Loquens 10(1-2)
Diciembre 2023, e100
eISSN 2386-2637
https://doi.org/10.3989/loquens.2023.e100

Multiple bursts in non-native and native English: Evidence from twelve L1s

Darío Barrera-Pardo
[1]Universidad de Sevilla
dario@us.es ORCID: https://orcid.org/0000-0002-3439-4883

Enviado: 09/06/2022; Aceptado: 13/11/2023; Publicado en línea: 14/12/2023

Citation / Cómo citar este artículo: Darío Barrera-Pardo (2023). Multiple bursts in non-native and native English: Evidence from twelve L1s. *Loquens, 10*(1-2), e100, https://doi.org/10.3989/loquens.2023.e100.

ABSTRACT: Voiceless plosives are frequently produced with multiple bursts (MBs), a phenomenon that has substantial implications for voice onset time measurement (VOT) of these consonants. MBs have been noted in previous research, but have not been systematically quantified. The objective of this study was to analyze MBs in non-native English (with data from twelve first languages) and native English, and to discern the effect of MBs on VOT measurement. Further, the potential effects of place of articulation (PoA), gender, speech rate, and age on MBs were explored. Results showed that VOT measurement method in the presence of MBs had a significant effect on the VOT values obtained for the plosives. In addition, MBs were influenced to a large extent by PoA, but not by gender, speech rate, or age. Comparisons between non-native English and native English revealed some significant differences, but in both varieties the analyses of MBs showed overall similar tendencies.

Keywords: multiple bursts, voiceless plosives, voice onset time measurement, non-native English, native English.

RESUMEN: *Barras de explosión múltiples en inglés no nativo e inglés nativo: datos provenientes de doce primeras lenguas.* Las oclusivas sordas se producen con frecuencia con barras de explosión múltiples, un fenómeno que tiene implicaciones sustanciales para la medición del tiempo de inicio de la sonoridad (VOT) de estas consonantes. Las barras de explosión múltiples se han observado en investigaciones anteriores, pero no se han cuantificado sistemáticamente. El objetivo de este estudio fue analizar las barras de explosión múltiples en inglés no nativo (con datos de doce idiomas como primera lengua) e inglés nativo, y discernir el efecto de las barras de explosión múltiples en la medición del tiempo de inicio de la sonoridad (VOT). Además, se exploraron los efectos potenciales del lugar de articulación (PoA), el género, la velocidad del habla y la edad en las barras de explosión múltiples. Los resultados mostraron que el método de medición de VOT en presencia de barras de explosión múltiples tuvo un efecto significativo en los valores de VOT obtenidos para las oclusivas. Además, las barras se explosión múltiples se vieron influenciadas en gran medida por el PoA, pero no por el género, la velocidad del habla o la edad. Las comparaciones entre el inglés no nativo y el inglés nativo revelaron algunas diferencias significativas, pero en ambas variedades los análisis de MB mostraron tendencias similares en general.

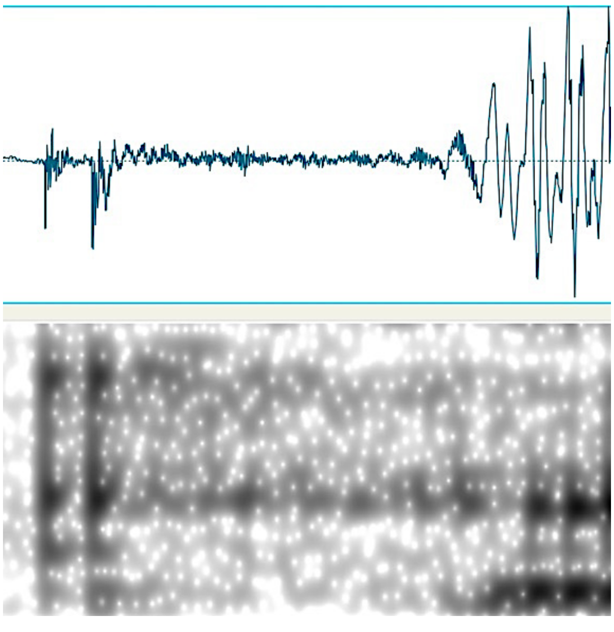
Palabras clave: barras de explosión múltiples, oclusivas sordas, medición del tiempo de inicio de la sonoridad, inglés no nativo, inglés nativo.

1. INTRODUCTION

Plosives are, as a group, the most common consonants in the languages of the world, and the greater part of world languages have voiceless plosives (Ladefoged & Maddieson, 1996; Maddieson, 1984). More specifically, Moran and McCloy (2019) found that /p/ had an 86% frequency in the languages they surveyed (2,186 languages); the frequencies for /t/ and /k/ were 68% and 90% respectively. A crucial characteristic that contrasts voiceless plosives among the languages of the world is their voice onset time (VOT) (e.g., Hayward, 2000). This refers to the time that elapses between the release of the plosive and the onset of vocal fold vibration (of the following vowel or approximant). There are three types of VOT: negative VOT, zero VOT, and positive VOT. The latter type can be further subdivided into long and short positive VOT; plosives with a long positive VOT are said to be aspirated (e.g., Wayland, 2019). The release stage of the plosive is evidenced acoustically by a burst or transient on the waveform, and a plosion bar on the spectrogram. As noted by Bóna and Auszmann (2014) and Ladefoged (2003), among others, measuring VOT is often marred with complications. One of them is that voiceless plosives can be released in multiple stages, thus producing multiple bursts (MBs). Figure 1 displays the production of the initial plosive in the word *kids* by a non-native speaker of English with Hindi as his first language (L1). The velar has two transients (as shown on the waveform) and two corresponding plosion bars (shown on the spectrogram.

A few explanations for the production of MBs have been advanced. According to Plauché (2001), this phenomenon may be due to rapid intraoral pressure during closure, which lowers abruptly upon the release of the plosive, producing multiple transients. As will be illustrated later (see sections 1.1 and 1.2), velar plosives have been shown to present many more MBs than other places of articulation (PoAs). Song, Demuth, and Shattuck-Hufnagel (2012) and Plauché (2001) explain that this phenomenon may result from the large area of the velar obstruction and its accompanying slow release, which gives rise to multiple burst releases. Plauché (2001) also notes that some researchers have posited that the closure stage may be conditioned by the Bernoulli force, whereby the quick airflow initiation creates negative pressure at the obstruction place.

Figure 1: Hindi speaker 19 production of *kids* [ˈkʰɪdz] with two bursts.



To reiterate, aspiration can only be analyzed by measuring the VOT of the plosive, and, as is in many occasions the case when voiceless plosives are produced with MBs, complications arise. In the presence of MBs, it has to be decided whether VOT measurement will be made from the first burst or the last burst (or some other point, see Gráczi & Kohári, 2014). Prior research has determined that different methods produce statistically significant disparate VOT durations, and that factors such as PoA, vowel height, and speech rate have an effect on MBs to varying degrees (Barrera-Pardo, 2022). In line with these past findings, the aim of the current study is to analyze MBs in non-native English and establish a comparison with native English. First, it explores whether VOT values are affected when measuring VOT from the first or last burst. Second, it investigates the effect of PoA, gender, speech rate, and age on MBs.

MBs have been identified in various languages, although few researchers have quantified them systematically (notable exceptions are Gráczi & Kohári, 2014, for Hungarian; Barrera-Pardo, 2022, and Lavoie, 2001, both for Spanish). The following sections review research on MBs in English and other languages.

