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The Effect of Speaking Rate on the Voice Onset Time (VOT) of Bahdini Kurdish Stops

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Abstract

This research examines the effect of speaking rate on the voice onset time (VOT) of stop consonants in Bahdini Kurdish. 30 native speakers are chosen to take part in this study. VOT values are measured for all 10 Kurdish stop consonants produced by participants in carrier words in initial prevocalic onset position. The duration of the carrier word is also measured by using the Web MAUS service (Munich Automatic Segmentation), which is used for word duration measurements. Word duration measurements are compared to the

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VOT measurements to check whether they are both correlated or not based on laryngeal state and place of stop articulation (POA).

Results reveal that there is an effect of speaking rate on VOT based on the three-way laryngeal contrast between the categories of voiced, voiceless aspirated and voiceless unaspirated stops in Bahdini Kurdish. VOT increases as word durations increase, which is inversely related to speaking rate. This means that VOT increases as speaking rate decreases. There is a systematic correlation between VOT and word duration based on different laryngeal states of voiced, voiceless aspirated and voiceless unaspirated stop categories. However, Place of Articulation (POA) does not show such an effect.

Key Word: Voice onset time, Bahdini Kurdish, speaking rate, word duration.

تأثير معدل الكلام على وقت بدء الجهر (VOT) للأصوات الانفجارية في الكردية البادية

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المستخلص

تبحث هذه الدراسة في تأثير معدل التحدث على وقت بدء الجهر (VOT) للأصوات الانفجارية في اللغة البهيدنية الكردية. تم اختيار 30 متحدثاً من الناطقين الأصليين الكرد للمشاركة في هذه الدراسة يتم قياس قيم VOT لجميع الاصوات الانفجارية الكردية العشرة التي يتم إنتاجها في الكلمات الحاملة في موضع البداية الأولي. يتم أيضاً قياس مدة الكلمة الحاملة باستخدام خدمة Web MAUS، والتي تُستخدم لقياسات مدة الكلمة. تتم مقارنة قياسات مدة الكلمة بقياسات VOT للتحقق مما إذا كان كلاهما مرتبطين أم لا بناءً على حالة الحنجرة و موضع النطق (POA). تكشف النتائج أن هناك تأثيراً لمدّة الكلمة الحاملة على الأصوات بناءً على التباين الحنجري ثلاثي الاتجاهات بين فئات الاصوات الانفجارية المهموسة الهائبة والمهموسة الغيرهائبة والمجهورة في البهيدنية الكردية. يزداد VOT مع زيادة مدة الكلمات، وهو ما يرتبط عكسياً بمعدل التحدث. هذا يعني أن VOT يزداد كلما قلت سرعة التحدث. هناك ارتباط منهجي بين VOT ومدّة الكلمة بناءً

على الحالات الحنجرية المختلفة للاصوات الانفجارية المهموسة الهائية والمهموسة الغيرهائية والمجهورة. ومع ذلك، لم يُظهر موضع النطق (POA) مثل هذا التأثير. الكلمات الدالة: وقت بدء الجهر، اللغة الكردية، معدل التحدث، مدة الكلمة.

1. INTRODUCTION

VOT is one of the perceptually important acoustic cues in stop categorization. It can be explained acoustically as the relative timing of stop closure, manifested in a low-frequency band on spectrograms, and the release of stop closure, to the start of laryngeal phonation, manifested in a high-frequency band that reflects the voicing of the following vowel. When there is a delay in the start of laryngeal phonation or the onset of pulsing after the release, there will be an interval of voicelessness caused by unimpeded air from the open glottis causing a puff of air known as aspiration. The longer the delay in onset pulsing after the release, the longer the VOT is.

VOT is proved to be affected by the overall temporal structure of speech including speaking rate for different languages as shown by Kessinger and Blumstein (1997) and Chodroff et al. (2015). This effect has not been measured before for Bahdini Kurdish stops. For this reason, this paper aims to measure the stop carrier word durations to investigate the effect of speech rate on VOT. This effect is also examined based on the influence of the laryngeal state and place of articulation (POA) of the stop categories.

