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Mária Gósy
Eötvös Loránd University, Budapest and Research Institute for Linguistics,
Hungarian Academy of Sciences, Budapest
Hungary

THE VOT OF THE HUNGARIAN VOICELESS PLOSIVES IN CAREFUL AND SPONTANEOUS SPEECH

SUMMARY

This paper aims at investigating the acoustic properties of VOTs of the three Hungarian voiceless stops (using the CSL50 device) when appearing in isolation (in syllables and in words) but also when occurring in spontaneous speech (5 female teachers served as subjects).

The results of the acoustic analysis show a clear difference between careful and spontaneous speech. Bilabials and velars are significantly shorter in fluent speech while dentals seem to be unchanged. Therefore, the actual duration of VOT is characteristic of the place of the articulation of stops in spontaneous speech while VOTs of bilabials and dentals do not differ from each other in careful speech. Vowels following the stops influence them more in careful than in spontaneous speech, which can also be explained by the experimentally confirmed phenomenon of the changing quality of the present-day Hungarian vowels into the neutral vowel. Voice onset time is a specific feature of the Hungarian plosive consonants and its values significantly differ from those of most languages in the world.

Key words: *Hungarian language, consonants, speech analysis*

INTRODUCTION

Due to the various techniques used in experimental phonetics and the language inventories, more and more has been learned about the nature of stops of the world's languages. Stop consonants occur in all languages; voiceless unaspirated stops being the most common ones (Henton, Ladefoged and Maddieson 1992). Multiple acoustic cues differentiate these consonants depending on language specificity. The basic acoustic property corresponding to the feature 'voiced' is the presence of low frequency spectral energy or periodicity due to the vibration of the vocal cords. Voiceless sounds do not have such periodicity. The differences in VOT have been termed lead vs. short lag where VOT itself is defined as the timing between the onset of phonation and the release of the primary occlusion of the vocal tract (Lieberman and Blumstein 1988:196). Phonation of stops in initial position can start coincident with the release of the stop, after the release of the stop, or before the release of the stop. In some languages the advanced vs. coincident contrast is the relevant phonemic distinction but delayed phonation can also exist (Laver, 1994). According to Lisker and Abramson (1964; 1971) the exact time intervals vary from language to language. In English, voiced consonants are either prevoiced, i.e. glottal excitation begins prior to the release of the stop consonant, or they have a short-lag VOT, i.e. the glottal excitation strarts some 5-15 ms after the release of the stop. In contrast, voiceless stops have a long-lag VOT, i.e. glottal excitation begins some 30 ms or more after the release of the stop closure (Lieberman and Blumstein 1988). In English most voiceless stops are aspirated with a VOT of about 50-80 ms. There are languages (e.g. Thai) where a three-category distinction for voicing exists, i.e. prevoicing, short-lag and long-lag VOT (Gandour and Dardarananda 1984). VOT values have been measured aiming at various goals in diverse languages, even to support the existence of categorical perception or some hypothesis of lexical access (Connine and Clifton 1987; Lieberman and Blumstein 1988). The category boundaries between voiced and voiceless plosives have been determined for native speakers of English, Spanish, Danish, Japanese, French, Portuguese, etc. (Fischer-Jørgensen 1964; 1972; Lisker and Abramson 1967; Williams 1977; Flege and Eefting 1986; Han 1992; Hazan and Boulakia 1993; Veloso 1995; etc.).

Research has focused not only on the acoustic patterns of stop consonants but also on their perceptual characteristics. Human listeners are able to differentiate stops according to their VOTs that exist in their languages. Independently of the actual values of the VOT, listeners' responses to the stimuli are reported to be showing categorical perception. A time difference of 20 ms has been determined to be necessary for the distinction between the two categories of 'voiced' and 'voiceless' while investigating many languages (Lisker and Abramson 1964). This value corresponds to a basic constraint of the human auditory system (Hirsch and Sherrick 1964) as well as the perceptual operations of one-month-old infants (Eimas et al. 1971). Discriminating results with aphasic patients also show sensitivity to this boundary of voiced and voiceless plosives even in cases when they are unable to identify the sounds themselves (Basso, Casati and Vignolo 1977). Recent investigations concerning the VOT of aphasics' speech claim that the values are dependent on the type of aphasia and show great individual differences (Baum *et al.* 1990).

