<0.05$) as illustrated in figure 10 and figure 11. Whereas the VOT before the high front vowel /i:/ is not significantly longer than that preceding the high back vowel /u:/ for voiceless and voiced stops ($p>0.05$).

Figure 10. The average VOT durations (ms) of voiceless stops followed by /a:/, /i:/, and /u:/ respectively.

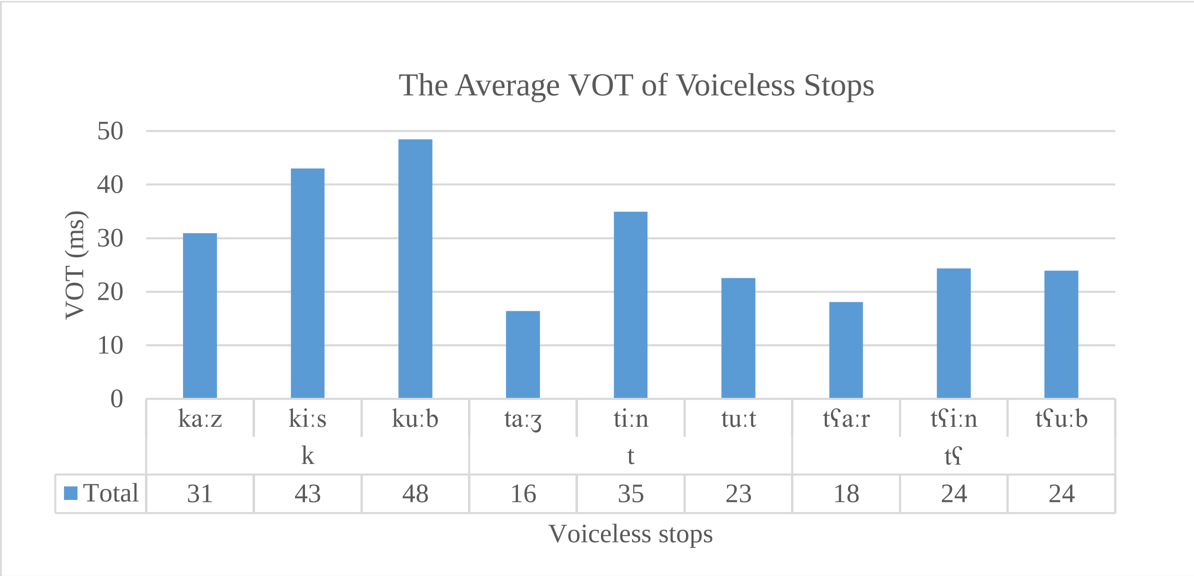
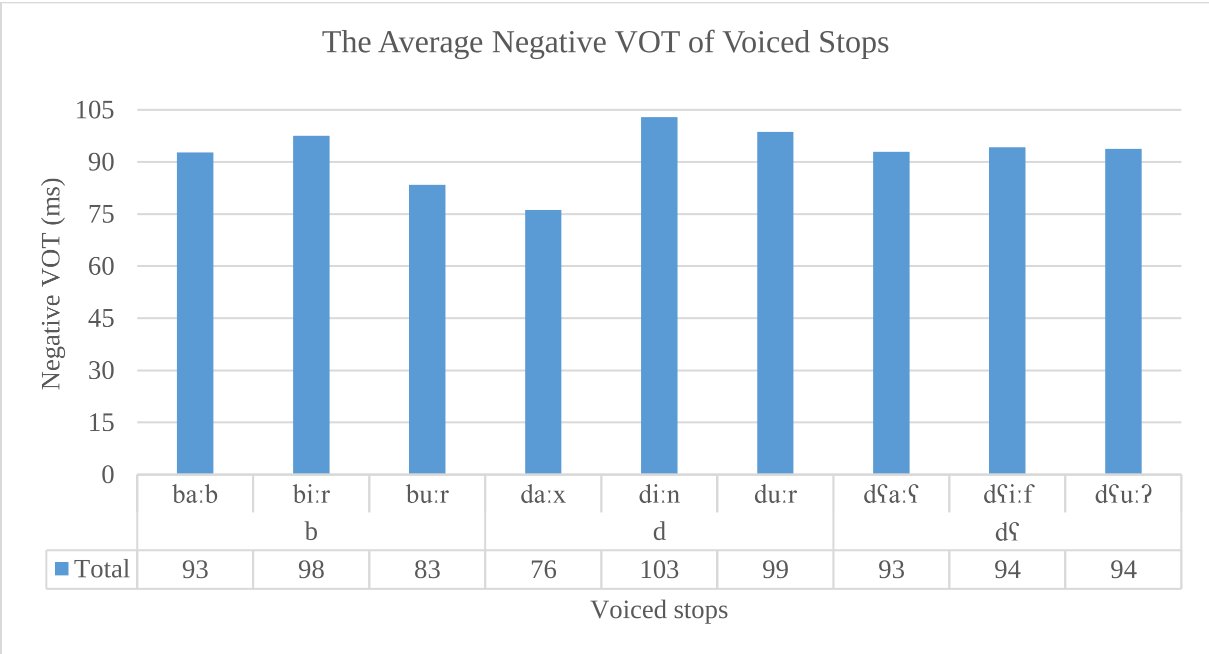


Figure 11. The average negative VOT durations (ms) of voiced stops followed by /a:/, /i:/, and /u:/ respectively.



Finally, the stop position is found to influence VOT. It was noted that in the Saudi dialect, the VOT in intervocalic position is significantly shorter than the VOT in word-initial position (Alghamdi, 1990). A similar effect of the stop position on VOT is observed in this study on the Palestinian dialect. VOT is significantly shorter for voiced and voiceless stops in intervocalic position than in initial position ($p < 0.001$) as illustrated in figure 12 and figure 13.

Figure 12. Average VOT (ms) of voiceless stops in initial and intervocalic positions.