1.1. MBs in English

Lavoie (2001) found in her North American English data MBs for /p/ (6 MBs), /t/ (1 MB), and /k/ (25 MBs). Interestingly, she reported many more MBs for the voiced plosives (11 for /b/, 9 for /d/, and 29 for /g/). In both voiceless and voiced plosives she analyzed 30 tokens per consonant, and the reported figures refer to the total number of MBs.

Repp and Lin (1989), for the same variety, found that MBs were common for alveolars and velars in back vowel contexts, and that MBs were always present for velars in front vowel contexts. A few cases of double bursts involving bilabials were also reported. They also found that, in spontaneous speech, MBs especially for velars were much less frequent. These researchers further noted that vowel type, speaker identity, and gender did not statistically affect the number of bursts, whereas PoA did. Like other studies, Parveen and Goberman (2012), also for North American English, reported a significant effect of MBs across PoA, such that velars had the highest number of MBs, followed by alveolars and then bilabials. Sučková (2020) investigated VOTs of North American English-speaking residents in a Czech language context, noting the presence of MBs, although she did not quantify them. For Australian English, Millasseau et al. (2019) also reported finding MBs in the production of plosives. Imbrie (2005) investigated the development of plosive production in North American English-speaking children. She determined that children produced more bursts than adults, with a statistically significant difference. Again, and as in prior research, the effect of PoA on the number of bursts was statistically significant, with velars presenting the highest number of bursts, and bilabials the least.

1.2. MBs in other languages

MBs have been attested for languages other than English. Yang (2018) determined that in Mandarin velars had more MBs than the alveolars and bilabials. The vowel context was found to have an effect on the number of bursts, whereby plosives followed by /i/ presented significantly more MBs than plosives before /a/ or /u/. In Spanish, Torres and Iparraguirre (1996) observed MBs for /k/. Asensi, Portolés, & del Río (1997) studied the plosives of Castilian Spanish, finding in their analyses that especially the velar had MBs, which had double and triple plosion bars, whereas /t/ presented double bars. Lavoie (2001) reported for Mexican Spanish numerous MBs for /k/ (31), whereas she found only 1 for /t/ and none for /p/. Barrera-Pardo (2022), analyzing the voiceless plosives of Western Andalusian Spanish, reported MBs across all three PoAs. 9.5% of bilabials had MBs, and the percentages for /t/ and /k/ were 15.22% and 33.33% respectively. The velar presented up to 5 bursts. Vowel context had a statistically significant effect on MBs, such that high vowels triggered more bursts.

MBs have also been reported for Hindi. Sirsa and Redford (2013) found MBs in the measurement of VOT for voiceless plosives of Hindi. Davis (1994) reported that velars in this language very frequently presented MBs. In Brazilian Portuguese, Michelon Melo et al. (2014) found MBs for both voiceless and voiced plosives. In the speech of child speakers of European Portuguese, Brinca et al. (2016) also reported MBs for voiceless plosives. Also for European Portuguese, Lousada, Jesus, and Hall (2010) found MBs in the speech of adult speakers. A language in which MBs have been identified and further quantified is Hungarian; Gráczi and Kohári (2014) determined that nearly 48% of the voiceless plosives they analyzed presented MBs: 27.5% of the bilabials had MBs, whereas the percentages for /t/ and /k/ were 45% and 66.4% respectively. They also reported that the height of the vowel following the plosive had no effect on the number of bursts, except for /k/, which, when followed by /i/, presented at least two bursts in 77.5% of the productions. For Czech, Kaňok and Novotný (2019) reported MBs in their analysis of the effects of age and gender on the plosives of this language. They reported MBs as occurring in their analyses, but no further quantification was offered.

In summary, PoA emerges as a powerful factor in the production of MBs, such that, according to most researchers, bilabial consonants have fewer MBs than alveolars, and these in turn present fewer MBs than velars. The pattern when quantifying MBs then appears to be /p/ < /t/ < /k/.

1.3. VOT measurement in the presence of MBs

MBs complicate VOT measurement (e.g., Foulkes, Docherty, & Jones, 2010). A number of methods may be employed to measure VOT in the presence of MBs (see Barrera-Pardo, 2022 for a review), although most researchers seem to take the first burst as the measurement point: 24 (63%) of the 38 studies reviewed by Barrera-Pardo chose this method. It is noteworthy, nonetheless, that only Gráczi and Kohári (2014) and in more detail Barrera-Pardo (2022) have investigated the effect of choosing a particular method when measuring VOT (first or last burst, in both studies). The results reported by these researchers suggest that this decision may be crucial for VOT measurement.

1.4. MBs and gender

Plauché (2001) investigated the acoustic cues that are used to identify the PoA of plosives; she determined that the number of bursts did not vary statistically significantly by speaker gender. Barrera-Pardo (2022) found that in a Spanish variety (Western Andalusian), gender did not play a role in the number of bursts that the voiceless plosives of this dialect presented.

1.5. MBs and speech rate

Sönmez et al. (2000) offered data that suggest that in spontaneous speech (with a concomitant faster speech rate), MBs were less numerous than in elicited speech. However, Barrera-Pardo (2022) reported a very weak and marginally significant ($\rho = 0.15$, $p = 0.8$) correlation between speech rate and the number of bursts produced, such that a faster speech rate appeared to be related to a larger number of bursts. Similarly, Wang et al. (2004) found that patients with traumatic brain injury who spoke at a faster speech rate produced more MBs.

1.6. MBs and age

For Mandarin, Yang (2018) examined developmental data of children, finding that children produced significantly more MBs than adults, a pattern that corroborated Imbrie's (2005) findings for English plosives. Parveen and Goberman (2012) explored MBs in younger and older adult speakers. They did not find statistically significant differences between PoA and age group; the effect of age group on the number of bursts was not statistically significant either.

1.7. Research questions

The current study investigates the production of MBs by non-native English speakers of twelve different L1s, as further explained in section 2.1. It further compares non-native productions with native productions of MBs. Given the findings presented in the preceding sections, it is hypothesized, first, that measuring VOT either from the first or last burst will produce markedly different VOT values for the three voiceless plosives analyzed (/p/, /t/, /k/). Second, it is expected that the number of MBs will be influenced by PoA, speech rate, and perhaps age; speaker gender, however, is not expected to play a role in the number of MBs. The present study seeks to answer the following research questions:

RQ1 What is the effect of measuring VOT in non-native English and native English according to two MB measurement methods?

RQ2 What are the effects of the factors PoA, speech rate, age, and gender on MBs in non-native English and native English?

2. THE STUDY

The data for this study were collected from native and non-native speakers of English with twelve different L1s. Native speaker data were collected to compare VOT measurement method in the presence of MBs and the effects of PoA, speech rate, age, and gender with non-native data. The selected L1s were listed as having the most native speakers in the world (Ethnologue, 2022); the languages are Mandarin, Spanish, Hindi, Bengali, Portuguese, Russian, Japanese, Vietnamese, Turkish, Korean, Farsi (Persian), and German. Arabic was excluded because this language does not have /p/ in its phonological inventory.