Since the perception of stop consonants is truly ambiguous and practically context-dependent, experimental results suggest that there are other acoustic cues besides low frequency periodicity which seem to be invariant factors in the voiced–voiceless contrast. Frequency of F1 at the onset of voicing, the nature of the fundamental frequency changes immediately following consonant release, the frequency of the burst and the second and higher formants, the intensity of aspiration noise relative to the vowel, the duration of the preceding vowel, all will affect stop identification (cf. Denes 1955; Stevens and Klatt 1974; Haggard, Ambler and Callow 1970; Abramson and Lisker 1973; Klatt 1975; Summerfield 1975; Repp 1979; Stevens and Blumstein 1981; Pickett, Bunnell and Revoile 1995). The voiced–voiceless distinction of stop consonants is a function of multiple acoustic cues based on complex articulatory gestures. Recent investigations concern acoustic and perceptual differences of stop consonants occurring in words and sentences or produced with various speaking tempos (Schmidt and Flege 1995). More research is required to find out (i) the most determining acoustic cue of voicing distinction of the stops of those languages that have not been analyzed yet, (ii) the speaking style dependencies of the secondary cues of this multiple pattern, (iii) the possible alternations of acoustic cues, and finally (iv) the language and perhaps the subject specificity of articulation, acoustics, and perception of stops.

For Hungarian, no systematic acoustic-phonetic analysis of the stops has been carried out so far. This paper aims at investigating the acoustic properties of VOTs of the three Hungarian voiceless stops when occurring in careful speech (in syllables and in words without any context) but also when occurring in spontaneous speech. Our hypothesis is that the VOT values would show significant differences depending on the context and on speaking style.

STOPS IN HUNGARIAN

The Hungarian language contrasts voiced and voiceless stop consonants with various and most frequent places of articulation among the world's languages (cf. Siptár 1997). Labial, dental and velar stops form phonemically existing minimal pairs (see Table 1). There are two categories of these consonants (i) stops with early onset of voicing and (ii) stops with simultaneous onset of voicing. Hungarian stops are not aspirated, i.e. there is no late onset of voicing in the language.

Table 1. System of Hungarian oral plosives
Tablica 1. Sustav mađarskih oralnih okluziva

Place of articulation Mjesto artikulacije	Voicing character / Zvučnost		
	Voiced Zvučni	Voiceless Bezvučni	English equivalents Hrvatski prijevodni ekvivalenti
Labial Usne	bár	pár	bar/pair bar/par
	bor	por	wine/dust vino/prašina
Dental Zubi	dán	tán	Danish/perhaps danski/možda
	dél	tél	noon/winter podne/zima
Velar Meko nepce	gén	kén	gem/sulphur dragi kamen/sumpor

