

## An Exploration in the Environmental and Gender Effects on Voice Onset Time

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### Keywords

- Acoustic phonetics
- Voice Onset Time (VOT)
- PRAAT
- Phonology

### Abstract

*Acoustic phonetics is an important field in the domain of phonetics and phonology. It enables phoneticians to analyze the individual differences in human speech especially the properties of formants and voice onset time. The aim of the current study was to analyze the differences in voice onset time across genders and in laboratory and external settings. The researchers collected voice samples from 6 participants; 3 Male and 3 Female participants aged between 22-26 years. The participants recorded three mono-syllabic words starting with plosive consonants; pet, top, and kit on PRAAT software, initially in lab settings and then in external settings. Afterward, the VOT values were observed and plotted on Excel and then represented in the form of bar graphs for a comparative analysis of the VOT values across gender and environment. The principal findings of the current study revealed that the values of voice onset time for female participants were comparatively higher than for male participants. Moreover, the voice onset time in lab settings for the majority of the voice samples was higher than the VOT values in external settings.*

## 1. Introduction

Voice Onset Time (VOT) is one of the acoustic features that has been utilized in the field of linguistics which was introduced by Lisker and Abrahamson (1964). They defined VOT as “the time interval between the burst that makes the release of the stop closure and the onset of periodicity that reflects laryngeal vibration” (Lisker & Abrahamson, 1964, p. 422). VOT acts as both an audio cue and an inferential estimate of speech motor control. This requires precise motor coordination of the respiratory, phonatory, and articulatory components Kent (2002). According to Hutter (1985); Abramso (1973) & Ito (1986) in English and several other languages, VOT is a reliable indication to differentiate between voiced and voiceless stops. Individual talkers have different acoustic characteristics, which is a well-known fact Allen et al (2003). However, these variations result from a variety of sources, including dialect Byrd, (1992). Despite the broad applicability across various linguistic fields of VOTs, there are a variety of elements that could affect them. The speaker’s gender is one of the variables that can affect VOTs. Reports on this subject appear to differ from language to language and study to study Malavi (2017). According to the majority of studies, women produce longer VOT values than men due to physiological differences between the sexes (Swartz, 1992) but other studies showed that males produce longer VOT durations as a result of societal influences (Oh, 2011). The influence of gender and environmental setting on VOT has been studied in different languages however, it has not been explored in Pakistani English. Hence conducting a study that deals with the influence of gender and environmental setting on VOT in Pakistani English seems to be very important. Therefore, this study attempts to investigate the influence of gender and environmental settings on VOT using the PRAAT Software. PRAAT is an open-source application for analyzing speech sounds in phonetics. It was created by Paul Boersma and David Weenink of the University of Amsterdam. The aim of this study is: to investigate the influence of gender on VOTs and to investigate the influence of environmental settings.

### 1.1 Research Objectives

The objectives of the current study are as follow:

- To analyze the influence of gender on Voice Onset Time.
- To analyze the impact of different external environments like laboratory and lounge on the Voice Onset Time of the participants.

### 1.2 Research Questions

1. What is the difference in Voice Onset Time of the monosyllabic words; pet, top and kit pronounced by different genders?

**H1:** The VOT values of Voice samples by female participants would be higher than the VOT values of the male participants.

2. What is the variance in the Voice Onset Time of the words; pet, top and, kit articulated in different environment settings like laboratory and lounge?

**H2:** The VOT values observed in the laboratory settings would be higher than the VOT values observed in the external settings.

### 1.3 Significance of the study

The current study, which aims at investigating the impact of gender and environmental settings on Voice Onset Time (VOT) in the context of Pakistani English has multiple implications. Firstly, it intends to contribute to the domain of linguistic variation within Pakistani English, especially with reference to the factors of gender and environmental settings and how these factors shape the speech patterns. This aspect of the present study holds the tendency to provide an understanding of sociolinguistic dynamics in different cultural and linguistic contexts. Secondly, it might provide technical understanding for the development of speech recognition and synthesis tools and technologies which are culturally sensitive and inclusive and can be employed in various fields. Thirdly, this study can significantly enhance the understanding of phonological processes across genders and speech production across various linguistic varieties. Furthermore, as the researchers have utilized software named “PRAAT” for the analysis, which is reliable and widely used tool in the field of phonetics, therefore, the current study would yield reliable findings, detailed analyses, and precise measurement that can enhance the credibility and replicability of the results.

### 1.4 Delimitations of the study

Delimitations determine the boundaries drawn by the researcher prior to embarking upon a study and are essential for narrowing the focus of study (Creswell, 2009). The study has been delimited:

- To the calculation of Voice Onset Time for only three monosyllabic words: pet, top, and kit.
- To the sample size of 6 university students (three males; three females).
- To the context of Pakistani variety of English.

## 2. Literature Review

Acoustic phonetics is a well-established field in the domain of linguistics; it enables linguists to analyze the segmental and supra-segmental features of human language. Phoneticians use different software like PRAAT and Audacity to analyze the acoustic properties of speech sounds. Many researchers during the last three decades have composed remarkable studies in the domain of acoustic phonetics especially focusing on Voice Onset Time (VOT). Some of these studies related to the context of the current study have been reviewed below; these studies provide the critical insight, methodological framework, and theoretical framework for the current study as well. Lisker and Abramson (1967) have a great contribution to the field of acoustic phonetics. Their study talks about the characteristics of voiceless aspirated and voiced consonants. The principle findings of this research work suggest that the English plosive sounds /b/, /d/, /g/, /p/, /t/, and /k/ can be discriminated by the variation in time and duration VOT. The sounds articulated in the glottal opening in comparison to the supra-glottal consonant sounds have different VOTs. The researchers mainly focused on the analysis of words starting with plosive consonants and their voice onset time (VOT). According to the researchers, VOT can be defined as the time duration between the abrupt release of the plosives under closure and the onset of the

periodicity that determines the voicing in vocal cords. These consonants are distinctly separate in their phonetic citations while in a continuous speech, less sharp difference and separation can be marked in these sounds. In some cases, an overlapping in the VOT can be seen. This study also concludes that in a continuous speech, some contextual features might influence the VOT which might result in overlapping. The researchers suggest that a voiceless aspirated stop/ plosive at starting of any stressed syllable results in a long lag or interval in the onset of vocal cord vibration. However, these stops in the start of any unstressed syllabic environment have a comparatively lower VOT. Particularly, an increase in voicing interval was observed by the researcher in syllables with stressed sounds at the final position. Thus, voice onset time is an important feature of speech sounds to recognize and distinguish them.