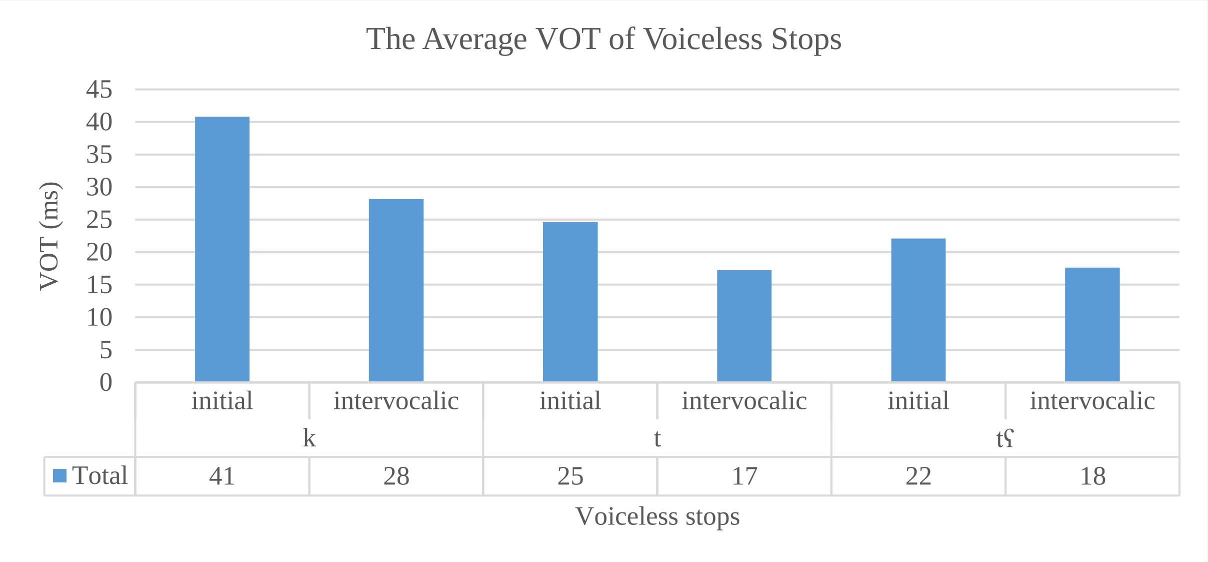
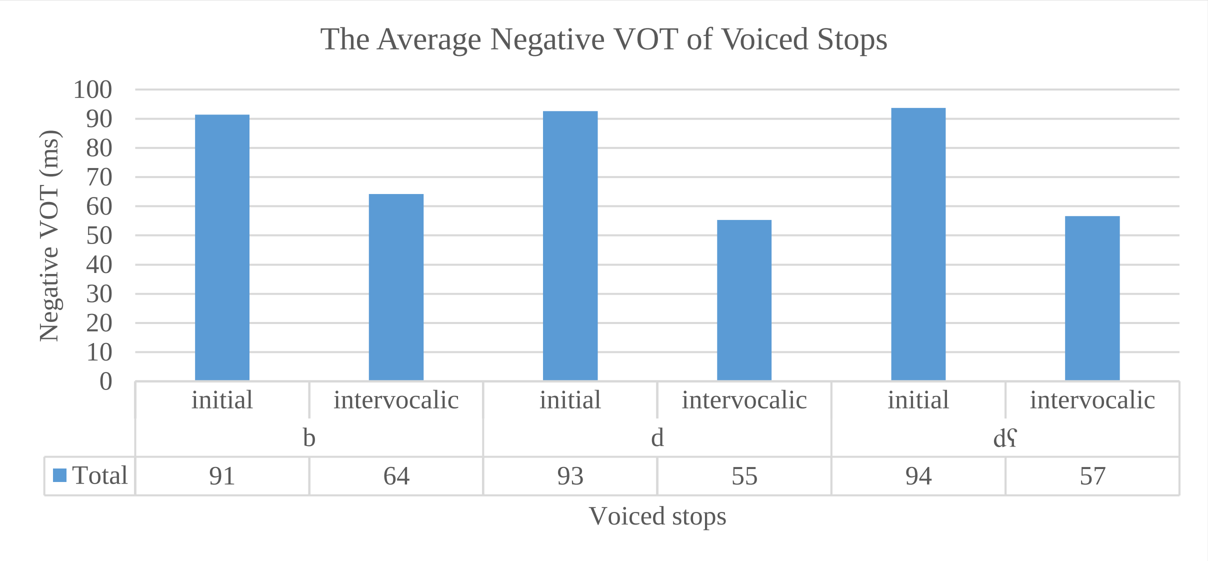


Figure 13. Average negative VOT (ms) of voiced stops in initial and intervocalic positions.



4. The perception experiments

Two perception experiments were conducted in the present study. The research questions, hypotheses, and predictions are discussed in section 4.1. Section 4.2 is dedicated to the methodology. The results of the first perception experiment are given in section 4.3.1. The results of the second perception experiment are shown in section 4.3.2.

4. 1. Research questions, hypotheses, and predictions

I examined weather Palestinian Arabic speakers respond to differences in VOT as observed in other Arabic dialects. I expected that in the phonetic categorization of the VOT continuum, it would be easier for listeners to identify stimuli that belong to the unambiguous area of the continuum (end points of the continuum) than the stimuli that belong to the narrow boundary region containing phonetically ambiguous stimuli. I also explored whether VOT is a sufficient acoustic cue for distinguishing between homorganic stops /$t^{ʕ}$/, /$d^{ʕ}$/, and, /t/, /d/. I anticipated that the participants would be able to identify homorganic stops when the duration of VOT is manipulated if VOT is the major acoustic cue for the distinction between these homorganic stops. Therefore, VOT was examined before the same vowel taken from the same word (the vowel was taken from a word where it follows a voiceless stop), and from different words (the vowel was taken from a word where it follows a voiceless stop, and from a word where it follows a voiced stop). I also investigated the VOT boundary between /t/and /d/ besides examining the VOT boundary between their pharyngealized counterparts /$t^{ʕ}$/ and /$d^{ʕ}$/.

4. 2. Methodology

Phonetic categorization task was used in this study. Participants listened to different stimuli ranging from one end of the VOT continuum to the other end. Participants were asked to choose between two given options.

4. 2. 1. Participants

The same eight participants (four males and four females) who took part in the production experiment were recruited in the perception experiment.

4. 2. 2. Materials

The dental stops /t/, /d/, and their pharyngealized counterparts /$t^{ʕ}$/, / $d^{ʕ}$/were investigated in minimal pairs shown in Table 9.