2.1. Speakers

The speaker characteristics are listed in Table 1. These speakers were selected for VOT and MB scrutiny according to their feasibility for acoustic analysis; recordings of poor quality were hence discarded. One of the biographical data reported in the *Speech Accent Archive* (see below section 2.2) is length of English residence (LOR; range 0 – 58), which was not included in the current study, since a non-parametric Spearman correlation between LOR and the number of bursts yielded a negligible and non statistically significant relationship ($\rho = 0.07$, $p = 0.09$). The *Speech Accent Archive* does not report speaker's level of English, but it does report English learning method (academic or naturalistic) and age of English learning onset. Speakers were thus chosen so that they had learned English in an academic setting and had started learning English after puberty (i.e., older than 12 years); the latter is a variable that has long been known to determine accented speech (e.g., Flege, 1981). Foreign-accented speech was evident in all the recorded samples chosen for further acoustic analysis. Thus, for the purposes of the current study, the non-native speakers evidenced equivalent characteristics. Regarding age, the range for the native speakers was 18 – 86, similar to the non-native speakers' range (18 – 84). There were roughly the same number of females and males in both groups of speakers, non-native and native.

Table 1: Speaker characteristics

L1	N	M_{age}	SD_{age}	Female	Male
English	125	39.3	19.8	59	66
Bengali	14	29.8	13.39	7	7
Farsi	15	29.1	11.70	8	7
German	15	35.3	11.11	9	6
Hindi	15	31.2	11.52	6	9
Japanese	15	41.4	19.54	8	7
Korean	15	31.9	13.88	7	8
Mandarin	15	31.6	8.99	9	6
Portuguese	15	29.5	8.09	8	7
Russian	15	37.6	16.02	8	7
Spanish	15	32.9	10.70	6	9
Turkish	15	25.3	5.96	7	8
Vietnamese	15	35.8	15.28	6	9
Total non-native	179	32.62	4.33	89	90

2.2. Material

Recordings from the 125 English native speakers and the 179 non-native speakers were retrieved from the *Speech Accent Archive* (Weinberger, 2015), which houses a large sample of native and non-native speakers of English, reading the elicitation passage that follows:

*Please call Stella. Ask her to bring these things with her from the store: Six spoons of fresh snow **peas**, five thick slabs of blue cheese, and maybe a snack for her brother Bob. We also need a small plastic snake and a big **toy** frog for the **kids**. She can scoop these things into three red bags, and we will go meet her Wednesday at the train station.*

The words *peas*, *toy*, and *kids* were used to measure the VOT and MBs (if any) of /p, t, k/. These words were chosen because the voiceless plosives are followed by a vowel, instead of an approximant, as in *please* or *train*. Words with different phonological shapes (e.g., multisyllabic words) might yield different results (see section 5). As previously mentioned, sound files for each language and speaker were carefully inspected in order to select those of good quality for acoustic analysis. The sound files were saved and subsequently normalized for peak amplitude.

2.3. Analysis

For the non-native L1s, 537 plosives were collected (3 tokens x 179 speakers). Of these, 69 plosives were discarded because they were impossible to analyze. This resulted in 468 plosives subjected to analysis: 155 bilabials, 159 alveolars, and 154 velars. For the English native speakers, 375 plosives were collected (3 tokens x 125 speakers). Of these, 43 plosives were discarded because it was not possible to analyze them. This resulted in 333 plosives subjected to analysis: 112 bilabials, 114 alveolars, and 107 velars. The release bursts of the voiceless plosives were identified on the waveform together with a wideband spectrogram. Figures 2 and 3 illustrate this procedure.

Figure 2. Mandarin speaker 14 production of *peas* [ˈp^{h}iz] with two bursts.

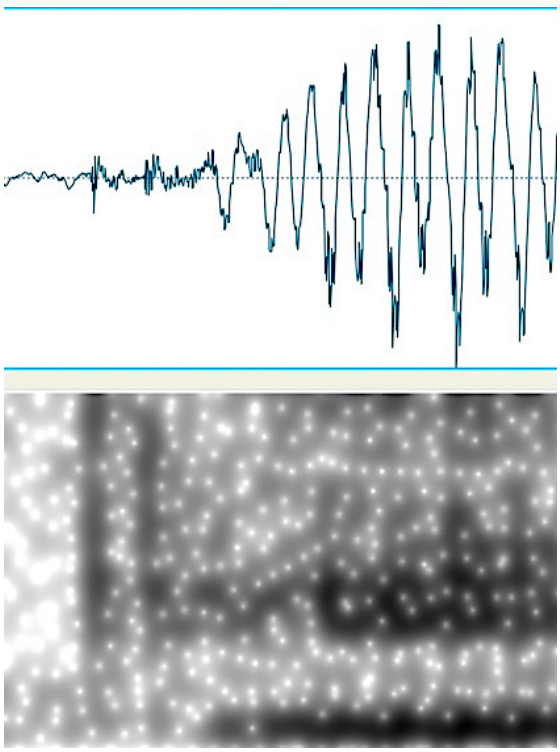
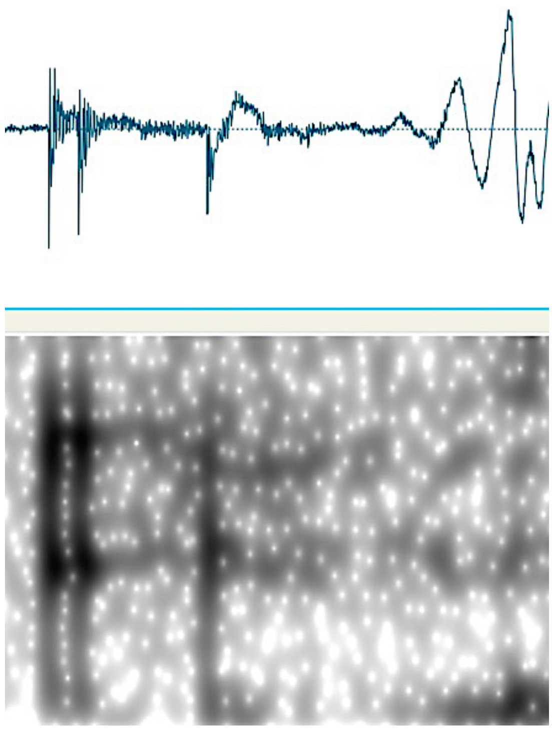


Figure 3. Spanish speaker 25 production of *kids* [ˈk^{h}ɪdz] with three bursts.



For each plosive that presented MBs, VOT was measured from the first burst and also from the last burst. For example, for the L1 Mandarin speaker production of *peas*, shown in Figure 2, the VOT as measured from the first burst resulted in 28 ms; when VOT was measured from the last burst, the VOT was 22 ms. In the case of the L1 Spanish speaker's production of *kids*, shown in Figure 3, the VOT measurement from the first burst was 62 ms, and from the last burst it resulted in 41 ms. VOT was measured in each token from the first and last burst, as indicated, to the beginning of periodicity, as marked by a clear F2 of the following vowel. It was decided to measure VOT from the last burst because, as explained by Keating et al. (1980), this may be the intended one. In addition, the number of MBs for each consonant was tallied separately for non-native and native English. Finally, to confirm the reliability of the data measurements (VOT, number of MBs), the author reanalyzed 25% of the data three weeks after the first analysis, which yielded a very high correlation between both rounds of measurements, $r = 0.87$, $p < 0.001$.