In their study, Allen et al (2003) claim that every distinct speaker has a variety in his/her acoustic properties that differ from another speaker. These varieties and acoustic properties pave the way for phonetic perception. The findings of some previous research work that revealed that the listeners can violate these acoustic differences to help them perceive and recognize speakers' voices and to recognize the words uttered by speakers familiar to them were taken as the conceptual framework for their study. Their study mainly focused on investigating the variation in the speech of an individual speaker especially his/her voice onset time (VOT). These researchers defined VOT as a "temporal property of speech" which clearly distinguishes voicing and un-voicing in plosive consonants. The research also claims that every distinct speaker differs from the other speaker greatly in their Voice Onset Time. The research work explored and analyzed monosyllabic words articulated by eight different speakers. These words are initiated with voiceless plosive consonants. Furthermore, these researchers used hierarchical linear modeling, however, a difference in VOT of different speakers was still observed even though these differences were attenuated. The results of these studies validate that VOT values significantly differ from one speaker to another.

Cooke and Selbie, (1997) have also made a remarkable contribution in the domain of acoustic phonetics and investigation of voice onset time. Their study tends to investigate the vocal cords movement before voicing especially in glottal, normal, and breathy onsets across gender. The methodology adopted by the researchers seemed to be really interesting; the glottal sounds were taken from some video recordings which had a strong laryngoscope and distinct voice onset categories. A relationship that was ( $p \leq 0.0055$ ) was extracted from all the onset categories on the basis of "gesture duration when moving from 80% to 20% of maximum distance during adduction", "maximum velocity", "duration between the completion of adduction" and phonation onset" and "ratios of maximum velocity to the maximum distance between the vocal processes, an estimate of stiffness". The findings revealed that the interval VOT was maximum in the breathy onsets and minimum in the glottal onset consonants. On the other hand, more velocity/ speed and tension were observed in glottal and hard onset consonants and lesser velocity and tension was observed for breathy onsets. The researchers concluded that VOT increases from glottal to normal and then to breathy and heavy voice onset categories.

The study by Whiteside et al, (2004) focused on the investigation of the Values and interval of Voice onset time (VOT) for the stop consonants /p/, /b/, /t/, /d/, /k/ and /g/ with the CVC environment with the following vowel sounds /i/ and /a/. The researchers selected five groups of forty-six males and females aged between five to eight years and thirteen to

twenty years as a sample. Their aim was to investigate the differences in VOT across different sexes and ages. The researchers came to the conclusion that the voice samples from female participants showed a long interval (Voice Onset Time) figure as compared to the VOT values for male participants. The principle findings also suggested that the VOT values of the thirteen to twenty-year-olds were comparatively higher. These differences across genders in VOT values suggested that CVC environment context has an influence on VOT; it is evident from the example that the highest gender differences have been observed for the voiceless stops, and in the vowel environment of /i/.

Zlatin (1974) has also made a great contribution to the field of acoustic phonetics. To conduct this research work the researcher attempted to investigate the role of VOT (voice onset time) in the recognition and articulation of words starting with voiced (with vibration in vocal cords) and voiceless (without vibration in the vocal cords) bilabial, dental, and velar plosives. A sample of twenty native English speakers above 18 years was selected. For the experimental procedure, artificial voice stimuli were composed. The subjects were exposed to the following four set of words as stimuli: “BEES/PEAS, BEAR/PEAR, DIME/TIME, and GOAT/COAT”. Afterward, in the second phase of this work, the researchers calculated the voice onset time for thirty voice samples for the similar syllables that were provided as stimuli for the process of recognition activity. The researchers observed the VOT values from spectrograms and waveforms. The main goal of this research work was to analyze the perceptual data. The principal findings of this work revealed that there were variations in the VOT values of the bilabial, dental, and velar plosives. It was observed that the articulation of voiceless and voiced plosive had a significant variation in the average values of VOT. The research also revealed that the VOT for bilabial and velar onsets were significantly different. The researchers then drew a comparison among recognitions and articulation of such syllables, the results revealed that there were high VOT values for articulated voice samples.

Port and Rotunno’s (1979) study seems to be interesting with respect to acoustic phonetics. Their research work investigated and calculated the VOT and time interval for English plosives and the time interval for a few voiced vowels in single syllables for the speakers in New York City. The results of this study revealed that the Voice Onset Time of a syllable starting with a consonant sound was longer when it was placed before a voiceless final consonant cluster as compared to when it was placed before a nasal sound. VOT was comparatively longer when a voiceless consonant was placed before the tense vowel sounds than the lax vowels. The study also found that the duration of vowels was comparatively longer in the CV environments where the Voice Onset Time seemed to be longer. No constant ratio was seen in the VOT values and the vowel duration. A change in values of VOT was observed for a syllable with a single vowel sound with different places of articulation particularly of the plosives. The researchers also conducted another phase of the experiment in which the syllables with tense vowels and final consonants were constructed and tested. Thus, the findings of this experiment revealed that the ratio of the time duration for vowels significantly changed during the whole procedure. Then the researchers concluded that “temporal implementation rules’ have a great effect on the acoustic time durations and intervals of both Voice Onset Time and the duration of the vowel. Klatt (1975), also has a great contribution in the field of acoustic phonetics. This study by this researcher aimed to investigate and measure the VOT and the time interval of the release of fricative sound for the articulation of a stop consonant. The researchers analyzed the spectrograms and waveforms of syllables starting with consonant clusters and

