

EFFECT OF INITIAL /S/ ON THE VOICE ONSET TIME (VOT) OF FOLLOWING STOPS IN BAHDINI KURDISH

LUREEN I. NASER and SAAED A. SAAED

Dept. of English Language, College of Basic Education, University of Duhok, Kurdistan Region-Iraq

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ABSTRACT

Voice onset time (VOT) is one of the acoustic properties of stop consonants. It is a durational measure of the time between stop release and vocal fold vibration. English voiceless stops are characterized by loss of aspiration when preceded by an initial /s/ and their VOT is largely reduced. This paper aims to examine this phenomenon in Bahdini Kurdish. It seeks to investigate the effect of initial /s/ on the VOT of following stops and whether variables of place of stop articulation, following vocalic context and gender influence this effect.

In order to measure this effect, the VOT values for voiceless stops were measured both initially and when preceded by /s/. (30) adult Bahdini Kurdish native speakers from Duhok City took part in this study. They read a list of words which contrasted words with initial voiceless stops with those followed by /s/. The list included two examples of each voiceless stop preceding a high and a low vowel. The results were analyzed acoustically and statistically to search for significant interactions. The study's findings demonstrate that Bahdini Kurdish voiceless stops have reduced VOT values when preceded by initial /s/. Variables of place of articulation (POA), following vowel height, and gender of participants all have significant effects on the results of the study.

KEYWORDS: Voice Onset Time, Voiceless Stops, Kurdish.

1. INTRODUCTION

While each speech sound has certain invariable features that distinguish it from other speech sounds, sounds are normally not produced in isolation. In connected speech, phonemic features usually overlap and undergo alteration or modification as a result of its phonetic environment. This disrupts the one-to-one correspondence between speech sounds and their usually defining features. A voiceless sound, for instance changes to a voiced one as a result of the influence of its phonetic environment. For this reason, any investigation of the phonetic or acoustic properties of speech sounds should take into consideration the influence of their phonetic context.

Although VOT is one of the fundamental properties of stop consonants, it is not an absolute value but is context sensitive. VOT variation is proved to be highly structured by its phonetic context. This paper aims to investigate whether adding an initial /s/ to voiceless stops of Bahdini Kurdish has an effect on their VOT measurements. It also aims to measure the effect of the variables of place of articulation (POA),

height of the vowel following the stop, and gender on the VOT measurements.

The objective of this research is to answer the following questions.

- Do VOT measurements of Bahdini Kurdish voiceless stops differ when preceded by an initial /s/ compared to those produced initially?
- Does the place of stop articulation (POA), whether bilabial, dental, or velar, affect this difference?
- Does the following vocalic context affect the VOT values of voiceless stops when preceded by an initial /s/?
- Are gender differences significant?

2. THEORITICAL BACKGROUND

Voice onset time (VOT) is a term associated with stops which are followed by voiced segments. It is defined by Lisker & Abramson (1964) as "the time interval between the burst that marks the release of the stop closure and the onset of periodicity reflecting laryngeal vibration".

It is one of the dimensions that is used to distinguish two phonemic categories based on

the temporal coordination of “two independently controllable parameters” as stated by Docherty (1992, p.14). Each member of a homorganic pair of stops occupies a different range along the dimension of VOT. This difference is always there even under different contextual factors. Thus, differences in VOT may serve as a basis for separating stop categories in languages.

VOT differs from one language to another. A VOT measurement of about 20-25 msec separates voiced from voiceless stops in English, for example. Any measurement below that range indicates a voiced stop, meaning that burst release and voicing of the following vowel are almost simultaneous. On the other hand, any measurement above that range is a characteristic of a voiceless stop indicating a temporal gap between burst release and voicing onset of the following vowel as indicated in Figure 1. When aspirated, these voiceless stops are also characterized by the presence of aspiration noise which perceptually contributes to recognition of stop type (Cho & Ladefoged, 1999).

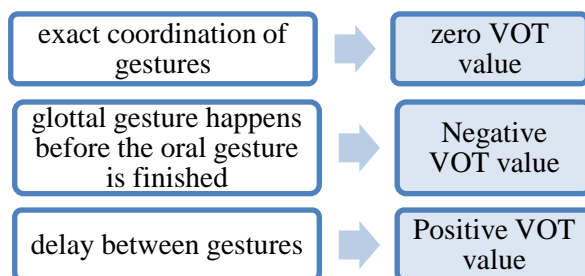


Fig. (1): Coordination of Oral and Glottal Gestures and Their Effect on VOT.