Table 9. Answer categories presented in the perception experiment.

Choices						
First Choice				Second Choice		
Arabic Script	IPA	Meaning		Arabic Script	IPA	Meaning
تاب	ta:b	repented		داب	da:b	dissolved
طاف	$t^{ʕ}$a:f	circled		ضاف	$d^{ʕ}$a:f	added

I used naturally produced tokens and then manipulated them. Four productions of each of these four words were recorded in the speech lab of the University of Amsterdam by the author who is a native Palestinian Arabic speaker. The VOT of the stops were measured, and the stop that has the closest VOT to the average was considered the best representative of the four repetitions, and the VOT of that stop was used for the manipulation of the stimuli. Table 10 shows the VOT values for the four stops used in the perception experiment which I will call the reference VOT in the following.

Table 10. The reference VOT values for /d/, /t/, /dˤ/, /tˤ/.

Stop	/d/	/t/	/dˤ/	/tˤ/
VOT	-67	22	-84	13

The burst duration and the burst amplitude were averaged to get an ambiguous burst for /d/, /t/, and for /dˤ/, /tˤ/. The remaining part /aːb/ for the /daːb/-/taːb/ pair was taken from /taːb/. The /aːf/ for /dˤaːf/ -/tˤaːf/ pair was taken from /tˤaːf/.

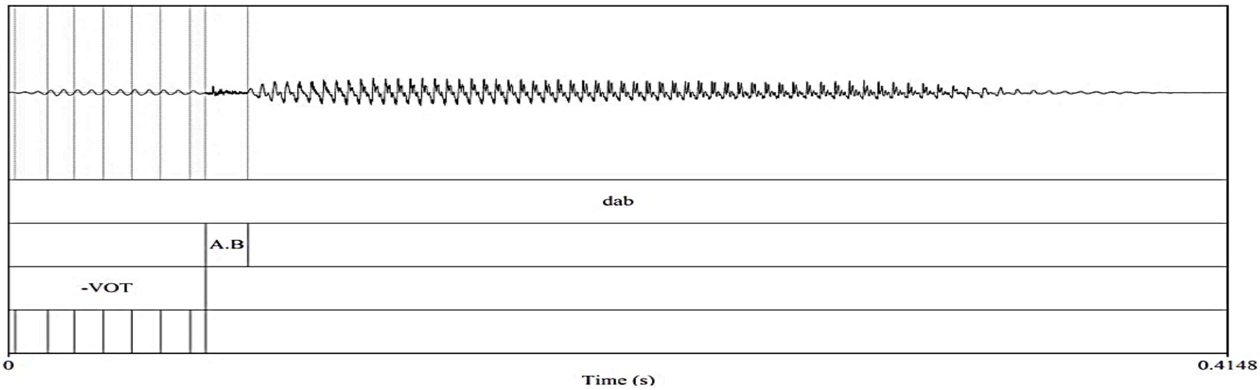
When I played back the separate /aːb/ and /aːf/, I noticed a trace of the previous /t/ in /aːb/, and of /tˤ/ in /aːf/. Therefore, I designed another perception experiment with the same ambiguous bursts, but the /aːb/ was taken from /taːb/ for the stimuli with positive VOT, and from /daːb/ for the stimuli with negative VOT. The same procedure was followed for the /tˤaːf/-/dˤaːf/ pair to investigate the effect of the following vowel on the VOT boundary. I hypothesized that if the vowel contains cues of the previous stop consonant, then the first experiment where the vowel was taken form the same word (the /aː/ was taken from /taːb/ for both stimuli with negative VOT and for stimuli with positive VOT), would influence the VOT boundary where more /taːb/ responses were predicted. Similarly, by taking the vowel from /tˤaːf/ for both stimuli with negative VOT and for stimuli with positive VOT, more /tˤaːf/ responses were expected.

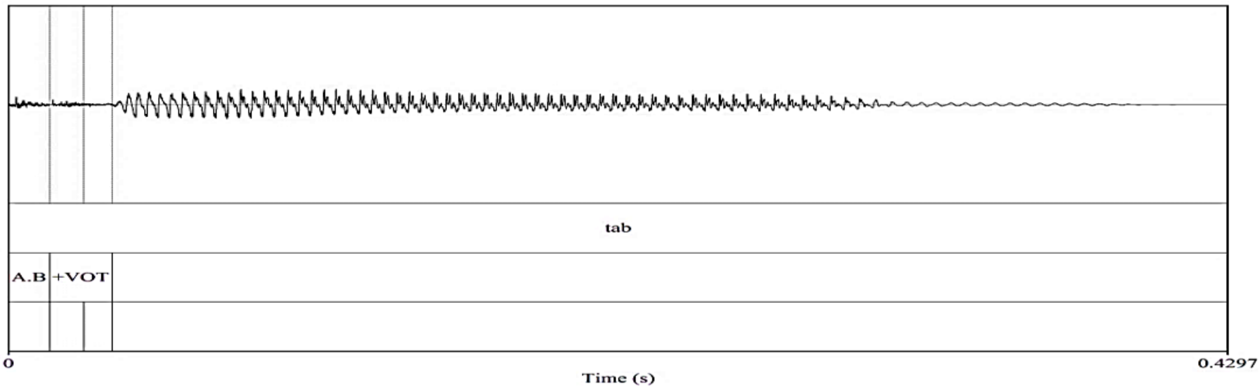
The prevoicing of -67ms (the reference VOT for /d/) was added before the ambiguous burst, then the /aːb/ was inserted after the burst to create the first stimulus /daːb/. The noise of 22 ms (the reference VOT for /t/) was added after the ambiguous burst, then the /aːb/ was inserted after the noise to create /taːb/. The two stimuli were ready to be used in the creation of the VOT continuum for /d/-/t/. The stimuli varied in steps of 10 ms, so 10 ms was cut off from the beginning of the prevoicing which results in creating 7 stimuli with VOT of -67, -57, -47, -37, -27, -17, -7. For the positive VOT stimuli, the 10 ms was cut from the noise to create the stimuli of 22ms and 12ms. One of the stimuli contained the ambiguous burst followed by the /aːb/ which was called stimulus 0. The negative and the positive parts of the continuum were not divided into equal steps since the reference VOT values of stop sounds were not multiples of ten, so the 10 ms step was not always possible. In addition, the steps which were intended to correspond to 10 ms were not exactly 10 ms since the cutting was at the zero crossing. (see figure 14). Table 11 shows the VOT continuum.