combinations. Data was collected from three participants who read English words from the same sentence. The researchers came up to the findings that the Voice Onset Time experienced a change when the place of articulation of the plosive was changed. The findings also indicated that the intervals VOT for /p/, /t/ and /k/ had a significant difference in different CVC environments. The researchers also found that the Voice Onset Time seemed to be comparatively longer when these stops were placed in front of high energy and sonorants vowels. On the other hand, when these stops were placed before mid, low, and less sonorous vowels the VOT was shorter. The researchers also found that a puff of air and aspiration was there in a CV environment with more sonorant vowels.

Another similar study has been conducted by Robb et al, (2005) that examined the impact of gender and environmental setting on voice onset time (VOT). The study involved participants producing six stop consonants paired with three vowels in both a laboratory setting (inside a sound booth) and a non-laboratory setting. The analysis revealed that females produced voiceless stops with longer VOT in both settings. Additionally, both gender groups produced tokens with significantly longer duration in the laboratory setting, but females continued to produce tokens with longer duration in the non-laboratory setting. The findings suggested that differences in vocal anatomy between genders may account for some of the observed effects, while socio-phonetic factors, such as speaking style, may also contribute to gender differences in speaking behavior

After reviewing the previous literature on VOT, we reached to the conclusion that the impact of gender and environmental context on Voice Onset Time (VOT) have received attention across various linguistic contexts. However, this phenomenon remains unexplored in the context of Pakistani English. Consequently, there exists a significant research gap into the influence of gender and environmental variables on VOT specifically within the context of Pakistani English. Hence, the importance of conducting a comprehensive study to address the influence of gender and environmental factors on VOT in Pakistani English emerges as a vital research endeavor. Therefore, this study endeavors to investigate the influence of gender and environmental settings on VOT using the PRAAT Software

### **3. Research Methodology**

The current study aims to investigate the difference in Voice Onset Time (VOT) of the monosyllabic words; pet, top and kit pronounced by different genders and the variance in the Voice Onset Time (VOT) of the monosyllabic words; pet, top, and kit articulated in different environmental settings like laboratory and lounge. In order to answer the above-mentioned research questions, we have designed and followed the specific research methodology elaborated below.

#### **3.1. Research paradigm.**

A paradigm is the framework or perspective that guides a researcher's approach for understanding a phenomenon (Creswell, 2014). The current study lies under a positive paradigm which revolves around the perspective that knowledge can be gained through empirical observation and scientific methods. This paradigm focuses on objectivity and quantification. It mostly follows a deductive approach and is used for testing hypotheses. Research within this paradigm often employs quantitative methods, such as experiments, surveys, and statistical analysis, to measure variables and establish causal relationships

(Creswell, 2014). The current study is quantitative in nature and deals with the quantities of Voice Onset Time provided by the software PRAAT. These quantities have been compared across the variables of gender and environmental settings.

### **3.2. Research Design**

Creswell (2014) defines research design as a comprehensive plan outlining the data collection and analysis methods employed to address the research question or hypothesis. However, the current study has employed a quantitative and experimental Research design. The demand of the research questions and hypothesis was to gain quantitative answers and to draw a comparison of the values of VOT across the variables of gender and environmental settings. Moreover, experimental design refers to a type of research design where the researcher manipulates one or more independent variables to observe the effects on one or more dependent variables while controlling for extraneous variables. However, for the current study the variable of Voice Onset Time of the monosyllabic words pet, top, and kit were measured against the Independence variables of gender and different environmental settings. The values of Voice Onset Time were recorded for a comparison against the two variable of male and female and these values were also recorded and compared in two different settings of laboratory and lounge to investigate the effect of these variables on the VOT of the words pet, top and kit.

### **3.3. Population and sample**

The present study was conducted using a qualitative research method. A total number of 6 participants; 3 males and 3 females were selected aged between 22 to 26 years. All the participants belong to a post graduate level and had a good competence and professional in English, or we can say Pakistani variety of English. All these participants belonged to the department of English; hence, their pronunciation patterns were better than the laymen and this factor helped the researchers in the process of data collection.

### **3.4. Sampling Technique**

The research participants were selected on the base of purposive sampling technique that allows the researchers to select the sample with no probability sampling technique where researchers deliberately select participants or the cases that possess specific characteristics relevant to the research question or objectives (Creswell, 2014). Following this sampling technique the researchers selected 6 MPhil scholars who were proficient in English language and had no history of any speech disorder. As the demand of the research was to measure the VOT values in the Pakistani variety of English, therefore, the students of MPhil linguistics were the better choice as they have a good command on this variety of English.

### **3.5 Selection of Words**

The words for data collection were also selected on the base of purposive sampling technique. We selected 3 highly familiar, monosyllabic consonant-vowel-consonant (CVC) Words; each of which began with a voiceless stop consonant. The words selected for the study are pet, top, and kit. Words beginning with voiced stop consonants /b/, /d/, /g/ were not used, because previous work has indicated that VOT values associated with voiced stops are subject to less variability than are VOT values associated with voiceless stops

e.g., Kessinger and Blumstein, (1997); Miller et al., (1986); we therefore chose to concentrate on voiceless stop consonants, where we expected that any individual differences in VOT would appear more clearly.