VOT can be reduced in certain contexts. The phenomenon of loss of aspiration after /s/ is commonly observed in certain languages and dialects. It refers to a reduction or absence of the aspirated quality typically associated with voiceless stops /p/, /t/, /k/ when they occur immediately after an /s/ sound. This results in a shorter VOT duration for these stops (Klatt, 1975).

The loss of aspiration after /s/ can be attributed to coarticulatory effects and assimilation processes. The airstream for producing the /s/ sound is already characterized by a turbulent noise, which resembles the noise associated with the aspiration of voiceless stops. As a result, the aspiration phase of the voiceless stop is assimilated to the preceding /s/ sound, leading to a reduction or complete absence of aspiration. This phenomenon is not a universal feature of all languages or dialects. It is more

commonly observed in certain languages or language families, such as some varieties of English or other Germanic languages. Additionally, the presence or absence of this phenomenon can vary across different regional accents or individual speakers within a language (Iverson & Salmons, 1995). This suggests that it needs to be examined for each language rather than predicted.

3. RELATED STUDIES

It is well documented in the literature that the context of stop consonants is known to have a direct effect on their aspiration and VOT. English, for instance, is characterized by loss of aspiration and thus a reduced VOT when preceded by /s/ (Klatt, 1975). Kahn (2015) suggests that voiceless stops are not aspirated after /s/ not because of the features of this specific sound but only because it prevents them from being syllable initial, which is the only position allowing these stops to be aspirated. Browman & Goldstein (1986) propose that the neutralization of aspiration contrast of voiceless stops after /s/ is due to the fact that in such a context only a single closing and opening gesture of the glottis can be found, forming one devoicing gesture. This gesture is the same whether any of the two consonant cluster members referred to are used as singletons or together as a cluster. The glottal opening starts and reaches its peak during the fricative /s/ production and by the time the following stop is released, the glottis becomes narrower resulting in aspiration loss and the production of a voiceless unaspirated stop. Kahn (2015) suggests that only syllable initial voiceless stops are aspirated, when the stop is not ambisyllabic, whether stressed or not. For example, in the word “happy”, the /p/ is not aspirated because it is shared by both syllables, not because it is unstressed. Stress, according to him, contributes to the degree of aspiration but is not the decisive element in aspiration presence. In the word “tomorrow”, the initial /t/ is aspirated even though it is not followed by a stressed vowel.

Arabic language seems to behave differently. Kasim (2009), for instance, examined the effect of initial /s/ before voiceless stops on VOT values in Mosuli Arabic. His results showed that there were no significant differences between the VOT values of stops when occurred initially or after /s/, meaning that the VOT values of

voiceless stops were not affected by the addition of an initial /s/.

This phenomenon has not been previously tackled before for Bahdini Kurdish. It is not clear whether aspiration contrast of voiceless stops is neutralized after /s/ or not, which is the aim of this paper.

4. METHODOLOGY

The stimuli of this experimental study contrast Bahdini Kurdish words which start with initial voiceless stops with words with voiceless stops preceded by /s/, which is known in the literature to have a direct effect on aspiration and VOT. A list of words was prepared, Table 1, including two examples for each voiceless stop in different vocalic contexts, preceding a high vowel and a low vowel.

Participants consist of (30) adult Bahdini Kurdish native speakers from Duhok City, with equal numbers of males and females. They were asked to read the prepared list of words and to repeat each word three times to provide three tokens. A zoom H1n digital portable audio recorder was used to record these productions in WAV format with a sampling rate of 44.1 kHz. Praat software, which is designed for the analysis of sounds and speech signals, was used to acoustically measure VOT durations of all stops.

The statistical analysis included fitting a liner mixed effect model (LME) to measure the significance of the interactions of all the variables of initial context, place of stop articulation, following vowel height and gender. Results are drawn and plotted in R, which is used for statistical modeling and visualization of data.