Table11. VOT continuum for /d/-/t/ with the calculated steps and the actual steps after cutting at zero crossing.

Stimuli	-67	-57	-47	-37	-27	-17	-7	0	12	22
Actual	-64.7	-53.7	-44.6	-34.9	-25.1	-15.3	-5.2		12.1	22.1
Steps		11	9.1	9.7	9.8	9.8	10.1		10	

Figure 14. The stimuli /daːb/-/taːb/. A.B: Ambiguous Burst.



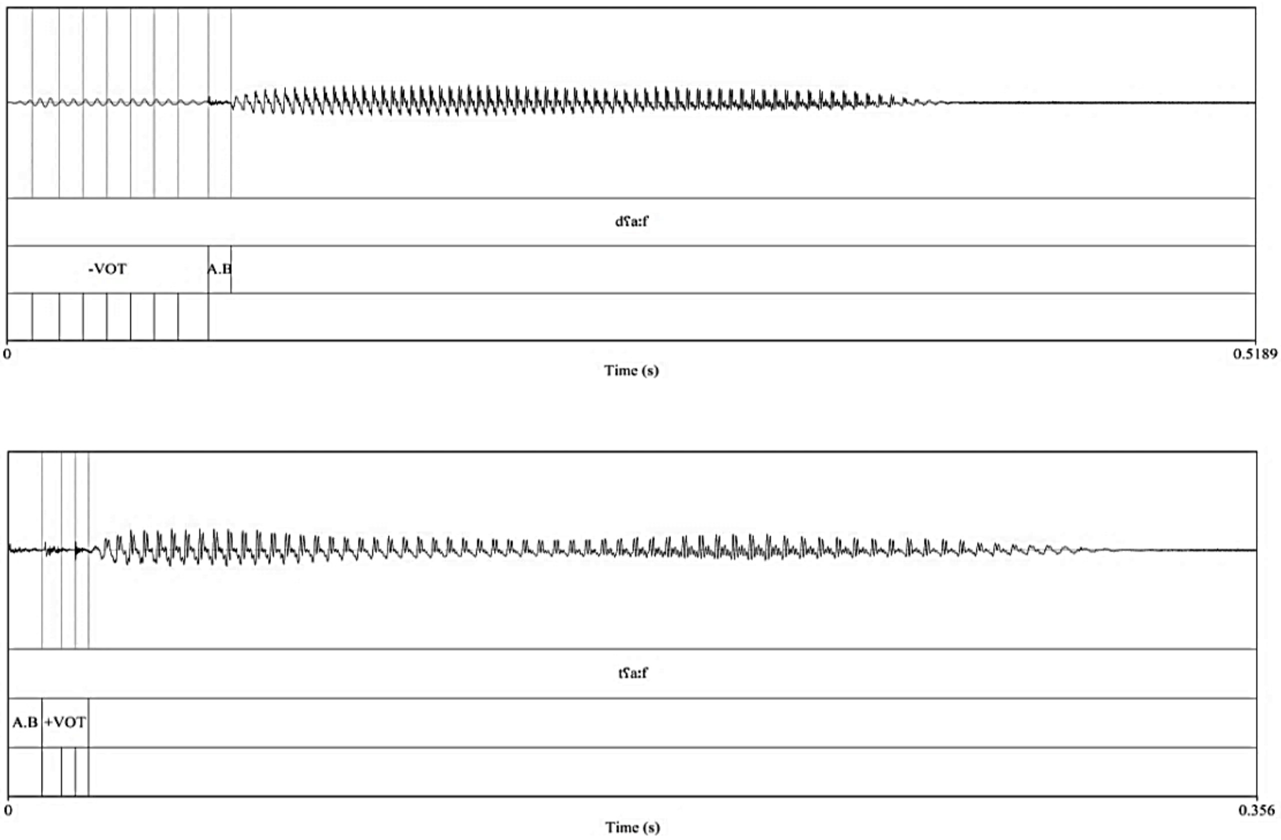


The /dˤaːf/ and /tˤaːf/ stimuli were created in the same way by adding the prevoicing of -84 ms for /dˤaːf/, and the noise of 13 ms for /tˤaːf/. The cutting of 10 ms steps produced 8 stimuli on the negative side of the VOT continuum. The reference VOT of /tˤ/ is 13 ms almost corresponds to one step, which would result in only one stimulus on the positive side of the VOT continuum. To avoid the risk that the participants could start choosing /tˤaːf/ responses haphazardly since they were presented with most of the stimuli with prevoicing, the 13 ms noise was cut into steps of 4 ms which led to two more stimuli on the positive side of the continuum namely stimuli with a VOT of 9ms and 5 ms respectively. The stimulus that contained the ambiguous burst followed by the /aːf/ was called stimulus 0. The continuum is not divided at equal steps for the reason mentioned above. The cutting was also at zero crossing, so the steps were not exactly as calculated (see figure 15). Table 12 illustrates the VOT continuum for /dˤ/- /tˤ/.

Table 12. VOT continuum for /dˤ/- /tˤ/

Stimuli	-84	-74	-64	-54	-44	-34	-24	-14	0	5	9	13
Actual	-83.5	-72.9	-61.7	-51.9	-42.1	-32.3	-22.5	-12.4		5.6	9.5	13.2
Steps		10.6	11.2	9.8	9.8	9.8	9.8	10.1		3.9	3.7	

Figure 15. The stimuli /dˤaːf/ -/tˤaːf/. A.B: Ambiguous Burst.



4. 2. 3. Procedure

The perception experiments were designed with Praat Experiment MFC (see appendix 6 for the script). Each stimulus in the continuum was played three times which resulted in 30 stimuli in the /daːb/-/taːb/ experiment, and 36 stimuli in /dˤaːf/, /tˤaːf/ experiment. The stimuli were played in a randomized order. The participants were offered an optional break in the middle of each experiment, and there was a "repeat" button that can replay the stimulus up to five times. Instruction were given in Arabic, and they appeared on the introductory screen. It was made clear in the instructions that the answers were not equally divided to avoid random answers. Appendix 7 shows the experiment screen for the /dˤaːf/, /tˤaːf/ experiment. In a quiet room using a headphone, the participants listened to the stimuli and chose from the options illustrated in table 9.