### **3.6. Data Collection Tool**

The researchers have used the tool PRAAT for the purpose of collection of data. PRAAT is a significantly used software tool for phonetic analysis, primarily used in linguistics and speech science research. It offers a comprehensive suite of tools for analyzing, synthesizing, and manipulating speech sounds. Researchers typically collect data in PRAAT by recording audio samples directly into the software or by importing existing audio files. Once the data is collected, PRAAT provides various forms of output, including spectrograms, waveforms, pitch contours, and acoustic measurements such as formant frequencies and intensity values, and Voice Onset Time. These data can be exported in formats such as text files, image files, or spreadsheets for further analysis or visualization. PRAAT's versatility and user-friendly interface make it an invaluable tool for studying various aspects of speech production and perception.

### **3.7 Data Collection and Analysis Procedure**

Considering the requirement of the study, the recording was taken in two different environmental settings, first in the language lab in the Department of Social Sciences, Air University Islamabad. The second setting was the launch of Air University. In the first setting, all the participants were seated in the language lab and through a microphone which was kept 12 in (30 cm) away from the mouth of the participants in both environmental settings. The word list was placed in front of the participants and with a 5-second pause every word was pronounced and recorded. The participants were instructed to produce their natural pronunciation. After that, we analyzed the recording using PRAAT Software for the data analysis and findings. Voicing occurred before the burst release was measured by placing the left cursor at the onset of the pre-burst voicing and the right cursor was positioned at the burst release. The VOT for this time interval was reported as a negative value. In addition to VOT, the overall duration of each CV token was measured. The CV duration was defined as the time interval between cursors at the burst release and the last instance of vocal fold vibration associated with the vowel. The CV duration was reported in milliseconds.



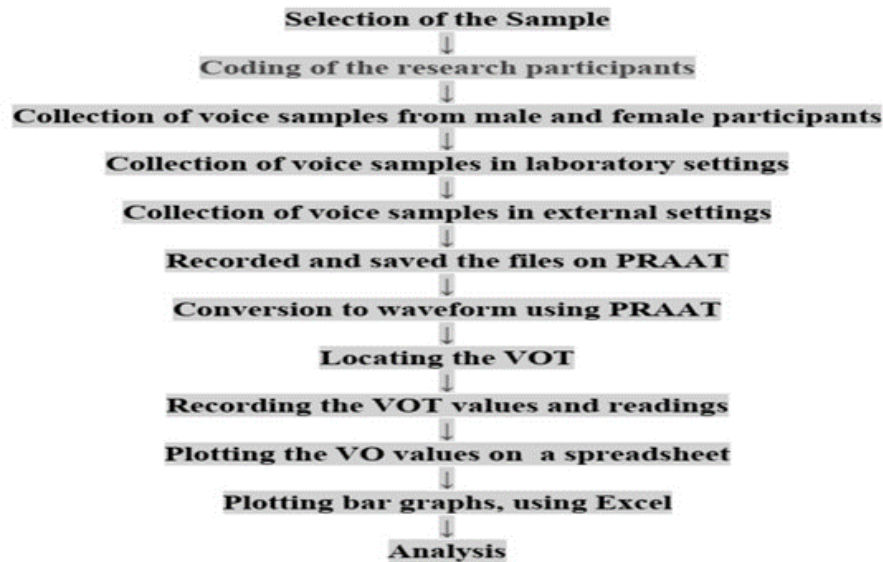


Figure 3: Data Collection and Analysis Procedure

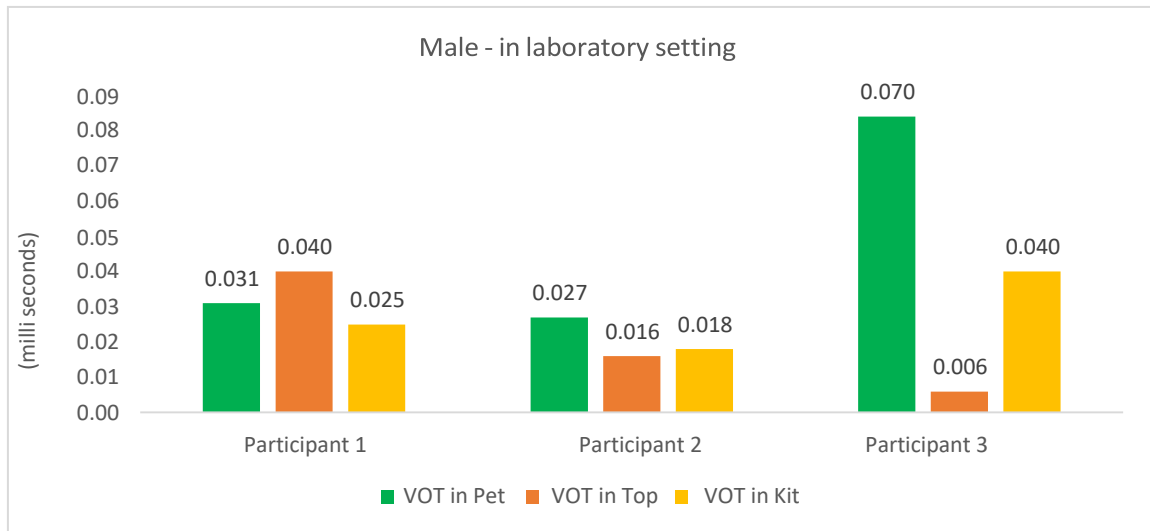
### 3.8. Ethical Considerations

Good research follows the moral guidelines and ethical principles during the conduct of the research. During the current study the researchers tried to follow most of the moral and ethical guidelines, for instance the consents of the research participants were taken before the collection of their voice samples. The participants were informed about the purpose of the study, and they were ensured that their Voice samples would solely be used for the purpose of research. Additionally, their identities were kept anonymous and private.