Table (1): Kurdish Words Used in the Research Experiment

		Words with Initial Stops		Words with Stops after Initial /s/	
		IPA	Gloss	IPA	Gloss
Kurdish	/p/	/p ^h ir/	religious instructor	/spilk/	egg white
		/p ^h art/	party	/spartin/	handing out
	/t/	/t ^h im/	team	/stin/	pillar
		/t ^h ax/	neighborhood	/stand/	stand
	/k/	/k ^h ir/	deep	/skinət/	tranquility
		/k ^h ar/	work	/skala/	Complaint

5. RESULTS AND DISCUSSION

The presence of an /s/ sound preceding a stop is one of the factors that can influence VOT, and the interaction between these factors can vary in different linguistic contexts. Table 2 shows results of statistical analyses of data of the current study. It includes the mean values and the standard deviations of the studied voiceless stops both initially and when preceded by /s/. The table shows that Kurdish voiceless stops have reduced VOT values when preceded by /s/, with mean averages of (11, 22 and 46) ms for [sp], [st] and [sk] respectively, compared to initial voiceless stops with mean averages of (59, 61 and 87) ms for [p^h], [t^h] and [k^h] respectively. These results are in line with results of English stop analysis by Klatt (1974). Similar to English, Kurdish VOT is directly affected by the addition

of an initial /s/ and is thus characterized by loss of aspiration in this context. Figure 2 shows a comparison of each stop in both contexts through a density plot. The plot clearly shows that VOT values of the studied voiceless stops are largely reduced when each stop is preceded by /s/. The liner mixed effect (LME) model output is included in Appendix A.

Table 2. Mean and Standard Deviations (SD) of VOT Values of Voiceless Stops Initially and When Preceded by /s/, Measured in Milliseconds (ms)

	[p ^h]	[sp]	[t ^h]	[st]	[k ^h]	[sk]
Mean	59	11	61	22	87	46
SD	15	8	22	9	24	19

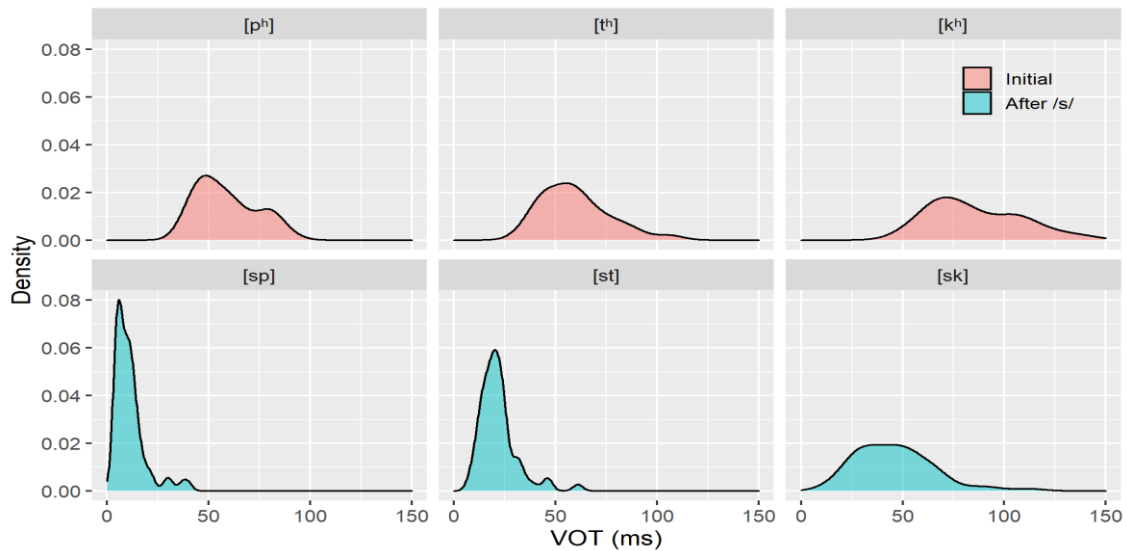


Fig. (2): Density Plot of VOT Values of Voiceless Stops with and without Initial /s/.

5.1. Place of Articulation (POA)

Place of articulation (POA) of initial voiceless stops with reference to their context has shown a significant effect on VOT with a $p < .001$ as revealed in the results of the LME model (Appendix A). Stops produced at different places of articulation exhibit different VOT durations (Cho & Ladefoged, 1999). The distinction between voiceless stops in both contexts, initially and when preceded by /s/, tends to be evident for all places of stop articulation but more evidently for bilabials and dentals than velar as visualized in Figure 3.