4. 3. Results and discussion

The results show that speakers responded to the difference in VOT which means that VOT is a major acoustic cue in the identification of the homorganic stops /t/, /d/ and, /tˤ/, /dˤ/; however, it was found that other acoustic cue played a role in the categorization experiment. I suggest that the following vowel contains some cues of the preceding stop consonant.

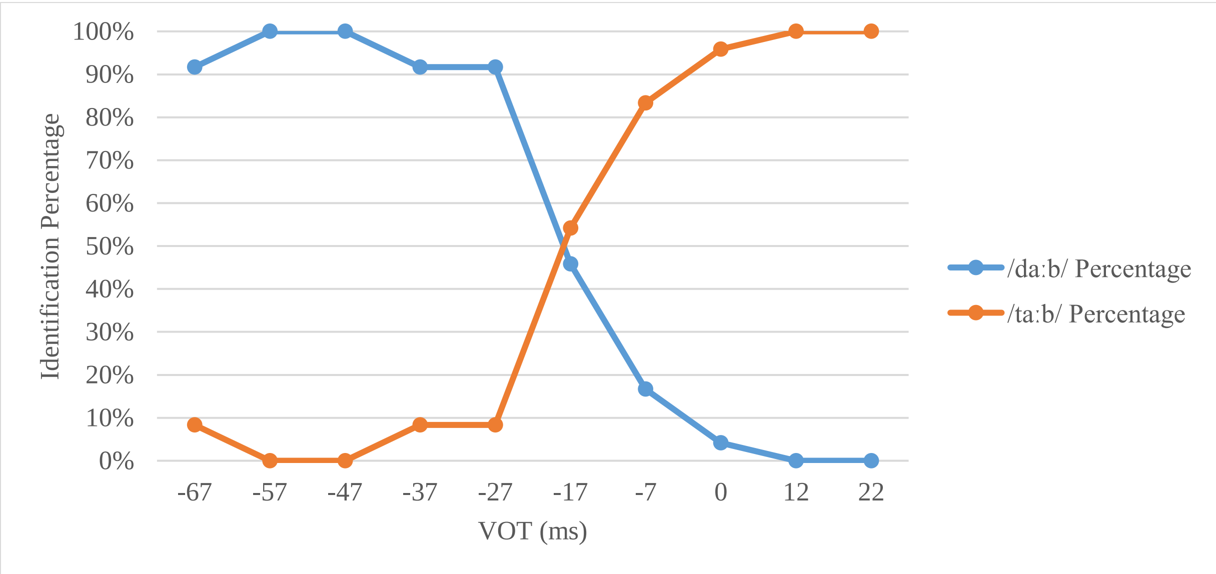
Section 4.3.1 contains a comparison of the results of /daːb/ - /taːb/ continuum in the first perception experiment, where the sounds following the stop under investigation were taken from the same words i.e. /aːb/ was taken from /taːb/ for the /daːb/ - /taːb/ continuum, besides the results of the second perception experiment, where the sounds following the stop under investigation were taken from different words i.e. /aːb/ was taken from /taːb/ for the positive part of the VOT continuum, and from /daːb/ for the negative part of the VOT continuum.

Section 4.3.2 shows a comparison of the results of /dˤaːf/- /tˤaːf/ continuum in the first perception experiment, where the rest of the test word after the stop was taken from the same words i.e. /aːf/ was taken from /tˤaːf/ for the /dˤaːf/- /tˤaːf/ continuum, in addition to the results of the second perception experiment, where the rest of the test word that follows the stop consonant was taken from different words i.e. /aːf/ was taken from /tˤaːf/ for the positive part of the VOT continuum, and from /dˤaːf/for the negative part of the VOT continuum.

4.3.1. Results and discussion of the /daːb/ - /taːb/ continuum:

In the first perception experiment where /aːb/ was taken from /taːb/, the results showed that the boundary between /d/ and /t/ was almost at a VOT of -18 ms as illustrated in figure 16. As expected, the stimuli with prevoicing of the initial stop and the /aːb/ taken from /taːb/ were not always identified as /daːb/. Two participants identified the stimuli with a VOT of -67, -37, -27 ms as /taːb/ once out of the three repetitions of these stimuli. On the other hand, from the VOT of -7 ms till +22ms, the stimuli were identified as /taːb/ between 83% - 100% of the times. These findings suggest that there is another acoustic cue that played a role in the identification experiment besides VOT. It was found that F0 of the following vowel differs after voiced and voiceless consonants where F0 starts high then falls after voiceless consonants and begins low then shifts upward after voiced consonants (Abramson & Lisker, 1985; Lehiste & Peterson, 1961; Whalen, Abramson, Lisker, & Mody, 1993). Therefore, F0 of the vowel in /daːb/ and F0 of the vowel in /taːb/ was measured. Measurements show that F0 of /aː/ in /taːb/ was higher than that in /daːb/ of 41 Hz.