## 4. Data Analysis and Discussion

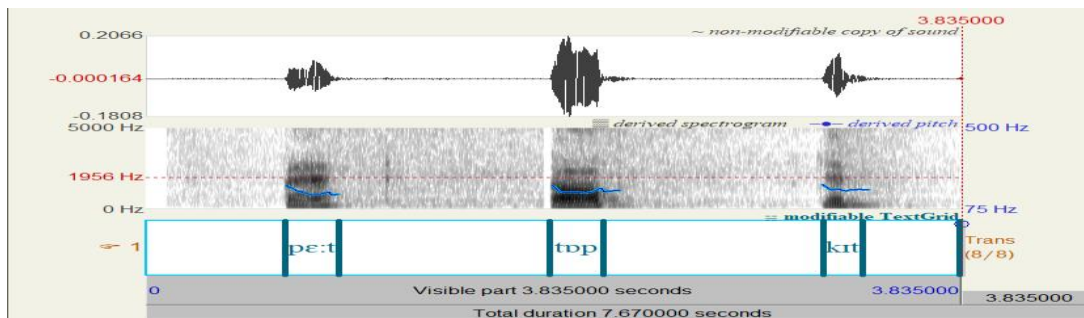
The collection of voice samples of the participants in both controlled laboratory setting and uncontrolled external setting was done while directly recording on PRAAT. After that the recorded files were saved in waveforms, for further analysis. Afterwards, the researchers analyzed the waveforms and spectrograms and located the burst of air and the pause in articulation VOT, then the time duration between the burst of air and voicing was noted and recorded in milliseconds. Furthermore, all the 36 readings of VOT were recorded and plotted on a spreadsheet for creating a visual representation of the results in form of bar graphs which could make the analysis and comparison of effects of gender and environmental setting on VOT easy and possible. Afterwards, the bar graphs were plotted using Microsoft Excel and spreadsheet, on which the VOT values have been plotted. The bar in green color represents the VOT value for the word *pet*, the bar in red color shows the VOT value for the word *top* and the bar in yellow displays the VOT value for the word *kit*. Moreover, the bar graphs that draw a comparison between variables and show their influence on the VOT value have been plotted and analyzed. The following figures showcased below display a step-by-step procedure followed by the researchers that have

been interpreted and discussed.

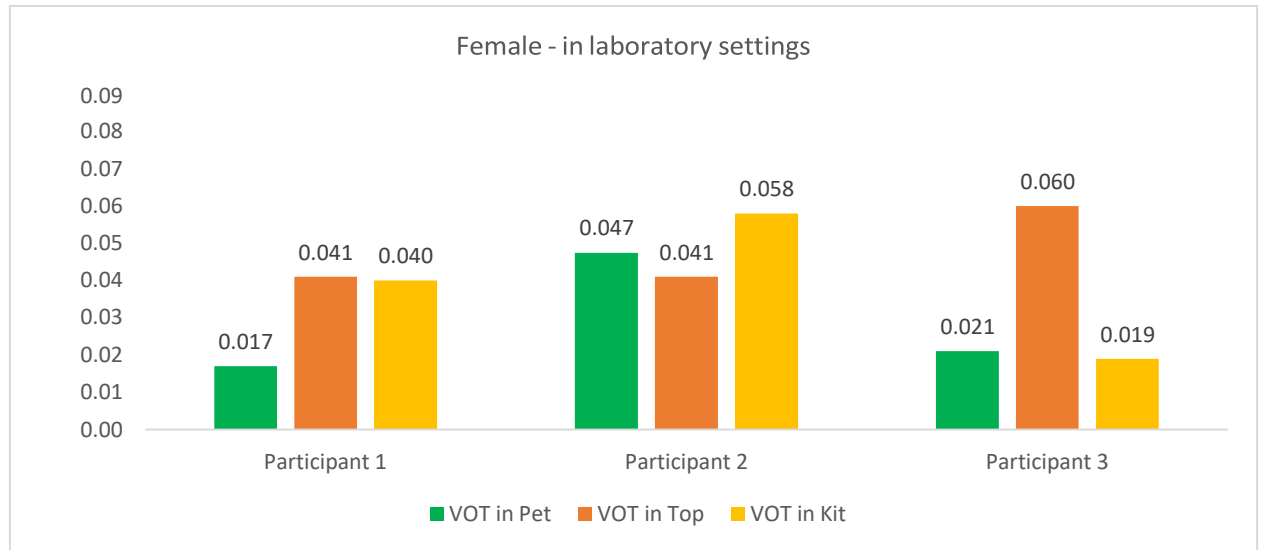


**Figure 1 (a): VOT in Male Voice Samples in Laboratory Setting**

Figure 1(a) shows the Voice Onset Time (VOT) values of the three monosyllabic words: pet, top, and kit, as pronounced by three male participants in a laboratory setting. Notably, the highest VOT value was recorded in the word "pet" pronounced by the third male participant, while the lowest VOT was observed in the pronunciation of the word "top" by the same participant as can be seen in the (figure 1(b) below)