The visualization of the data shows that the voiceless bilabial stop /p/ exhibits shorter VOT

values compared to the dental /t/ and the velar /k/ stops. The presence of initial /s/ has led to a reduction in VOT duration for voiceless bilabial stops more than the other stops.

The voiceless dental stop /t/ shows a moderate range of VOT values. The presence of initial /s/ after this stop has also led to reduced or shorter VOT durations but it has less effect than on the bilabial stops.

The voiceless velar stop /k/ have longer VOT values compared to bilabial and dental stops. The impact of initial /s/ on the VOT of the voiceless velar stop is less than the other stop types and has led to the smallest reduction in VOT durations.

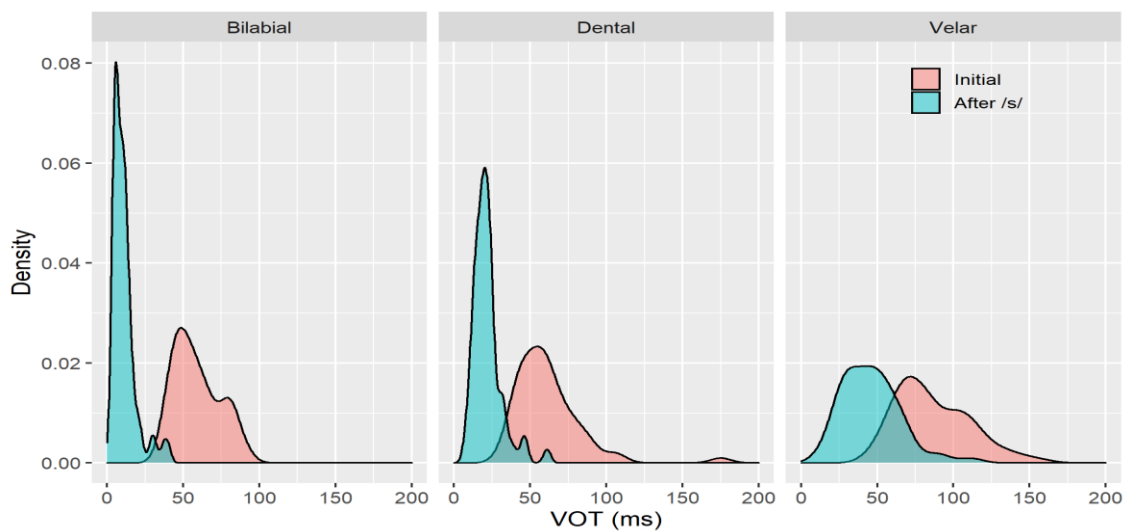


Fig. (3): Distribution of Mean VOT Values of Voiceless Stops with and without Initial /s/ based on POA.

5.2. Vocalic Context

The interaction between the /s/ sound and the following vowel can result in variations in VOT of stops. The acoustic properties of the following vowel, such as its quality, can affect the timing and realization of the stop consonant that follows /s/. VOT of voiceless stops with reference to their context is significantly affected by the height of the following vowel with a $p < .001$ (Appendix A) as indicated by the analysis of the LME model results. The distinction between

voiceless stops in both contexts tends to be more evident when followed by high vowels, opposed to low vowels, as displayed in Figure 4

The specific vowel quality has influenced the articulatory coordination and timing between the /s/ and the subsequent stop. The articulatory gestures involved in producing different vowels can affect the release of the stop consonant and, consequently, the VOT duration (Fischer-Jørgensen & Hutters, 1981).