3. RESULTS

3.1. Effect of measurement method of MBs on VOT

Table 2 presents the descriptives related to RQ1, for non-native English. Expectedly, the VOT measurement method produced different VOT values. However, it appears that the mean differences between the first and last burst measurement were very similar for both /p/ and /t/, about 6 ms for each, whereas for /k/ the difference was much larger, about 14 ms. The spread of the values, as indicated by their SDs, was also similar in the bilabials and alveolars, although higher for these than for the velars.

Table 2: VOT by measurement method (First, Last burst) in non-native English.

Burst	Plosive	N	Mean VOT	SD
First	Bilabial	41	63.61	30.51
	Alveolar	39	65.84	28.77
	Velar	112	77.06	21.04
Last	Bilabial	41	56.82	30.87
	Alveolar	39	59.48	28.92
	Velar	112	62.70	21.06

To analyze in non-native English the effect of VOT measurement method (from the first burst, or from the last burst), an ANOVA with VOT as the dependent variable and PoA (Bilabial, Alveolar, Velar) and VOT measurement (First burst, Last burst) as factors was planned. Prior to running this test, the assumptions of ANOVA were checked. VOT was not normally distributed, as evidenced by visual inspection of boxplots, and more formally assessed by a Shapiro-Wilk test ($W = 0.98$, $p < 0.001$). Accordingly, non-parametric equivalents of ANOVA, the

Kruskal-Wallis test, were run. There was a statistically significant effect of PoA, $\chi^2(2) = 41.86$, $p < 0.001$, with a medium effect size, $\eta^2 = 0.06$ (for the interpretation of the effect size indices hereafter reported, see Cohen, 1988). A statistically significant effect of measurement method was found, $\chi^2(5) = 33.62$, $p < 0.001$, $M_{difference} = 11.12$, with a medium effect size, $\eta^2 = 0.09$. Post-hoc tests with a Bonferroni correction showed the following. For /p/, there was not a statistically significant difference as measured from the first or last burst, $M_{difference} = 6.79$, $p_{bonferroni} = 1$, with a small effect size, $d = 0.22$; for /t/, there was not a statistically significant difference as measured from the first or last burst, $M_{difference} = 6.36$, $p_{bonferroni} = 1$, with a small effect size, $d = 0.26$; and finally, for /k/, there was a statistically significant difference as measured from the first or last burst, $M_{difference} = 14.36$, $p_{bonferroni} < 0.001$, with a large effect size, $d = 0.72$.

The descriptives for the MB measurement method for native English speakers are presented in Table 3. In this case, the mean difference of the bilabial when measured from the first or last burst was nearly 8 ms, 11.5 ms for the alveolar, and about 14 ms for the velar. Thus, the mean differences for /p/ and /t/ were higher in native English than in non-native English; /k/ had the same mean difference in non-native and native English. It should also be remarked that the SDs for the native English productions in Table 3 are on the whole lower than the SDs for the non-native English data presented in Table 2.

Table 3: VOT by measurement method (First, Last burst) in native English.

Burst	Plosive	N	Mean VOT	SD
First	Bilabial	37	60.71	15.55
	Alveolar	18	83.55	23.37
	Velar	72	80.52	15.45
Last	Bilabial	37	52.84	16.55
	Alveolar	18	72.05	22.70
	Velar	72	66.34	16.99

In order to analyze in native English the effect of VOT measurement method (from the first burst, or from the last burst), an ANOVA with VOT as the dependent variable and PoA (Bilabial, Alveolar, Velar) and VOT measurement (First burst, Last burst) as factors was planned. Prior to running this test, the assumptions of ANOVA were checked. VOT was normally distributed ($W = 0.99$, $p = 0.77$), and homogeneity of variances corroborated ($F(5, 250) = 1.72$, $p = 0.13$). An ANOVA with VOT as the dependent variable and Burst measurement (First, Last), and PoA (Bilabial, Alveolar, Velar) as factors revealed a statistically significant effect of measurement method, $F(1,250) = 19.69$, $p < 0.001$, with a medium effect size, $\eta^2 = 0.07$, and a statistically significant effect of PoA, $F(2,250) = 28.44$, $p < 0.001$, $\eta^2 = 0.18$, which is a large effect size. There was a statistically nonsignificant interaction of Burst X PoA, $F(2,250) = 0.83$, $p = 0.43$, with a trivial effect size, $\eta^2 = 0.007$. Post-hoc Bonferroni-adjusted tests on this interaction showed that the following. There was a non statistically significant for /p/ according to measurement method, $M_{difference} = 7.73$, $p_{bonferroni} = 0.39$, with a medium effect size, $d = 0.44$. For /t/, with a $M_{difference} = 11.50$, the difference was not statistically significant, $p_{bonferroni} = 0.35$, with a medium effect size, $d = 0.66$. Lastly, for /k/, there was a $M_{difference} = 14.18$, which was statistically significant, $p_{bonferroni} < 0.001$, with a large effect size, $d = 0.82$.

3.2. Effects of PoA, gender, age, and speech rate on MBs

3.2.1. MBs and PoA

In non-native English, a total of 468 plosives were subjected to analysis. Of these, 192 had MBs (range = 2 - 5), i.e., 41% of the plosives. A chi-square test on this result yielded a statistically significant difference, $\chi^2(1) = 111.08$, $p < 0.001$, with a medium effect size, Phi = 0.41. 26.45% of bilabials presented MBS, 24.52% of alveolars had MBs, and 72.72% of velars had more than one burst. These differences are statistically significant, with a large effect size, $\chi^2(4) = 191.35$, $p < 0.001$, Cramer's V = 0.76. In native English, a total of 333 plosives were analyzed. Of these, 256 had MBs (range = 2 - 5), that is, 76.87% of the plosives. A chi- square test on this result yielded a statistically significant difference, $\chi^2(1) = 299.15$, $p < 0.001$, with a very large effect size, Phi = 0.80. 33.92% of bilabials presented MBs, 15.78% of alveolars had MBs, and 67.28% of velars had more than one burst. These differences are statistically significant, with a large effect size, $\chi^2(4) = 159.19$, $p < 0.001$, Cramer's V = 0.69.

The difference between non-native English and native English in the number of plosives that had MBs is statistically significant, with a medium effect size, $\chi^2(1) = 27.95$, $p < 0.001$, Phi = 0.38.

Table 4 shows the mean number of bursts by PoA in non-native and native English, which are almost identical for both varieties. A Kruskal-Wallis test showed that non-native and native English did not differ statistically significantly in the number of MBs, $\chi^2(1) = 0.19$, $p = 0.65$, with a negligible effect size, $\eta^2 = 0.001$.

Table 4: Number of bursts by PoA in non-native and native English

Plosive	L1	N	Mean	SD	Min	Max
Bilabial	Non-native	82	2.20	0.55	2	5
	Native	76	2.21	0.52	2	4
Alveolar	Non-native	78	2.08	0.26	2	3
	Native	36	2.28	0.45	2	3
Velar	Non-native	224	2.86	0.88	2	5
	Native	144	2.86	0.93	2	5

Table 5 displays the frequency of occurrence of MBs across PoA for non-native and native English. For non-native English, these differences were statistically significant, $\chi^2(6) = 82.16$, $p < 0.001$, Cramer's V = 0.37, which is a medium effect size. For native English, a chi-square was also statistically significant, $\chi^2(6) = 57.63$, $p < 0.001$, with a medium effect size, Cramer's V = 0.31. For the /p/, non-native and native English differed significantly in the occurrence of MBs across PoA, $\chi^2(3) = 8.7$, $p = 0.03$, Cramer's V = 0.21, a small effect size. For /t/, non-native and native English differed significantly in the occurrence of MBs across PoA, $\chi^2(3) = 13.93$, $p = 0.003$, with a small effect size, Cramer's V = 0.26. Finally, for /k/, non-native and native English did not differ significantly in the occurrence of MBs across PoA, $\chi^2(3) = 0.62$, $p = 0.89$, with a trivial effect size, Cramer's V = 0.05.