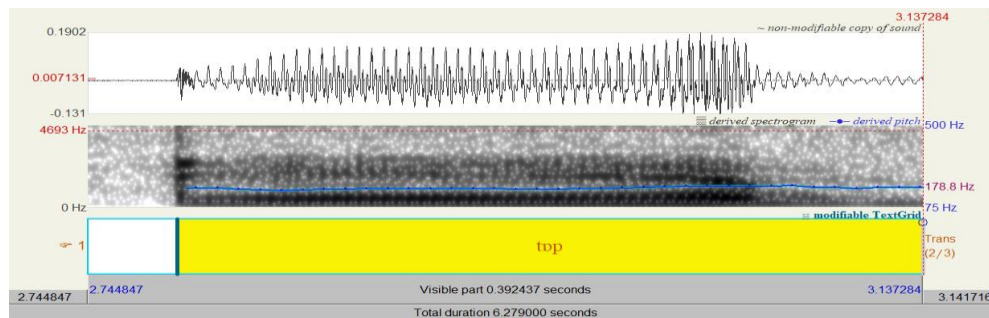


**Figure 1 (b): Spectrogram of VOT in Laboratory Setting**

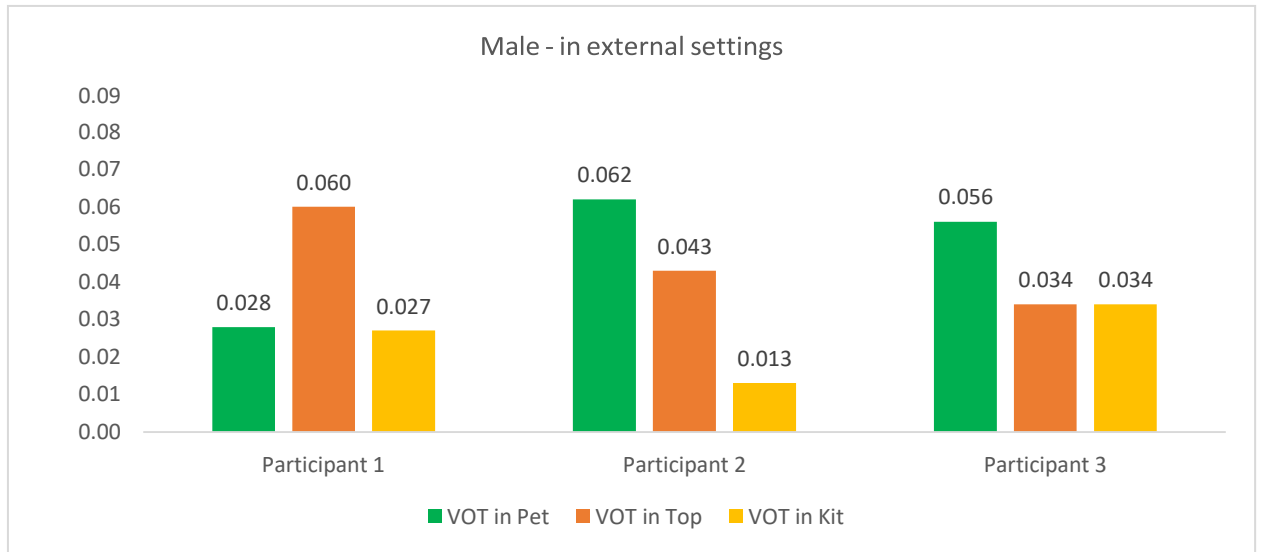


**Figure 2(a): VOT in Female Voice Samples in Laboratory Setting**

The Figure 2(a) shows the VOT values of female participants within a controlled laboratory environment. Notably, the highest VOT values were observed in the pronunciation of the word "top" by female participant number 3 (see Figure 2(b) , while the lowest VOT was recorded for the word "kit" pronounced by female participant number 1.