2. RELATED LITERATURE

Being a temporal interval, VOT is believed to be influenced by other aspects of the temporal structure of speech such as speech ratio, vowel duration and stop constriction duration. Port and Rotunno (1979) attempted to investigate the temporal effects of speech timing that extend over a whole syllable and the way they interact. They found that within the same syllable, the longer the vowel duration, the longer the VOT. This is the result of temporal implementation rules that act as instructions to the articulators to decide on the duration of temporal intervals based on certain features of neighboring context or the adjacent segments.

Chodroff et al. (2015) found that VOT differences between individuals were mainly attributed to speaking rate differences. Theodore et al. (2009) shared the same view and affirmed that increasing speaking tempo had a shortening effect on VOT. Kessinger and Blumstein (1997) examined the effect of rate of speech on VOT of English, French and Thai. They observed that increasing rate of speech only decreased the VOT of voiceless stops but had no significant effect on that of voiced stops. Similar results were reported by Pind (1994) and Heimisdóttir (2015) indicating such an affect for voiceless aspirated stops but not for unaspirated stops in Icelandic.

Magloire and Green (1999) examined the effect of speaking rate on English and Spanish VOT. They found that English VOT decreased when speaking rate increased across all stop types. Spanish VOT, however, had the same effect only for voiced stops. They suggested that the reason may be due to the fact that Spanish voiceless stops have a long lag VOT, which according to them was only minimally affected by speaking rate. Additionally, it was noted that when speaking rate raised

the voiced-voiceless distinction became less distinct creating category overlapping (Lisker & Abramson, 1967; Kessinger & Blumstein, 1997)

Allen et al. (2003) found that VOT of voiceless stops can also vary even when speaking rate is the same. This can be attributed to idiolectal individual differences that affect VOT. Hullebus et al. (2018) investigated speaker specific variability in German. They found that there is variability in speakers' VOT based on place of articulation (POA) which tends to be higher with higher overall means. This variability of speakers' VOT had a consistent structure, which may contribute to speaker identification when needed. Theodore et al. (2009) also investigated the talker-specific effect of speaking rate and place of articulation on VOT of American stops. They found that as speaking rate decreased VOT increased. This increase was different from one talker to another within but constant across the different places of articulation.

To examine these effects in Bahdini Kurdish, this research tries to examine the following points.

- The effect of speaking rate on the VOT of Bahdini Kurdish stops.
- The effect of laryngeal state (voiced, voiceless aspirated and voiceless unaspirated) on the relation between VOT and speaking rate.
- The effect of Place of articulation (POA) on the relation between VOT and speaking rate.

3. METHODOLOGY

Research on VOT belongs to the field of experimental phonetics, which investigates the physical properties of speech sounds using specialized technical instruments. It offers scientific practical support for sound analysis instead of a theoretical intuition-based description and thus provides accurate descriptions of phonemes whether physical, acoustic, or articulatory. By convention, the relevant study adopts an experimental methodology. The study went through different stages of participant selection, word list selection, recording, required software installation, acoustic analysis (VOT duration measurements and word duration measurements), and finally statistical analysis.

Participants are Bahdini Kurdish speakers from Duhok City. They are asked to read a list of words with initial stops in prevocalic onset position. Each participant is instructed to repeat each word three times. These productions are recorded using an audio recorder. VOT measurements of stops are measured in Praat. R Studio for statistical computing is used to evaluate and visualize the results, using an LMER model. The durations of the whole carrier words are also measured to check the effect of speaking rate on VOT measurements. These measurements are carried out through Munich Automatic Segmentation, [Web MAUS](#), which is a web service that provides durational measurements of segmented audio files online. It requires uploading the audio file along with a paired orthographic or phonetic transcript, as shown in Figure.