Table 5: Occurrence of MBs across PoA, in percentages

Plosive	L1	2 bursts	3 bursts	4 bursts	5 bursts
Bilabial	Non-native	85.36	12.20	0	2.44
	Native	84.21	10.52	5.27	0
Alveolar	Non-native	92.31	7.69	0	0
	Native	72.22	27.78	0	0
Velar	Non-native	41.97	36.61	16.07	5.35
	Native	44.44	31.94	16.66	6.96

In non-native English, a Kruskal-Wallis test showed that the PoA of the plosive had a statistically significant effect on the number of MBs, $\chi^2(2) = 87.54$, $p < 0.001$, with a substantial effect size, $\eta^2 = 0.23$. Post-hoc tests with a Bonferroni correction showed that there were significant differences between /p/ and /k/, $p < 0.001$, with large effect size, $d = 0.89$, and between /t/ and /k/, $p < 0.001$, with a very large effect size, $d = 1.19$. There was no statistically significant difference between /p/ and /t/, $p = 0.47$, with a small effect size, $d = 0.27$.

In native English, a Kruskal-Wallis test showed that the PoA of the plosive had a statistically significant effect on the number of MBs, $\chi^2(2) = 37.72$, $p < 0.001$, with a large effect size, $\eta^2 = 0.15$. Post-hoc tests with a Bonferroni correction showed that there were significant differences between /p/ and /k/, $p < 0.001$, with a large effect size, $d = 0.85$, and between /t/ and /k/, $p = 0.002$, with a large effect size, $d = 0.78$. There was no statistically significant difference between /p/ and /t/, $p = 0.39$, with a small effect size, $d = 0.14$.

Table 6: Multiple bursts by L1 in non-native English

L1	Mean bursts	SD	Min	Max
Bengali	2.46	0.76	2	4
Farsi	2.50	0.60	2	4
German	2.65	1.02	2	5
Hindi	2.38	0.63	2	4
Japanese	2.62	1.01	2	5
Korean	2.64	0.82	2	4
Mandarin	2.56	0.70	2	4
Portuguese	2.33	0.47	2	3
Russian	2.58	0.97	2	5
Spanish	2.53	0.70	2	4
Turkish	2.89	0.75	2	4
Vietnamese	2.60	0.87	2	5

Table 6 displays the mean number of bursts by L1. A Kruskal-Wallis test showed that the L1 did not have a statistically significant effect on the number of MBs, $\chi^2(11) = 8.94$, $p = 0.62$, with a small effect size, $\eta^2 = 0.02$. None of the Bonferroni-corrected post-hoc pairwise comparisons between L1s were statistically significant, all $p > 0.05$.

3.2.2. MBs and gender

Tables 7 and 8 show the mean number of bursts by gender, in non-native and native English respectively. The data indicate that the mean differences were very small. In non-native English, a Kruskal-Wallis test showed that there was no effect of gender on the number of bursts, $\chi^2(1) = 0.03$, $p = 0.85$, with a trivial effect size, $\eta^2 = 0.001$. The same result was obtained for native English, $\chi^2(1) = 0.24$, $p = 0.62$, $\eta^2 = 0.001$.

Table 7: Mean bursts by gender in non-native English

Gender	Female	Male
Mean	2.58	2.52
SD	0.85	0.75
Minimum	2	2
Maximum	5	5

Table 8: Mean bursts by gender in native English

Gender	Female	Male
Mean	2.61	2.55
SD	0.87	0.79
Minimum	2	2
Maximum	5	5

3.2.3. MBs and age

A non-parametric Spearman's rho correlation between the number of bursts and age in non-native English yielded a very weak and marginally significant effect, $\rho = 0.10$, $p = 0.05$. In native English, the association was trivial and nonsignificant, $\rho = 0.03$, $p = 0.62$.

3.2.4. MBs and speech rate

Speech rate was computed as the mean number of syllables per second. In non-native English, the resulting speech rate was $M = 2.88$, $SD = 0.63$. There was no significant correlation between speech rate and the number of bursts, with a negligible effect size, $\rho = 0.03$, $p = 0.47$;

for native English, speech rate and the number of bursts were not statistically associated either, and the effect was as well trivial, $M = 3.69$, $SD = 0.54$, $\rho = 0.05$, $p = 0.41$.

4. DISCUSSION

The results presented in the preceding sections will be considered in terms of their effect sizes, rather than referring only to their statistical significance (see Cumming, 2012, especially chapter 2). There is a growing trend in the social sciences to answer research questions not with a dichotomous yes or no, that is, whether a result is statistically significant or not. Rather, the focus of statistical interpretation is shifting to a recognition of the magnitude of the detected effects, instead of solely considering its statistical significance below an arbitrary p value (e.g., $p < 0.05$; see Cohen, 1990). This statistical reform movement is gathering momentum in areas such as second language acquisition (see, e.g, Gass, Loewen, & Plonsky, 2021), and it firmly encourages answering research questions as *how much* of an effect was found, not as *whether or not* there was an effect (Cumming, 2012, p. 34).

One aspect of the statistical analyses that merits attention is the decision to use separate analyses for the native and non-native data. One motivation to do this was that, for the analysis of VOT measurement method in non-native English, the data were not normally distributed, and hence non-parametric tests were opted for. In contrast, the data for native English for the same variable were normally distributed. Thus, the analyses were split by language population, which potentially lessens the interpretation of the results. It may have been more fruitful to make a more general analysis on all the data, for example including nativeness as a predictor (i.e., native English vs. non-native English), together with the other factors and their interactions. This is a limitation of the study and future research may circumvent this methodological problem, perhaps by implementing statistical tests that are robust to violations of statistical assumptions such as normality of the data.

The first research question asked about the effect of measurement method of MBs on VOT, that is, whether the VOT values of the voiceless plosives differed substantially when this acoustic characteristic was measured from the first or the last burst to the onset of voicing. In non-native English, it was found that the measurement method in the presence of MBs had a fair impact on VOT. These two methods differed by about 11 ms, which in terms of VOT can be a substantial difference, for example, when describing a voiceless plosive as aspirated or not (e.g., Docherty, 1992). The effect size for this finding was medium, $\eta^2 = 0.09$, which means that 9% of the variance in VOT values was associated with the MB measurement method. For native English, it was found that the MB measurement method had as well a medium effect size, $\eta^2 = 0.07$. The two methods in native English differed by almost 13 ms, which also constitutes a meaningful difference. Both results are to some extent comparable with the findings of Barrera-Pardo (2022), who found that in Western Andalusian Spanish 18% of the variance in VOT values was associated with the measurement method in the presence of MBs. This researcher also reported a difference of 8 ms when the voiceless plosives were measured from the first or last burst. In Hungarian, Gráczi and Kohári (2014) reported on the effects of three VOT measurement methods when MBs were present (the first burst, the most intense burst, and the last burst), finding that these differed statistically significantly and with medium effect sizes, similarly to the results of the current study. It could be argued that, obviously, the two VOT measurements would produce different results; the first measurement will logically yield larger values than the second, in all measurements, and it could also be reasoned that with a large enough sample size a significant difference and an associated substantial effect size will be found. There are, however, two problems with this reasoning. First, it is far from clear which measurement method researchers use in their analyses of VOT, since this is many times not reported. Thus, VOT values described in past research might be affected by this methodological inconsistency. Second, statistically, the effect size is not dependent on sample size; it is derived from two parameters, the mean and the standard deviation (for example, Cohen's d). Thus, effect sizes are not biased by either large or small sample sizes (Plonsky & Oswald, 2014).