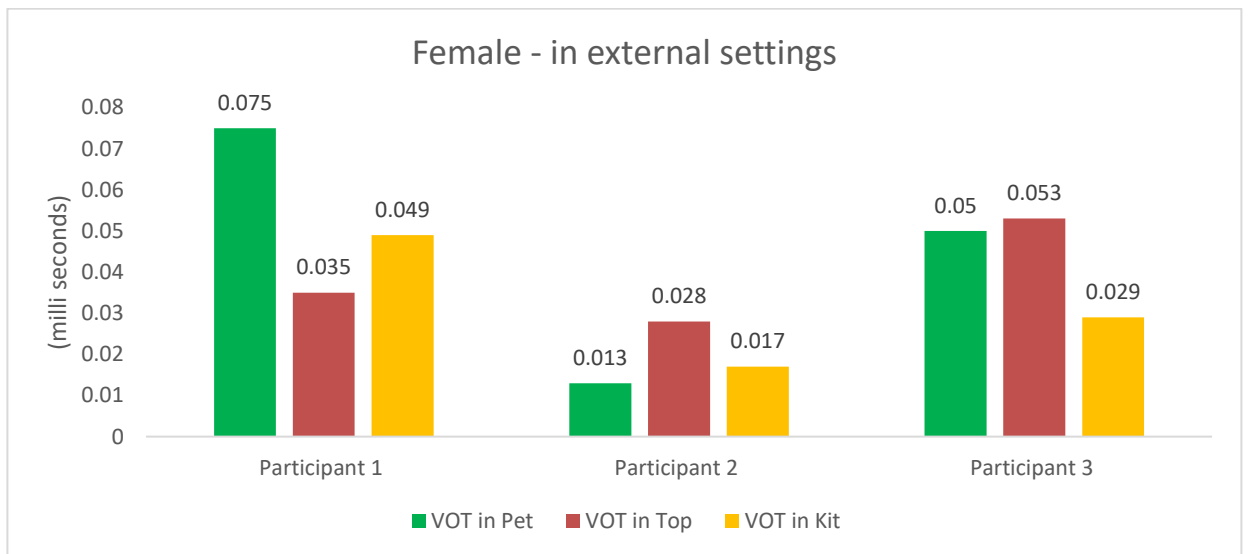


**Figure 2(b): Spectrogram of VOT in Laboratory Setting**



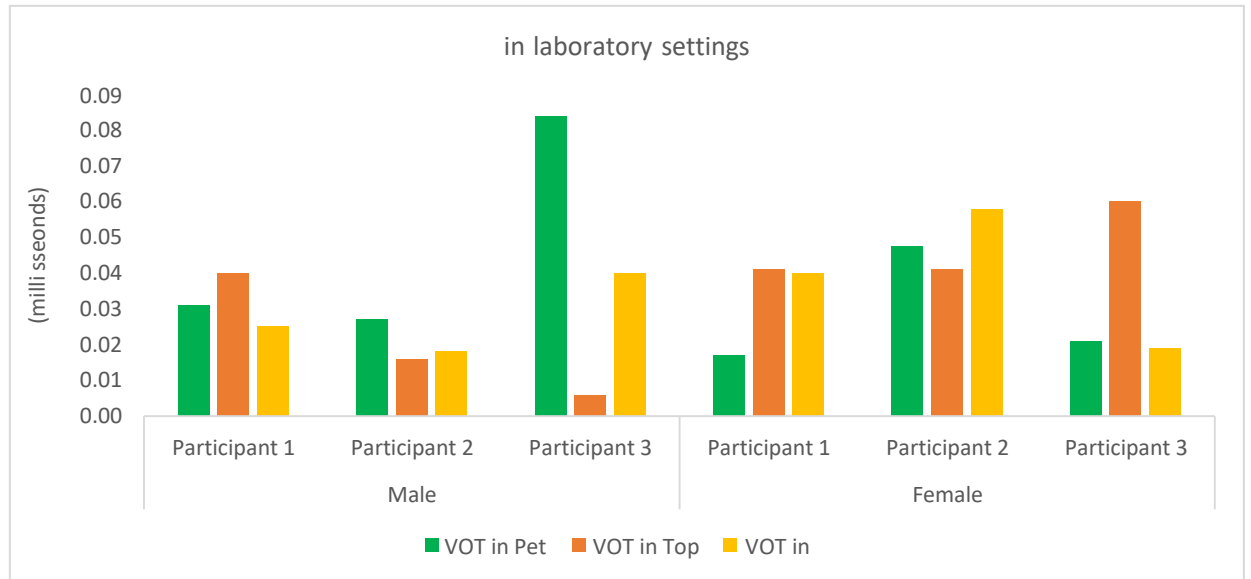
**Figure 3:** VOT in Female Voice Samples in Laboratory Setting.

Figure 3 shows the voice onset time values for the male participants in external settings. The highest voice onset time value has been recorded for the word *pet* pronounced by the male participant number 2. The lowest VOT has been observed for the word *kit* pronounced by male participant number 2.



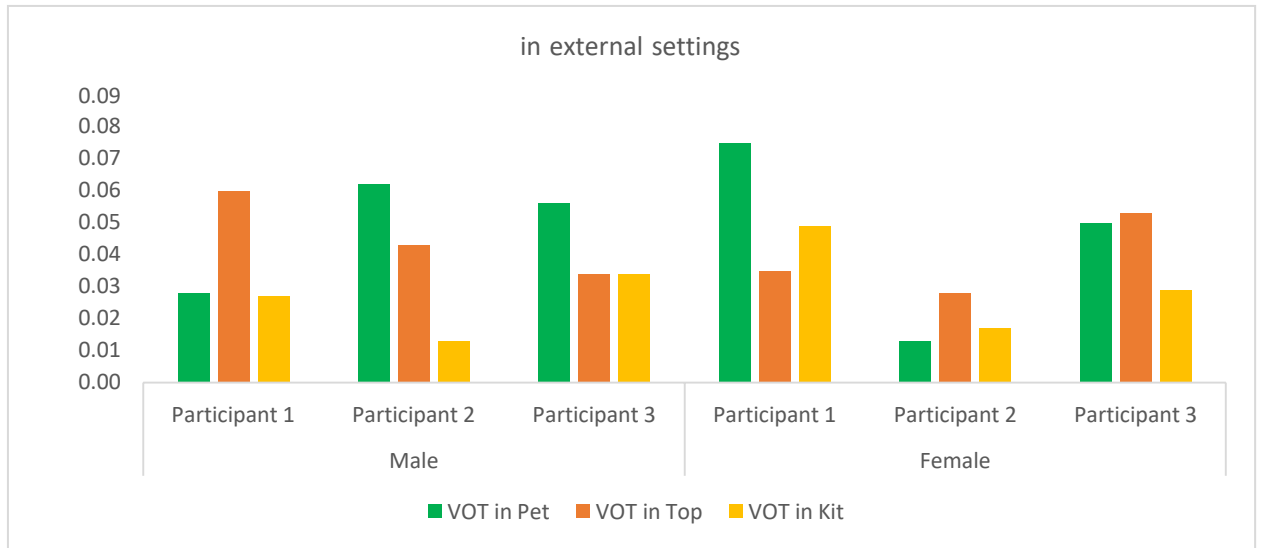
**Figure 4:** VOT in Female Voice Samples in External Settings

The Figure 4 shows the VOT values for the female participants in external settings. The highest VOT value has been observed for the word *pet* pronounced by female participant number 1. The lowest VOT value has been observed for the word *pet* pronounced by the female participant number 2.



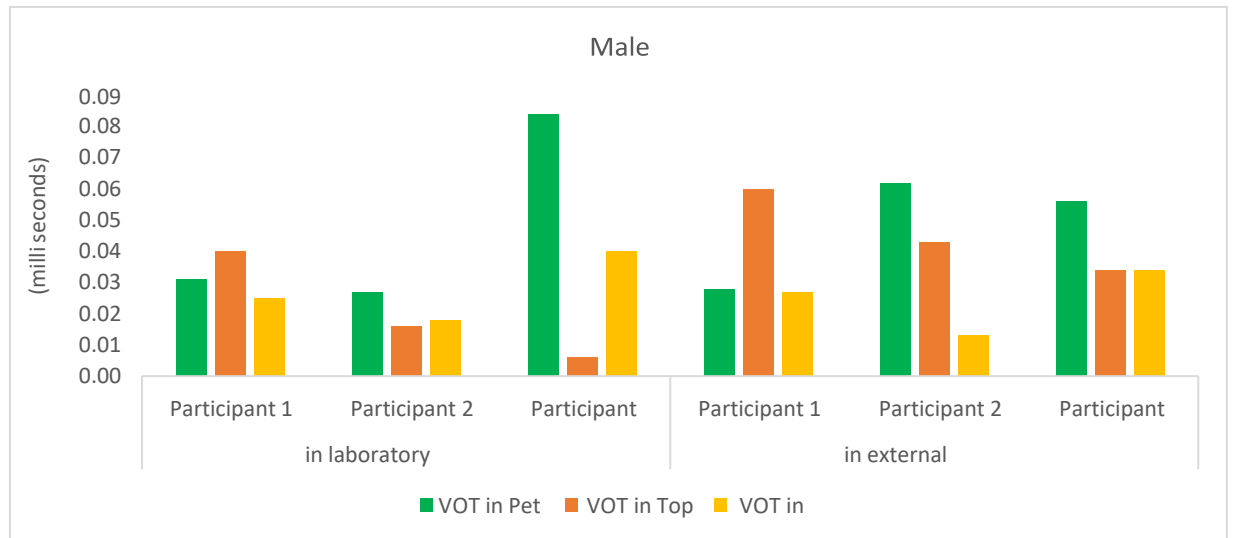
**Figure 5:** VOT in Male and Female Voice Samples in Laboratory Settings.