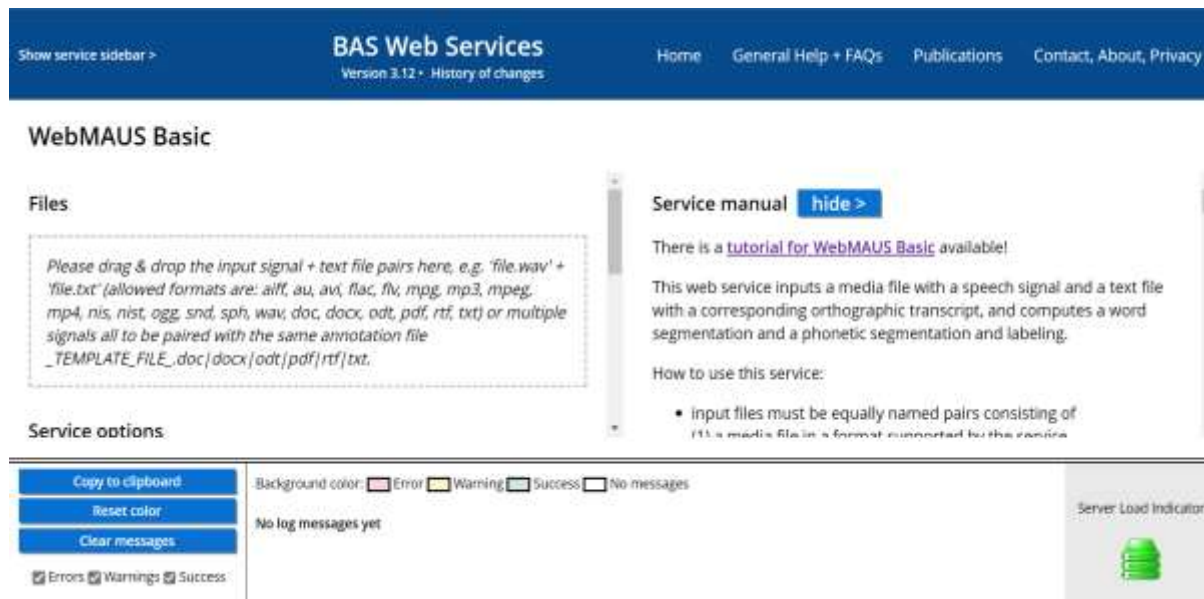


Figure 1. Web MAUS Online Segmentation and Durational Services

4. RESULTS

The analysis of the effect of carrier word duration on Bahdini Kurdish VOT in this research has shown that duration of the carrier word has a significant effect on VOT of voiced, voiceless unaspirated, and voiceless aspirated stops. Their VOT increase as word durations increase, with: $F(1,1858) = 89.7$; $p < .001$ (Table 1). However, the effect is larger on the VOT of voiced and voiceless aspirated stops than that of the voiceless unaspirated stops, which only has a marginal effect. The deviation between VOT duration and word duration is displayed in Figure 2. This indicates that speaking rate have a significant effect on the VOT of Kurdish stops. The difference is in the expected direction to what is commonly found in the literature, meaning that VOT decreases as speaking rate increases.

Table 1. Analysis of Variance for Fixed Factors in Kurdish VOT LME Model with Satterthwaite's Method, Indicating F Statistic, Denominator Degree of Freedom and p Values.

Fixed Factors	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Word Duration (ms)	26466	26466	1	1858	89.77	< .001 ***
Laryngeal	20025989	10012994	2	3492	22074.69	< .001 ***
Word Duration (ms): Laryngeal	216021	108011	2	3483	366.35	< .001 ***
Word Duration (ms):POA	1124	375	3	3474	1.27	=.282