The first research question also inquired about the role that PoA may play in VOT values, in the presence of MBs. The effect of PoA on VOT in non-native English was statistically significant, with a medium effect size ($\eta^2 = 0.06$). In native English this effect was as well statistically significant and much larger, $\eta^2 = 0.18$. These findings are in line with the data reported in previous literature, especially in the case of native English. The post-hoc tests revealed that in non-native English, for /p/, when measured from the first or the last burst, there was a mean difference of almost 7 ms, with a small effect size ($d = 0.22$). In native English, the difference amounted to about 8 ms, in this case with a medium effect size ($d = 0.44$). The results for /t/ are as follows. In non-native English, the mean difference according to measurement method was around 6 ms, and the associated effect size was small ($d = 0.26$). In native English, this plosive differed in 11.50 ms as per measurement method, which is a sizable amount; the effect size related to this difference was medium ($d = 0.66$). Lastly, /k/ yielded the largest mean differences and associated effect sizes in both non-native and native English; for the former, the mean difference was about 14 ms, with a large effect size ($d = 0.72$), and for the latter, there was the same mean difference of around 14 ms, with an associated large effect size ($d = 0.82$). The effect sizes reported by Barrera-Pardo (2022) for the Spanish dialect he investigated are to different degrees in line with the findings of the current study. In this research, /p/ presented a mean difference of 6 ms according to measurement method, with a large effect size, $d = 0.78$; the mean difference for /t/ was 5 ms, with a medium effect size, $d = 0.65$; and for /k/ the mean difference was 13.51 ms, with a very large effect size, $d = 1.75$. Thus, the data for this Spanish variety are, to a certain extent, comparable to the findings for non-native English reported in the present study, on account of the mean differences found according to the VOT measurement method in the presence of MBs. These cumulative findings therefore suggest that the measurement method plays a significant role in the VOT values obtained, and future research on VOT in which MBs are found should probably be aware of this important methodological issue, as further discussed in Barrera-Pardo (2022).

The role of PoA, gender, age, and speech rate in MBs was the focus of the second research question. Regarding PoA, in non-native English 41% of the plosives analyzed exhibited MBs, with an associated medium effect size. This percentage is higher than in the Spanish dialect researched by Barrera-Pardo (2022), who found that 25% of the plosives presented MBs. It is also much higher than the percentage reported by Lavoie (2001) for American English, whose analysis found that only 9% of the voiceless plosives had MBs. Further, Lavoie found that 11.5% of the Spanish voiceless plosives she examined had MBs, a figure that is clearly much lower than what was reported in the current study. Lastly, Gráczi and Kohári (2014), who quantified MBs in Hungarian, documented that nearly 48% of the voiceless plosives realizations evidenced MBs; this result is somewhat similar to the data reported above for non-native English. Almost 77% of the plosives produced in native English presented MBs (with a very large effect size) a figure that surpasses all the previous results. The difference between non-native English and native English in MBs yielded a statistically significant result, with a medium effect size (Phi = 0.38).

Proceeding with the number of MBs for the three plosives, it was found that in non-native English slightly over a quarter of the bilabials had MBs, and that in native English the percentage was about 34%. This result is in line with the percentage reported for Hungarian by Gráczi and Kohári (2014), 27.5%, but very different from the data presented for English by Lavoie (2001), 5%, and for Spanish by the same author, 0%. Barrera-Pardo (2022) found that in Spanish only about 10% of the bilabials had MBs. The next plosive, /t/, presented MBs in a quarter of its realizations in non-native English, and in native English about 16% of the productions of /t/ had MBs. Gráczi and Kohári (2014) reported many more MBs for /t/ (45%), and Lavoie (2001) found 0.8% of MBs for this consonant in English, whereas she reported 0% MBs for /t/ in her Spanish data. Also for Spanish, Barrera-Pardo (2022) found that about 15% of /t/ productions presented MBs. Finally, in non-native English in the current study /k/ had MBs in nearly 78% of the realizations, and around 67% of the /k/ productions had MBs in native English. This finding is overall in agreement with the data obtained by Gráczi and Kohári (2014), but very different from the 21% of MBs for /k/ reported by Lavoie (2001) for English. In Spanish, Lavoie found that 32% of the /k/ productions presented MBs, which is coincident with the percentage found by Barrera-Pardo (2022). The present study found that non-native English and native English did not vary in the mean number of bursts, which for both varieties was $M = 2.40$, with a trivial effect size.

Addressing now the number of bursts by PoA, non-native English /p/ had the majority of bursts in the 2-burst rank, as did this consonant for native English. /t/ in non-native English had almost all of the MBs also in the 2-burst category, whereas native English was more spread between the 2- (72%) and 3-burst (28%) ranks; it is remarkable that this consonant did not show any MBs in the 4- and 5-burst categories for either English variety. /k/ had MBs across the entire series of ranks, and with the same percentages for both non-native and native English. Non-native English and native English differed in the occurrence of MBs by PoA in the bilabials, with a small effect size, a result that also applied to the alveolars; for the velars, however, the difference was negligible, as per the effect size observed. The results reported by Barrera-Pardo (2022) for Spanish and by Gráczi and Kohári (2014) for Hungarian are to a great extent comparable to the data of the current study. Thus, this seems to corroborate a general tendency of the voiceless plosives that exhibit MBs. The PoA of the plosives had a large effect on the number of MBs both in non-native English and native English, explaining 23% and 15% of the variance respectively; this concurs with the data reported by Barrera-Pardo (2022). A related question was whether the L1 had an effect on the number of MBs; it was found that the difference in mean bursts by L1 was not statistically significant and the corresponding effect size was small (only 2% of the variance in MBs could be ascribed to the L1). None of the pairwise comparisons yielded significant differences in the mean number of bursts among the twelve L1s. This result is perhaps unexpected, since the various L1s analyzed present very different VOT patterns in their native speech. For example, Russian voiceless plosives are not aspirated (Yanushevskaya & Bunčić, 2015), but Hindi has a phonological contrast between voiceless unaspirated and voiceless aspirated plosives (Ladefoged & Johnson, 2015).

An additional factor that may play a role in MBs is speaker gender. In line with Plauché (2001) and Barrera-Pardo (2022), the current study did not find an association between gender and MBs. Speech rate, as in previous studies (but partially contrary to Barrera-Pardo, 2022), was not found to have an effect on MBs in either non-native English or native English. Lastly, in non-native English, the factor age had a small effect on the number of bursts ($\rho = 0.10$,), and it played essentially no role in native English. Parveen and Goberman (2012) also reported a lack of association between age and MBs.