The Figure 5 provides a comparison of Voice Onset Time (VOT) values for both male and female participants in laboratory settings. Upon analysis of the graph, it is clearly evident that the VOT values for female participants are significantly higher than those of male participants. This indicates a noticeable difference in the way speech sounds are produced by males and females



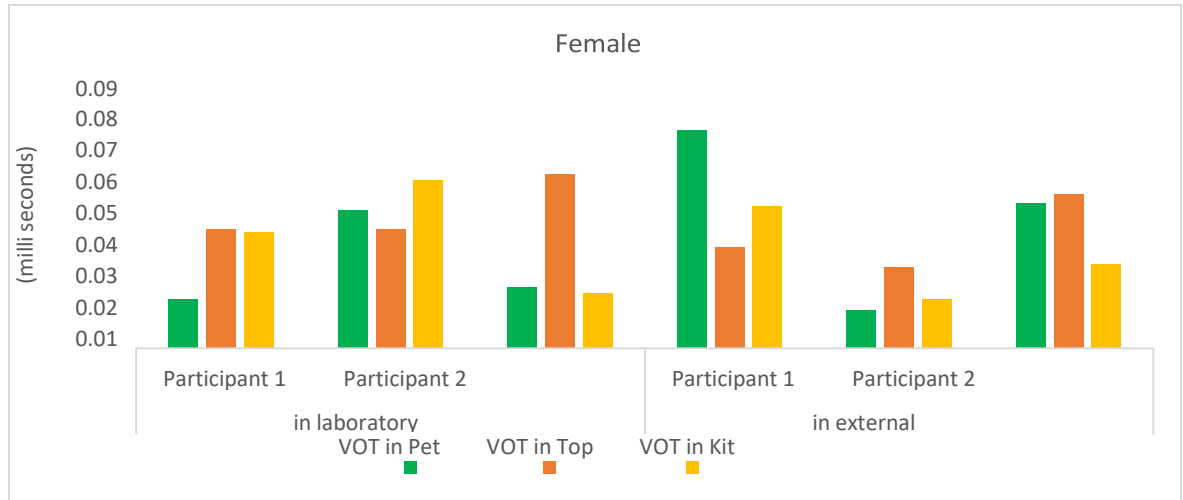
**Figure 6:** VOT in Male and Female Voice Samples in External Setting

The Figure 6 presents a comparison between the Voice Onset Time (VOT) values of male and female participants in external settings. By analyzing the graph, it can be observed that the average VOT value for male participants is significantly higher than the average VOT value for female participants. This suggests that there is a difference in the way male and female speakers initiate phonation, which can be attributed to biological, physiological or sociolinguistic factors.



**Figure 7:** VOT in Male Voice Samples in Laboratory and External Settings

The data presented in Figure 7 highlights the variation in voice onset time (VOT) values for male participants across laboratory and external settings. Upon examining the graph, it becomes apparent that the VOT values for the male voice samples obtained in laboratory settings are significantly higher than the corresponding values observed in external settings. This finding suggests that the acoustic properties of the environment can have a noticeable impact on speech production, particularly in terms of the timing of vocalic and consonantal sounds.



**Figure 8:** VOT in Female Voice Samples in Laboratory and External Settings

The figure 8 shows that there is a noticeable difference in the voice onset time (VOT) values of female participants between laboratory settings and external settings. Specifically, the VOT values recorded in laboratory settings are observed to be higher than those recorded in external settings. This finding suggests that the environment in which speech is produced can have an impact on the VOT values of female participants.

The study utilized PRAAT Software to analyze Voice Onset Time (VOT) values of male and female participants pronouncing monosyllabic words in both laboratory and external settings. The data was presented through graphical representations illustrating VOT values for different participant groups and settings. The results of the current study supports H1, indicating that female participants exhibited higher VOT values compared to male participants across both laboratory and external settings. This finding is consistent with previous research suggesting gender-related differences in VOT production. Furthermore, the study validates H2 by demonstrating that VOT values tended to be higher in laboratory settings compared to external settings for the majority of voice samples.

## 5. Conclusion

The purpose of this study was to explore how gender and environmental setting impact VOT, using the PRAAT Software. Upon thorough analysis of the data, the results indicated that female participants had higher values of voice onset time compared to their male counterparts. Additionally, voice onset time was generally higher in lab settings than in external settings for the majority of voice samples. The study offers valuable insights into the relationship between gender, environmental settings, and VOT values in speech production. By leveraging PRAAT Software, the research advances our understanding of acoustic phonetics and contributes to the existing body of knowledge in phonology. The findings underscore the need for further exploration of gender-related differences in speech



production and emphasize the role of environmental factors in shaping phonetic variation.

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