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

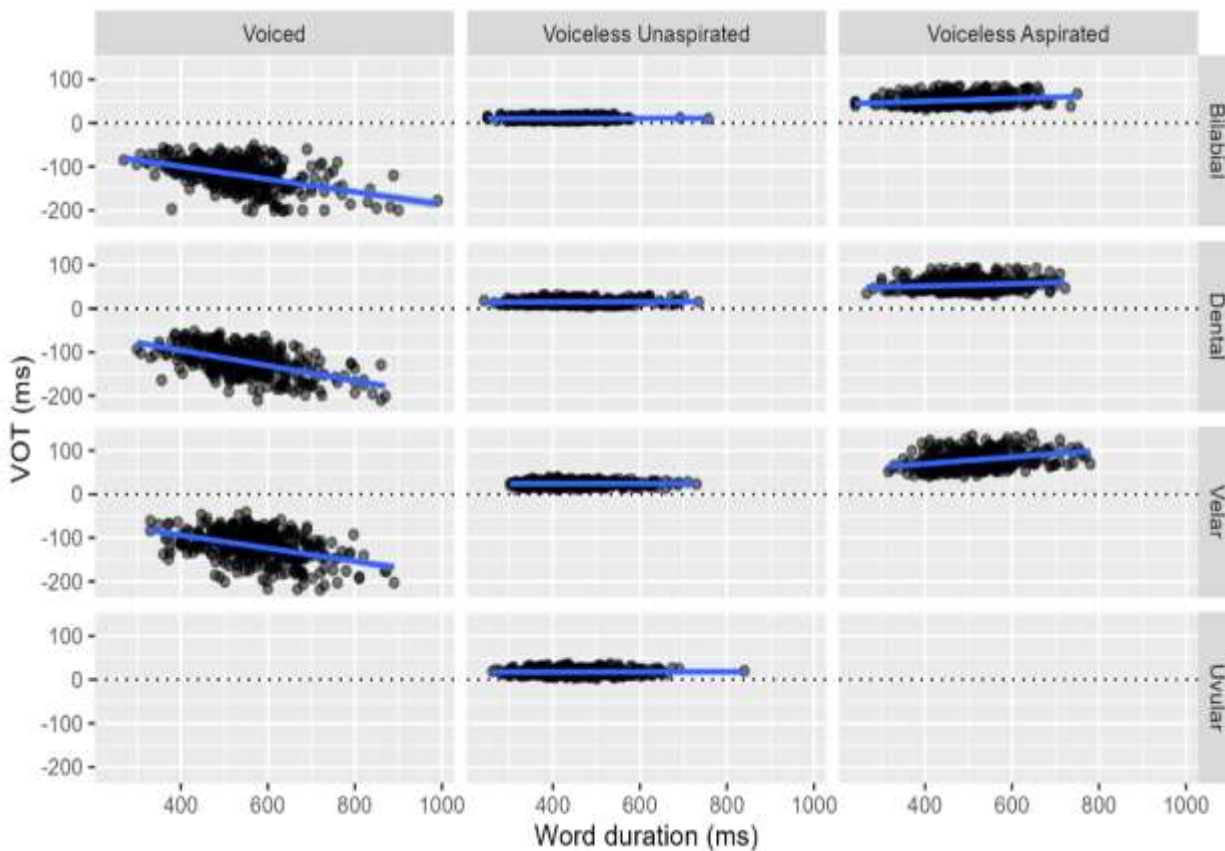


Figure 2. Scatterplot of VOT and Word Duration Deviations (both in milliseconds) based on Laryngeal State, with a Superimposed Linear Smoother

The effect of word duration on VOT with reference to place of articulation (POA), displayed in Figure 3, shows no effect.