Finally, this investigation of MBs may be relevant in a number of speech research areas. MBs have been repeatedly reported in pathological speech when measuring VOT (e.g., Fischer & Goberman, 2010; Kopkalli-Yavuz, Mavis, & Akyldiz, 2011; Novotný et al., 2015). Lacking full control of their motor capabilities, these speakers tend to evidence a substantially higher number of MBs than speakers without speech disorders, as reported in past studies. The cumulative results of the current study, together with those of previous research (Barrera-Pardo, 2022), suggest that MBs are present in nonpathological populations to a larger extent than what may have been normally assumed. VOT has also been extensively explored in second language (L2) perception (Major, 2001) and production (Zampini, 2008). However, to date, the presence of MBs and the complications that may arise when measuring the VOT of L2 speakers' productions remains an uncharted area. The current study suggests that in non-native English, as reported for the twelve L1s explored, the presence of MBs needs to be considered when analyzing VOT. Systems of automatic detection of VOT (e.g., Kazemzadeh et al., 2006) should probably take into account the potential occurrence of MBs in the data they probe.

5. CONCLUSION

Systematically analyzing and quantifying MBs has been rarely addressed in the literature. The current study aimed at discerning the role of MBs in VOT measurement and the potential role of the factors PoA, gender, speech rate, and age in two varieties, non-native English, with data from twelve L1s, and native English. Expanding on previous studies, it was found that the VOT measurement method in the presence of MBs had a substantial effect in both varieties, and it is therefore concluded that researchers who embark on VOT measurement of voiceless plosives take heed of the findings reported in prior research and in the present study. Since VOT is one of the most studied consonant features in the phonetics literature (Whalen, DiCanio, & Dockum, 2022), this recommendation seems all the more pressing. The results of the present study also supported previous research findings that clearly indicate an effect of PoA on MBs, especially for /k/. In addition, this study quantified MBs of voiceless plosives, something that has rarely been done in the literature: MBs are almost routinely noted, but data of the type reported here add to our knowledge base of this phonetic event. These data also suggest that although there are some sizeable differences between non-native English and native English, overall both varieties exhibited similar tendencies when the factors of PoA, gender, age, and speech rate were subjected to analysis. Together with previous research, these findings seem to unveil aspects of voiceless plosives that are not language-specific. To conclude, a number of limitations of the current study will be noted. Data were obtained from only three words in the elicitation passage, and future research of the type reported here should expand to more tokens, and in different vowel contexts, considering that prior research has suggested a potential effect for vowel height on MBs (Barrera-Pardo, 2022; Yang, 2018). The current study focused on aspirated voiceless plosives; it would be pertinent to address voiceless plosives in unstressed positions, and examine whether they also present MBs. In American English, Lavoie (2001) found no MBs for unstressed /p/ and /t/, and only 10% of unstressed voiceless velars presented MBs. She analyzed voiceless plosives in both initial (as in *Tucson*) and medial position (as in *boutique*); the present study obtained data only from three monosyllabic words (*peas*, *toy*, *kids*), and it would be relevant to extend this research to multisyllabic words. All these factors may play a role in the production of MBs. In addition, the analysis of speech rate in the current study was conditioned by the recorded speaking task, the elicitation passage, and future research may avoid this limitation by carrying out a different production task.

6. ACKNOWLEDGEMENTS

The author would like to thank three anonymous reviewers for *Loquens* whose feedback contributed decisively to greatly improve the final version of this article.

7. REFERENCES

Asensi, L. Portolés, S., & del Río, A. (1997). Barra de explosión, VOT y frecuencia de las oclusivas sordas del castellano. *Estudios de Fonética Experimental*, *IX*, 221-242. /https://www.ub.edu/journalofexperimentalphonetics/pdf-articles/EFE-IX-LlAsensi_SPortoles_AdelRio-Barra_explosion_VOT_frecuencia_oclusivas_sordas.pdf

Barrera-Pardo, D. (2022). Measurement of the VOT of voiceless plosives: Multiple bursts in Western Andalusian Spanish. *Estudios de Fonética Experimental*, *XXXI*,81-95. https://www.ub.edu/journalofexperimentalphonetics/pdf-articles/XXXI-07-Barrera.pdf

Bóna, J., & Auszmann, A. (2014). Voice onset time in language acquisition: Data from Hungarian. In S. Fuchs, M. Grice, A. Hermes, L. Lancia, & D. Mücke (Eds.), *Proceedings of the 10th International Seminar on Speech Production (ISSP)* (pp. 41-44). Cologne, Germany. /http://real.mtak.hu/15397/1/BA_VOT.pdf

Brinca, L. Araújo, L., Nogueira, P., & Gil, C. (2016). Voice onset time characteristics of voiceless stops produced by children with European Portuguese as mother tongue. *Ampersand*, *3*, 137-142. https://www.sciencedirect.com/science/article/pii/S2215039015300114

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. 2nd ed. Lawrence Erlbaum.

Cohen, J. (1990). Things I have learned (so far). *American Psychologist*, *45*(12), 1304-1312. https://psycnet.apa.org/record/1991-11596-001?doi=1

Cumming, G. (2012). *Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis*. Routledge.

Davis, K. (1994). Stop voicing in Hindi. *Journal of Phonetics*, *22*, 177-193. https://www.sciencedirect.com/science/article/pii/S0095447019301925

Docherty, G. J. (1992). *The timing of voicing in British English obstruents*. Foris.

Ethnologue. (2022). Available online at https://www.ethnologue.com/, Accessed on 2 February 2023.

Fischer, E., & Goberman, A. M. (2010). Voice onset time in Parkinson disease. *Journal of Communication Disorders*, *43*(1), 21–34. DOI: 10.1016/j.jcomdis.2009.07.004

Flege, J. E. (1981). The phonological basis of foreign accent: A hypothesis. *TESOL Quarterly*,*15*(4),443-455. https://doi.org/10.2307/3586485

Foulkes, P., Docherty, G, & Jones, M. (2010). Analyzing stops. In M. Di Paolo, & M. Yaeger-Dror (Eds.), *Sociophonetics: A student's guide* (pp. 58-71). Routledge.

Gass, S., Loewen, S., & Plonsky, L. (2021). Coming of age: the past, present, and future of quantitative SLA research. *Language Teaching*, *54*, 245–258. https://www.cambridge.org/core/journals/language-teaching/article/coming-of-age-the-past-present-and-future-of-quantitative-sla-research/B30BA387E-DA5B60A07DBBBF03E4BC45C