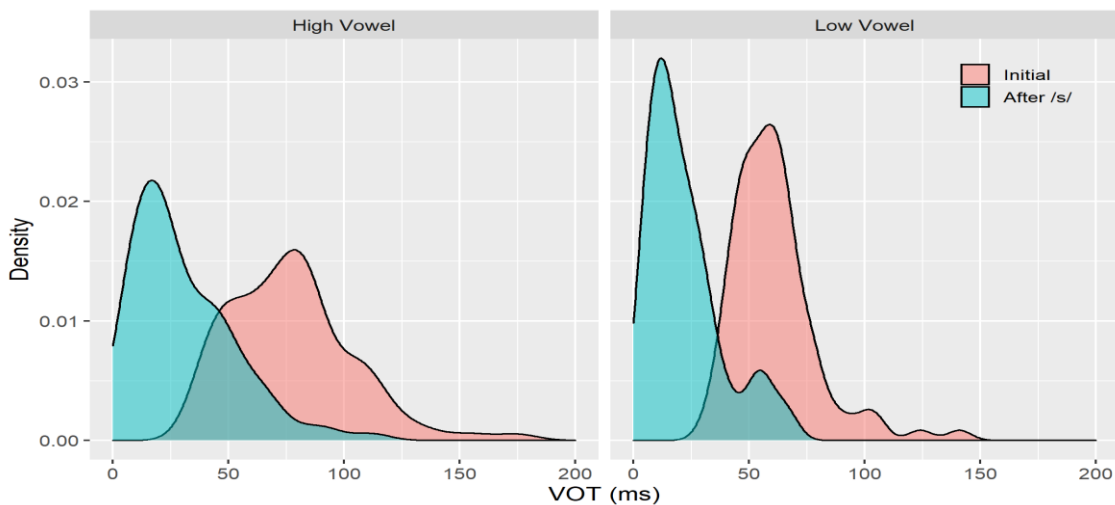


Fig. (4): Distribution of Mean VOTs of Voiceless Stops with and without Initial /s/ based on Vocalic Context.

5.3. Gender

Anatomical and physiological differences between male and female vocal tracts can result in variations in speech production. These differences can potentially manifest in VOT values, although the extent and significance of the gender effect may depend on other factors.

The gender of participants of this study has an effect on VOT values of Bahdini Kurdish voiceless stops with reference to their context with a $p = .037$ (Appendix A). The distinction between voiceless stops initially and when preceded by /s/, tends to be more evident for male speakers than females as displayed in Figure 5.

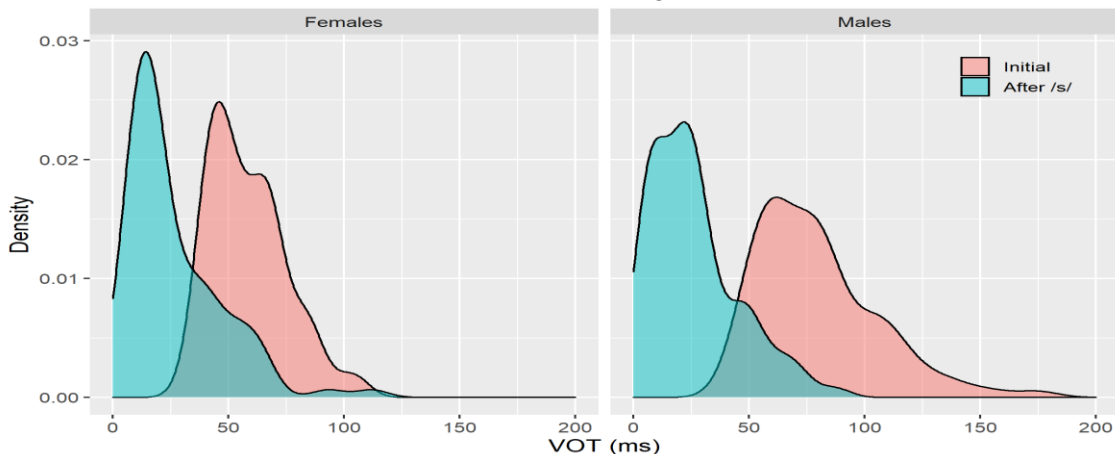


Fig. (5): Distribution of Mean VOTs of Voiceless Stops with and without Initial /s/ based on Gender.

6. CONCLUSIONS

- The presence of /s/ sound preceding voiceless stops has shown to be one of the factors that influence Voice Onset Time (VOT) in Bahdini Kurdish. The interaction between /s/ and the following stop consonant varies depending on the specific phonetic environment.
- Bahdini Kurdish voiceless stops have reduced VOT values when preceded by initial /s/. This reduction can be attributed to the coarticulatory effects of the /s/ sound, where the articulatory gestures involved in producing /s/ carry over to the stop, resulting in a shorter VOT. This indicates that VOT and aspiration have a significant role in the identification of initial voiceless stops. These results are in line with those of Klatt (1974) on English voiceless stop analysis.
- There is a distinction between VOT values of voiceless stops initially and after /s/ for all places of stop articulation but more evidently for bilabials and dentals than velar. This may be due to the fact that VOT generally tends to be longer the more posterior the place of stop articulation is (Cho & Ladefoged, 1999). Since velars are characterized by long VOT values, there is less room for disparity along the VOT continuum in different contexts. The opposite is true for bilabials and dentals.
- The quality of the following vowel affects the VOT values of the stop consonant that follows /s/. Voiceless stops followed by high vowels tend to have longer VOT values than those followed by low vowels. The distinction between voiceless stops in both contexts tends to be more evident before high vowels.
- Gender has an effect on VOT values of voiceless stops. Initial voiceless stops have more evidently longer VOT values than when preceded by /s/ for male speakers than females. This may be attributed to physiological