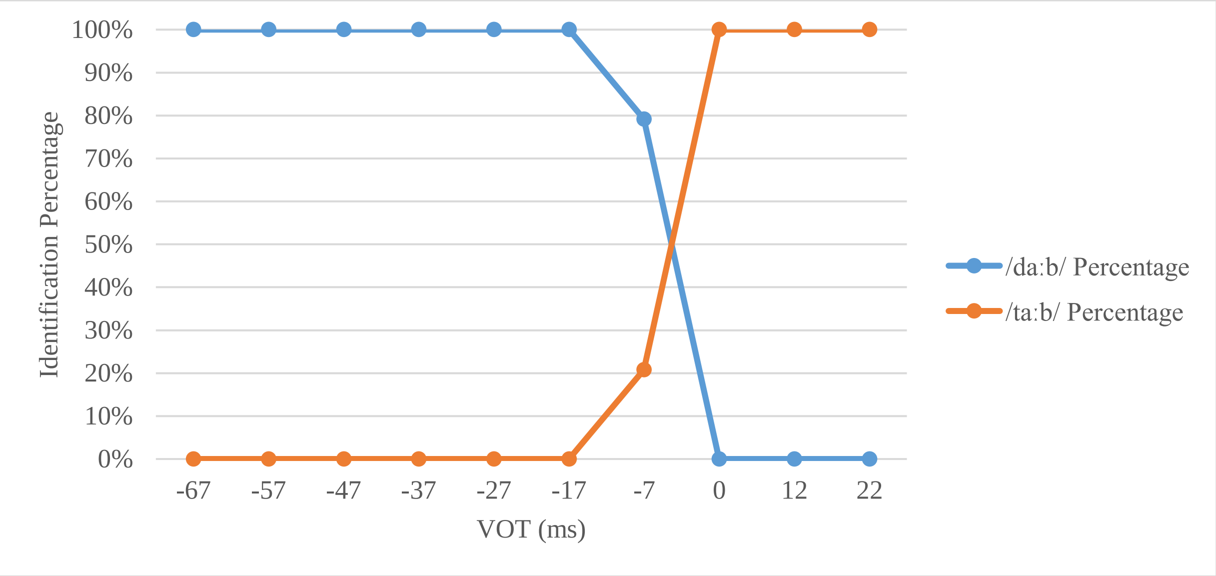
Figure 16. The results of the first perception experiment for the /daːb/-/taːb/ continuum.



On the other hand, in the second perception experiment where /aːb/was taken from different words i.e. from /daːb/ for the negative VOT stimuli, and from /taːb/ for the positive VOT stimuli, the boundary was between 0 and -7 ms as shown in figure 17. The boundary was shifted to the right where more /dab/ responses were obtained. The stimulus with a VOT of -7 ms was identified as /daːb/ 79% of the times by the participants, and the shift was almost at -4 ms were /daːb/ and /taːb/ responses were equally obtained.

A comparison of figures 16 and figure 17 shows that the stimuli on the low negative part of the continuum in the second perception experiment were more clearly identified as /da:b/ than those in the first experiment. I suggest that in addition to the VOT, another acoustic cue contributed to the identification of the voiced stop /d/ which is the low F0 of the following vowel /a:/. This finding supports the hypothesis that the following vowel influences the perception of the previous stop consonant, and that the VOT despite being the major acoustic cue in the distinction between voiced and voiceless homorganic stops /d/and /t/, F0 plays a minor role in the perception.

Figure 17. The results of the second perception experiment for the /da:b/-/ta:b/ continuum.



4. 3. 2. Results and discussion of /dˤa:f/- /tˤa:f/ continuum:

In the first perception experiment where /a:f/ was taken from /tˤa:f/ for all stimuli, the identification percentage of the stimuli on the low negative part of the continuum was not 100% /dˤa:f/; whereas, the identification percentage of the stimuli with the VOT of -14 ms and more was 100% /tˤa:f/ except for the stimulus with a VOT of 5 ms which was identified as /tˤa:f/ 96% of the times. The VOT boundary between /dˤ/ and /tˤ/ was at the VOT of -34 ms as illustrated in figure 18.

On the other hand, in the second perception experiment, where /a:f/ was taken from /tˤa:f/ for the positive VOT stimuli and from /dˤa:f/ for the negative VOT stimuli, the boundary was shifted to the right (-14 ms to 0 ms). More /dˤa:f/ responses where obtained; in addition, all the negative VOT stimuli lower than the VOT of -14 ms were always identified as /dˤa:f/ except for the stimulus with a VOT of -34 ms which was identified once by one participant as /tˤa:f/

which shows that participants clearly identified the voiced stop /dˤ/. The zero stimulus which has the ambiguous burst without prevoicing, and the positive VOT stimuli were always identified as /tˤaːf/ as shown in figure 19.

A Comparison of the results of the two perception experiments for the /dˤaːf/ -/tˤaːf/ continuum indicates that there is another acoustic cue played a role in the identification of /dˤ/ besides the prevoicing (negative VOT). The following vowel was found to have an influence on the VOT boundary which suggests that the vowel contains some perceptual cues of the preceding stop consonant. I suggest that the lower F0 of the /aː/ in /dˤaːf/ was used as a cue by the participants in the second perception experiment. Measurements show a difference in F0 of the vowel in /dˤaːf/, and the F0 of the vowel in /tˤaːf/ of 42 Hz. The results of /dˤaːf/- /tˤaːf/ continuum show a similar trend as the results of the /daːb/-/taːb/ continuum regarding the effect of the following vowel on the VOT boundary.

Figure 18. The results of the first perception experiment for the /dˤaːf/- /tˤaːf/ continuum.