Gráczi, T. E., & Kohári, A. (2014). Multiple bursts in Hungarian voiceless plosives and VOT measurements. In S. Fuchs, M. Grice, A. Hermes, L. Lancia, & D. Mücke (Eds.), *Proceedings of the 10th International Seminar on Speech Production (ISSP)* (pp. 158-161). Cologne, Germany. /https://www.researchgate.net/profile/Anna-Kohari/publication/305635295_Multiple_bursts_

in_Hungarian_voiceless_plosives_and_VOT_measurements/links/579648c508aed51475e54c81/Multiple-bursts-in-Hungarian-voiceless-plosives-and-VOT-measurements.pdf
Hayward, K. (2000). *Experimental phonetics.* Pearson Education.
Imbrie, A. K. K. (2005). *Acoustical study of the development of stop consonants in children*. [Doctoral dissertation]. Massachusetts Institute of Technology, United States of America. https://dspace.mit.edu/handle/1721.1/33072
Kaňok, M., & Novotný, M. (2019). Effect of age and gender on articulation of voiced and voiceless stop consonants in Czech. *Lekar a Technika: Clinician and Technology*, 49(3), 97-101. https://ojs.cvut.cz/ojs/index.php/CTJ/article/view/5957
Kazemzadeh, A., Tepperman, J., Silva, J., You, H., Lee, S., Alwan, A., & Narayanan, S. (2006). Automatic detection of voice onset time for use in pronunciation assessment. *INTERSPEECH 2006*, n.p.
Keating, P. A., Westbury, J. R., & Stevens, K. N. (1980). Mechanisms of stop-consonant release for different places of articulation. *Journal of the Acoustical Society of America*, *67*, S93. https://doi.org/10.1121/1.2018489
Kopkalli-Yavuz, H., Mavis, I., & Akyldiz, D. (2011). Analysis of VOT in Turkish speakers with aphasia. *Clinical Linguistics & Phonetics*, *25*(4), 287-301. DOI: 10.3109/02699206.2010.529541
Ladefoged, P. (2003). *Phonetic data analysis: An introduction to fieldwork and instrumental techniques*. Blackwell.
Ladefoged, P., & Johnson, K. (2015). *A course in phonetics.*7th ed. Cengage Learning
Ladefoged, P., & Maddieson, I. (1996). *The sounds of the world's languages*. Blackwell.
Lavoie, L.M. (2001). *Consonant strength: Phonological patterns and phonetic manifestations*. Routledge.
Lousada, M. Jesus, L.M.T., & Hall, A. (2010). Temporal acoustic correlates of the voicing contrast in European Portuguese stops. *Journal of the International Phonetic Association*, *40*(3), 261-275.
DOI:https://doi.org/10.1017/S0025100310000186
Maddieson, I. (1984). *Patterns of sounds*. Cambridge University Press.
Major, R. C. (2001). *Foreign accent: The ontogeny and phylogeny of second language phonology*. Lawrence Erlbaum.
Michelon Melo, R., Bolli Mota, H., Lisbôa Mezzomo, C., de Castro Brasil, B., Lovatto, L, & Arzeno, L. (2014). Acoustic characterization of the voicing of stop phones in Brazilian Portuguese. *Revista CEFAC*, *16*(2), 487-499. https://www.scielo.br/j/rcefac/a/ZB9NzFyfJxgHCpK7s44RSwf/abstract/?lang=en
Millasseau, J., Bruggeman, L., Yuen, I., & Demuth, K. (2019). Durational cues to place and voicing contrasts in Australian English word-initial stops. In S. Calhoun, P. Escudero, M. Tabain, & P. Warren (Eds.), *Proceedings of the 19th International Congress of Phonetic Sciences* (pp. 3759-3762). Canberra: Australasian Speech Science and Technology Association Inc. https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2019/papers/ICPhS_3808.pdf
Moran, S., & McCloy, D. (2019). Phoible 2.0. Max Planck Institute for the Science of Human History. Available online at http://phoible.org, Accessed on 21 May 2023.
Novotný, M., Pospíšil, J, Čmejla, R., & Rusz, J. (2015). Automatic detection of voice onset time in dysarthric speech. In *2015 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 4340-4344).IEEE. DOI: 10.1109/ICASSP.2015.7178790
Parveen, S., & Goberman, A.M. (2012). Presence of stop bursts and multiple bursts in younger and older adults. *Asia Pacific Journal of Speech, Language, and Hearing*, *15*(4), 265–275. https://www.tandfonline.com/doi/abs/10.1179/136132812804731811
Plauché, M. (2001). Acoustic cues in the directionality of stop consonant confusions [Doctoral dissertation]. University of California, Berkeley, United States of America. https://escholarship.org/uc/item/8hz6k4c2
Plonsky, L., & Oswald, F. L. (2014). How big is "big"? Interpreting effect sizes in L2 research. *Language Learning*, *64*(4), 878-912. https://doi.org/10.1111/lang.12079
Repp, B.H., and Lin, H-B. (1989). Acoustic properties and perception of stop consonant release transients. *Journal of the Acoustical Society of America*, *85*(1), 379-396. https://pubs.aip.org/asa/jasa/article-abstract/85/1/379/969397/Acoustic-properties-and-perception-of-stop?redirectedFrom=fulltext
Sirsa, H., & Redford, M.A. (2013). The effects of native language on Indian English sounds and timing patterns. *Journal of Phonetics*, *41*, 393–406. https://www.sciencedirect.com/science/article/abs/pii/S0095447013000399
Song, J. Y., Demuth, K., & Shattuck-Hufnagel, S. (2012). The development of acoustic cues to coda contrasts in young children learning American English. *Journal of the Acoustical Society of America*, *131*(4), 3036-3050. https://pubs.aip.org/asa/jasa/article-abstract/131/4/3036/830852/The-development-of-acoustic-cues-to-coda-contrasts?redirectedFrom=fulltext
Sönmez, K., Plauché, M., Shriberg, E., & Franco, H. (2000). Consonant discrimination in elicited and spontaneous speech: A case for signal-adaptive front ends in ASR. *Sixth International Conference on Spoken Language Processing, ICSLP 2000 / INTERSPEECH 2000*. Beijing, China. https://www.isca-speech.org/archive/pdfs/icslp_2000/sonmez00_icslp.pdf
Sučková, M. (2020). First language attrition in voice onset times in Anglophone expatriates residing in the Czech Republic. *Brno Studies in English*, *46*(2), 47-66. https://digilib.phil.muni.cz/en/handle/11222.digilib/143206
Torres, M. I., & Iparraguirre, P. (1996). Acoustic parameters for place of articulation identification and classification of Spanish unvoiced stops. *Speech Communication*, *18*, 369-379. https://www.sciencedirect.com/science/article/abs/pii/0167639396000258
Wang, Y-T., Kent, R. D., Duffy, J. R., Thomas, J. E., & Weismer, G. (2004). Alternating motion rate as an index of speech motor disorder in traumatic brain injury. *Clinical Linguistics & Phonetics*, *18*(1), 57-84. https://www.tandfonline.com/doi/abs/10.1080/02699200310001596160
Wayland, R. (2019). *Phonetics: A practical introduction*. Cambridge University Press.
Weinberger, S. (2015). *Speech Accent Archive*. George Mason University. Retrieved from http://accent.gmu.edu
Whalen, D. H., DiCanio, C., & Dockum, R. (2022). Phonetic documentation in three collections: Topics and evolution. *Journal of the Phonetic International Association*, *52*(1), 95-121. DOI:https://doi.org/10.1017/S002310030000079
Yang, J. (2018). Development of stop consonants in three- to six-year-old Mandarin-speaking children. *Journal of Child Language*, *45*, 1091-1115. DOI:https://doi.org/10.1017/S030500918000090
Yanushevskaya, I., & Bunčić, D. (2015). Russian. *Journal of the International Phonetic Association*, *45*(2), 221-228. https://doi.org/10.1017/S0025100314000395
Zampini, M. (2008). L2 speech production research. In J. H. E. & M. Zampini (Eds.), *Phonology and second language acquisition* (pp. 219-249). John Benjamins.