differences between male and female vocal tracts which can cause variation in speech production.

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Appendix A

Analysis of Variance for Fixed Factors in All LME Models 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)	
Gender	4596	4596	1	8	6.67	= .037	*
POA	65996	32998	2	340	47.9	< .001	***
Vowel.Height	13723	13723	1	340	19.92	< .001	***
Gender:POA	1110	555	2	340	0.81	=.448	
Gender:Vowel.Height	513	513	1	340	0.75	=.389	
POA:Vowel.Height	1273	636	2	340	0.92	=.398	
Gender:POA:Vowel.Height	156	78	2	340	0.11	=.893	

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

پوختە

دەنگی پەقیی کبی پفدار د زمانی ئینگلیزیدا پفداریا خو ژ دەست دەت دەما /S/ ل پیشیا وی دەیت و دەمی دەستییکا دەنگداریی (VOT) کورت دبیت ب ریژەکا بلند. ئارمانج ژ قی قە کولینی ئە وە لیکولینا قی چەندی د زمانی کوردییا بادینیدا بکەت . (VOT) یا دەنگیت پەقی ل دەستییکا پەقا بە راورد دگەل ئەوین کو پیشگر بیت ب /S/ هاتە پیقان . (30) کەس کو بزمانی کوردییا بادینی دئاخفن ژ باژیری دھوکی پشکداری کرد قی لیکولینیدا , ب خاندنا لیستەکا پەیقان کو دەستپیدکەت ب دەنگیت پەقی ل دەستییکا پەیقان بە راورد دگەل ئەوین ل دیف /S/ دەین . ئەف لیستە دوو نمونە بو هەر دەنگەکی پەقی پیشگر ب دەنگەکی دەنگدیری ب بلند و نزم پەیدا دکەت . ئەنجامین قە کولینی دیارکرن کو دەنگیت پەقی یین کوردی بەھایین (VOT) یین کیم هە نە دەما پیشگر دبن ب /S/ . جیاوازیین جھی درکرنی (POA) و بلندیا دەنگی دەنگدیری باشگر وە رەگەزی پشکداران کارتیکنین مەزن هە نە ل سەر ئەنجامین قە کولینی .

پەقیین سەرەکی: دەمی دەستییکا دەنگداریی، دەنگی پەقیی کب، زمانی کوردی

تأثير /S/ الأولي على وقت بدء الجهر (VOT) للاصوات الانفجارية التالية في اللغة الكوردية البهيدنية

الخلاصة

يتميز الصوت الانفجاري المهموس الهائي في اللغة الإنجليزية بفقدان الصفة الهائية عندما يسبقها /s/ الأولي ويتم تقصير وقت بدء الجهر (VOT) إلى حد كبير. يهدف هذا البحث إلى دراسة هذه الظاهرة في اللغة الكوردية البهيدنية. تم قياس قيم VOT للاصوات الانفجارية في بداية الكلمة وعندما تسبقها /s/. (30) ناطقون باللغة الكوردية البهيدنية من مدينة دهوك شاركوا في هذه الدراسة حيث قرأوا قائمة من الكلمات التي تبدأ بالاصوات الانفجارية مع تلك التي تليها /s/. تضمنت القائمة مثالين لكل صوت انفجاري يسبق صوت علة مرتفع ومنخفض. تظهر نتائج الدراسة أن الاصوات الانفجارية الكوردية قد قلت من قيم VOT عندما سبقتها /s/. كان لمتغيرات مكان النطق (POA) ، ارتفاع حرف العلة التالي ، وجنس المشاركين تأثيرات كبيرة على نتائج الدراسة.

الكلمات الدالة: وقت بدء الجهر ، الصوت الانفجاري ، اللغة الكوردية.