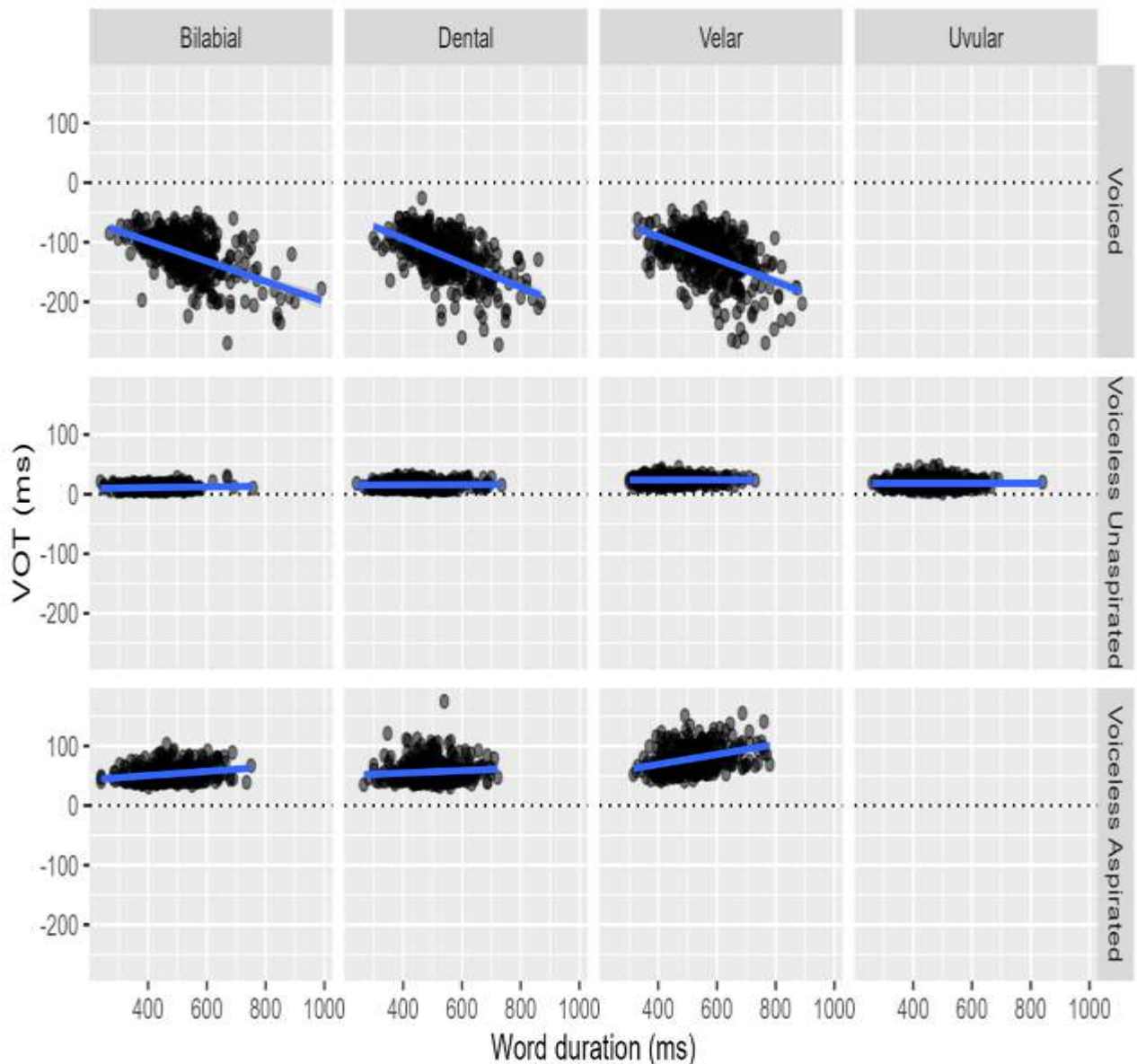


Figure 3. Scatterplot of VOT and Word Duration Deviations (both in milliseconds) based on Place of Articulation (POA), with a Superimposed Linear Smoother

The effect of word duration on VOT with reference to each stop type, displayed in Figure 4, shows a more detailed individual effect of speaking rate on VOT. This figure also supports the previous statement on speaking rate with reference to different laryngeal states; that VOT of Kurdish stops is inversely related to speaking rate for all stop categories.