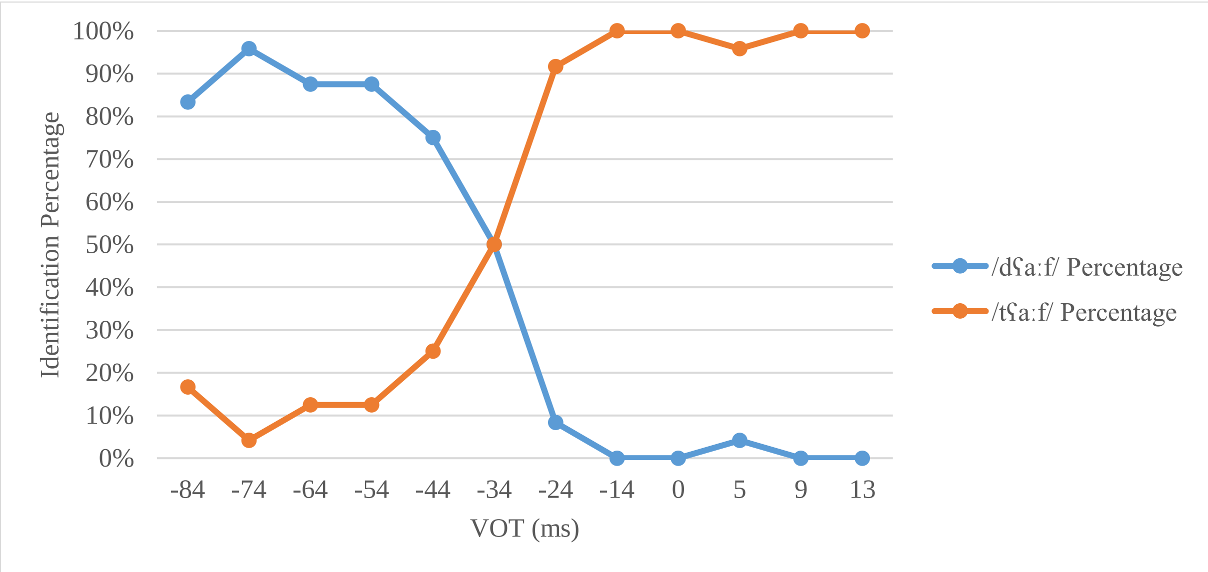
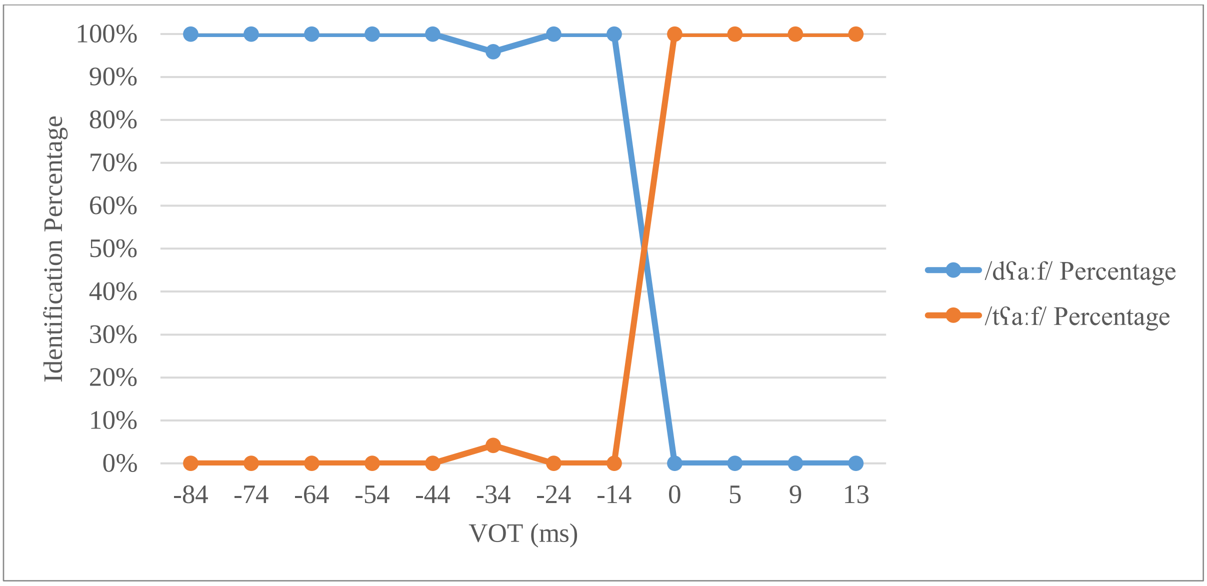


Figure 19. The results of the second perception experiment for the /dˤa:f/- /tˤa:f/ continuum.



5. Conclusions

The observed pattern of VOT values for voiceless stops in relation to the place of articulation of the stop is found in the Palestinian dialect. The VOT of the voiceless velar stop /k/ is significantly longer than the VOT of the voiceless alveolar stop /t/. In addition, the following vowel affects VOT: stops preceding the high front vowel /i:/ have longer VOT durations than those preceding the vowel /a:/. Furthermore, the stop position in the word influences VOT duration where shorter VOT is found in intervocalic position than in initial position. The Palestinian Arabic dialect has regressive voicing assimilation: the underlyingly voiceless stops become voiced to a large extent before voiced consonants, and voiced stops become minimally devoiced before voiceless consonants. VOT is the major acoustic cue in the identification of the homorganic stops /t/, /d/ and, /tˤ/, /dˤ/ as shown in the two categorization experiments. Nevertheless, another cue is found to influence the perception of these stops: Higher F0 occurs after voiceless consonants and lower F0 occurs after voiced stops. F0 has a minor effect compared to VOT in the perception of the homorganic stops /t/, /d/ and, /tˤ/, /dˤ/.

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7. Appendices

Appendix 1

Stop in Word-Initial Position			
Test word	Arabic script	Meaning	VOT (ms)
baːb	باب	door	-93
buːr	بور	wild/heath	-83
biːr	بير	well	-98
taːʒ	تاج	crown	16
tuːt	توت	blueberry	23
tiːn	تين	figs	35
daːx	داخ	daze	-76
duːr	دور	turn around	-99
diːn	دين	religion	-103
kaːz	كاز	kerosene	31
kuːb	كوب	cup	48
kiːs	كيس	bag	43
tˤaːr	طار	flew	18
tˤuːb	طوب	bricks	24
tˤiːn	طين	mud	24
dˤaːʕ	ضاع	lost	-93
dˤuːʔ	ضوء	light	-94
dˤiːf	ضيف	add	-94

Appendix 2

Stop in intervocalic Position				
Stop	Test word	Arabic script	Meaning	VOT (ms)
b	muba:ħ	مباح	allowed	-64
t	futa:t	فتات	crumbs	17
d	huda:	هدى	A girl name	-55
k	zuka:m	زكام	cold	28
$t^ʕ$	ħut^{ʕ}a:m	حطام	wreckage	18
$d^ʕ$	s^{ʕ}ud^{ʕ}a:ʕ	صداع	headache	-57

Appendix 3

Stop in a Medial Consonant Cluster			
Stop	Test word	Arabic script	Meaning
b	mabʃarah	مبشرة	grater
t	matʒar	متجر	store
d	madxaneh	مدخنة	chimney
k	makbu:t	مكبوت	repressed
$t^ʕ$	mat^{ʕ}ʕam	مطعم	restaurant
$d^ʕ$	mod^{ʕ}ħek	مضحك	funny