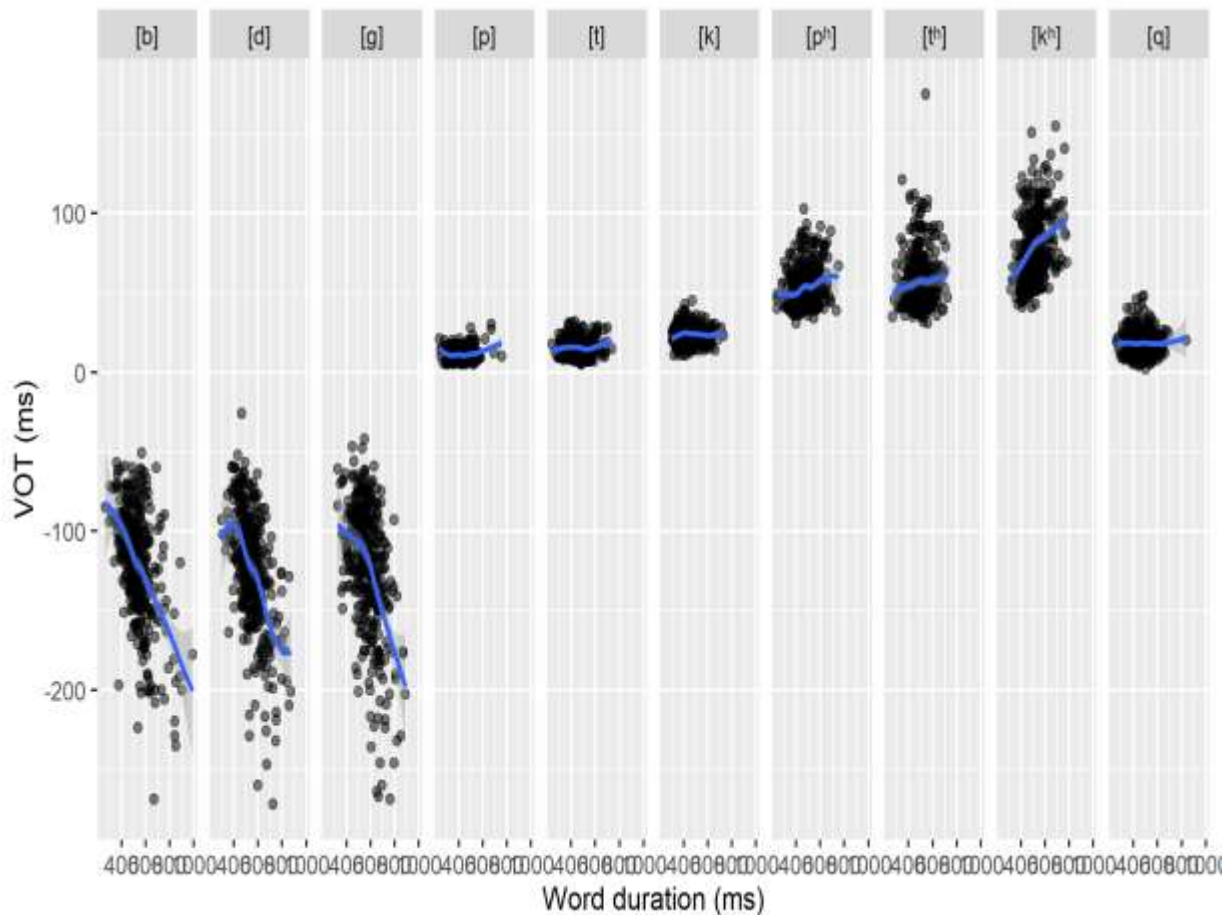


Figure 4. Scatterplot of VOT and Word Duration Deviations (both in milliseconds) for all stop Types in Bahdini Kurdish, with a Superimposed Linear Smoother

5. DISCUSSION

Although VOT is used in categorization of stop consonants, it has been demonstrated that variations in speaking speed affect the category's range of values. It is well known in the literature that the VOT of stop consonants lengthens significantly as speaking rate is slowed. Conversely, the VOT of voiceless stops shortens as speaking rate increases, and the VOT differences at the laryngeal states of voiced, voiceless unaspirated and voiceless aspirated boundary may be reduced, sometimes resulting in overlap between the VOT categories. The aim of this paper is to examine the correlation between the duration of VOT of Bahdini Kurdish stops and its carrier word to inspect the effect of speaking rate on VOT.

The analysis of data of this research has shown that Bahdini Kurdish stop categories are separated by their VOT measurements. voiced stops are produced with a voicing lead, voiceless unaspirated stops are produced with a short lag, while those of voiceless aspirated stops are produced with a long lag. Increasing speaking rate has a shortening effect on VOT. This is the case because both are temporal intervals which are likely to interact and influence each other. This effect may only be found in one stop category but not in others like voiced (Magloire & Green, 1999) or voiceless stops

(Kessinger & Blumstein, 1997), which is different from one language to another. Unlike the results of these studies, and in line with the results of Theodore et al. (2009), this effect is found in all stop categories in Kurdish. This shortening effect, however, has not affected the separation of categories. This suggests that the laryngeal state of Kurdish stops has a systematic effect on the correlation between VOT and speaking rate.

6. CONCLUSIONS

The results of the current research are as follows:

- There is an effect of carrier word duration on VOT. VOT increases as word durations increase, which is inversely related to speaking rate. This means that VOT increases as speaking decreases.
- There is an effect of laryngeal state (voiced, voiceless aspirated and voiceless unaspirated) on VOT and speaking rate. The correlation between VOT and speaking rate is systematically differentiated between different stop categories. However, the effect was larger on the VOT of voiced and voiceless aspirated stops than that of the voiceless unaspirated stops, which only has a marginal effect.
- There is no effect of Place of articulation (POA) on the relation between VOT and speaking rate.

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