Appendix 4

The script used to calculate VOT durations of stops in word-initial and intervocalic positions:

```
speaker$ [1] = "M-Speaker1"
speaker$ [2] = "M-Speaker2"
speaker$ [3] = "M-Speaker3"
speaker$ [4] = "M-Speaker4"
speaker$ [5] = "F-Speaker5"
speaker$ [6] = "F-Speaker6"
speaker$ [7] = "F-Speaker7"
speaker$ [8] = "F-Speaker8"

numberOfSpeakers=8
numberOfRepetitions=3
numberOfFiles=3

writeInfoLine: "speaker", tab$, "gender", tab$, "repitition", tab$, "word", tab$, "vot", tab$,
"duration"

for file to numberOfFiles
  for repetition to numberOfRepetitions
    for speaker to numberOfSpeakers
        speakerName$ = speaker$ [speaker]
        gender$ = left$ (speaker$ [speaker], 1)
        @dofile: file, repetition, speakerName$, gender$
    endfor
  endfor
endfor

procedure dofile: fileNumber, repitition, speakerName$, gender$

  fileName$ = "repetition" + string$(repitition) + "\" + speakerName$ + string$(fileNumber)
  textgrid = Read from file: fileName$ + ".TextGrid"
  numberOfIntervals = Get number of intervals: 1

  for interval to numberOfIntervals
    word$ = Get label of interval: 1, interval

    if word$ <> ""
      vot$ = Get label of interval: 2, interval
      start = Get starting point: 2, interval
      end = Get end point: 2, interval
      duration = end - start
      duration = duration * 1000

      if left$(vot$,1) == "-"
          duration = duration * -1
      endif

      appendInfoLine: speakerName$, tab$, gender$, tab$, repitition, tab$, word$, tab$, vot$,
      tab$, fixed$ (duration, 2)
    endif

  endfor

  removeObject: textgrid
endproc
```

Appendix 5

The script used to calculate the voicing percentage of stops in medial consonant clusters:

```
speaker$ [1] = "M-Speaker1"
speaker$ [2] = "M-Speaker2"
speaker$ [3] = "M-Speaker3"
speaker$ [4] = "M-Speaker4"
speaker$ [5] = "F-Speaker5"
speaker$ [6] = "F-Speaker6"
speaker$ [7] = "F-Speaker7"
speaker$ [8] = "F-Speaker8"

numberOfSpeakers=8
numberOfRepetitions=3

writeInfoLine: "speaker", tab$, "gender", tab$, "repitition", tab$, "word", tab$,
..."stop", tab$, "Stop duration", tab$, "voicing duration"

for repetition to numberOfRepetitions
  for speaker to numberOfSpeakers
    speakerName$ = speaker$ [speaker]
    gender$ = left$ (speaker$ [speaker], 1)
    @dofile: 4, repetition, speakerName$, gender$
    @dofile: 5, repetition, speakerName$, gender$
  endfor
endfor

procedure dofile: fileNumber, repitition, speakerName$, gender$

  fileName$ = "repetition" + string$(repitition) + "\" + speakerName$ + string$(fileNumber)
  textgrid = Read from file: fileName$ + ".TextGrid"
  numberOfIntervals = Get number of intervals: 1

  for interval to numberOfIntervals
    word$ = Get label of interval: 1, interval
    if word$ <> ""
      stop$ = Get label of interval: 2, interval
      stopStart = Get starting point: 2, interval
      stopEnd = Get end point: 2, interval
      stopDuration = stopEnd - stopStart
      stopDuration = stopDuration * 1000
      voicing$ = Get label of interval: 3, interval
      voicingStart = Get starting point: 3, interval
      voicingEnd = Get end point: 3, interval
      voicingDuration = voicingEnd - voicingStart
      voicingDuration = voicingDuration * 1000
      appendInfoLine: speakerName$, tab$, gender$, tab$, repitition, tab$, word$, tab$,
      ...stop$, tab$, fixed$ (stopDuration, 2), tab$, fixed$ (voicingDuration, 2)
    endif
  endfor

  removeObject: textgrid
endproc
```

Appendix 6

The experiment MFC using Praat for the /dˤaːf/, /tˤaːf/ experiment*.

```
"ooTextFile"
"ExperimentMFC 5"
stimuliAreSounds? <yes>
stimulusFileNameHead = ""
stimulusFileNameTail = ".wav"
stimulusCarrierBefore = ""
stimulusCarrierAfter = ""
stimulusInitialSilenceDuration = 1 seconds
stimulusMedialSilenceDuration = 0.8 seconds
numberOfDifferentStimuli = 12
"+5" ""
"+9" ""
"+13" ""
"0" ""
"-14" ""
"-24" ""
"-34" ""
"-44" ""
"-54" ""
"-64" ""
"-74" ""
"-84" ""
numberOfReplicationsPerStimulus = 3
breakAfterEvery = 18
randomize = <PermuteBalancedNoDoublets>
startText = "التجربة هذه في بكم مرحبا
سمعتها التي الكلمة على انقر .الكلمات من مجموعة الى تستمع سوف.
عشوائيا مرتبة الكلمات و التساوي على مقسمة ليست الأجوبة :ملاحظة.
المثال سبيل على:
التوالي على مرات عشر الكلمة نفس تختار ان يمكنك
دائما الكلمة نفس تختار ان يمكنك حتى أو
شكرا
للبدء انقر"
runText = "سمعتها؟ التي الكلمة هي ما"
pauseText = "أردت ان استراحة تأخذ ان يمكنك"
endText = "لمشاركتكم شكرا .التجربة انتهت!"
maximumNumberOfReplays = 5
replayButton = 0.4 0.6 0.01 0.20 "إعادة" ""
okButton = 0 0 0 0 "" ""
oopsButton = 0 0 0 0 "" ""
responsesaAreSounds? <no> "" "" "" "" 0 0
numberOfDifferentResponses = 2
0.1 0.4 0.3 0.8 "\FIpic/taf.jpg" 50 "" "tˤ"
0.6 0.9 0.3 0.8 "\FIpic/daf.jpg" 50 "" "dˤ"
numberOfGoodnessCategories = 0
```

* Praat does not accept writing from right to left, so this problem was handled by writing the Arabic sentences that would appear on the introductory screen in a reversed order in the script so that when the experiment was run, the sentences would appear in the right order.

Appendix 7

The experiment screen for the /dˤa:f/, /tˤa:f/ experiment.