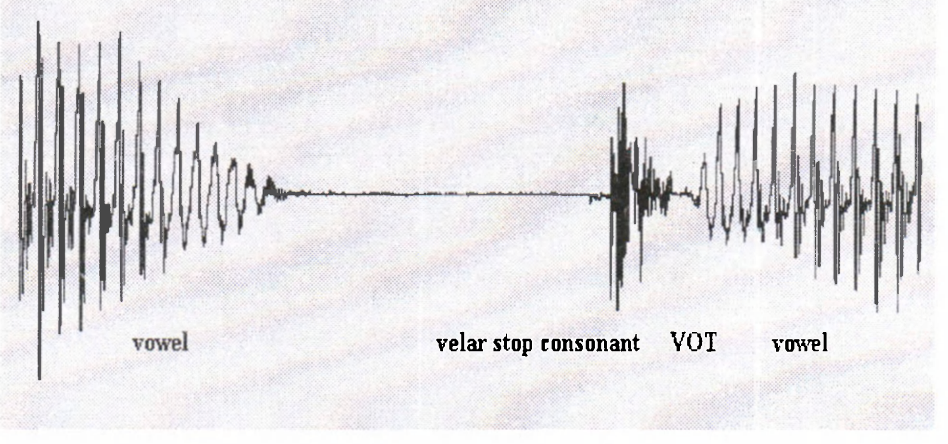
METHOD AND MATERIAL

Three types of speech material served as the basis for analysis. (i) A set of CV syllables – where the consonants are represented by the three voiceless stops while Vs being represented by all Hungarian vowels ([a:, ɑ , o, o:, u, u:, y, y:, ø, ø:, i, i:, e:, ɛ]) – was established. Taking into consideration the 14 vowels altogether 42 CV syllables were created. (ii) A set of Hungarian bisyllabic words formed the second speech set. The criterion for the selection of words was that they had to contain the CV syllables in question in the second syllables like *rakott, aput, lapát, akit, mutat*. The words were of various categories (verbs, nouns, etc.) and most of them were inflected. Since the language does not offer real words containing the /pu:/ and /py:/ syllables in the required place, they were replaced by sound sequences (that could have phonotactically been real Hungarian words). (iii) 75-minute spontaneous speech was recorded for further analysis.

Five female speakers (school teachers) from the capital of the country – with no known hearing or speech defects – were asked to read aloud the syllables and the words three times. A week later their spontaneous speech – about 15 minutes each – was recorded under laboratory conditions. (They were asked to speak about their leisure time and professional problems.) Thus, 5 times 126 syllables and 126 words were recorded (by means of a professional tape recorder and microphone in the Phonetics Laboratory). The spontaneous speech of our subjects contained a great number of voiceless stops although their distribution according to the CV syllables with the Hungarian vowels was not equalised.Ten occurrences of each CV combination of each speaker, i.e. 50 samples of data for one particular CV combination – were defined to be necessary for obtaining reliable measurements in spontaneous speech. Because of the small number of occurrences of some combinations they had to be omitted from further analysis (this concerned all possible combinations with [u:] and [y:] which is in connection with the very low frequency of occurrence of these vowels in Hungarian).

The whole speech material was digitalized at a sampling rate of 20,000 Hz by means of the Kay Elemetrics' Computerized Speech Lab (CSL50). Oscillographic and spectrographic analysis was carried out using both narrow- and broad-band spectrograms with the bandwidths of 50 Hz and 146 Hz. The display range was 8 kHz. The VOT duration was measured in all cases by both visual inspection of the acoustic waveforms and auditory perception (cf. an illustration of the measurements: Figure 1). Amplitude display was also added to a normal three-dimensional spectrogram. To test statistical significance, variance analysis was conducted (two-tailed Student t-test).

Figure 1 Illustration of the VOT measurements
Slika 1. Ilustracija mjerenja vremena uključenja glasa



RESULTS

Uttering syllables and words in isolation will result in careful speech since neither speech planning nor wider context influence articulation. In such cases speakers will automatically speak in a very "disciplined" way exerting unconscious control on their speech tempo. As a consequence, duration measurements support that speech tempo of the words in isolation is significantly slower for each speaker than their articulation tempo when speaking spontaneously. Concerning the identical speech material of all speakers in isolation, irrelevant differences could be expected for speech tempo. Table 2 shows the articulation tempo differences (mean and standard deviation) of words produced in isolation and in spontaneous speech.

Table 2. Tempos of words in isolation and that of spontaneous speech of the subjects

Tablica 2. Tempo govora za izolirane riječi i spontani govor

Speakers Govornici	Temporal characteristics of produced words Vremenske karakteristike izgovorenih riječi			
	In isolation (sound/s) U izolaciji (glasova/s)		In spontaneous speech (sound/s) U spontanom govoru (glasova/s)	
	Mean / prosjek	SD	Mean / prosjek	SD
S1	9.5	1.4	11.6	1.7
S2	9.9	2.3	12.3	2.9
S3	9.2	1.2	10.9	1.5
S4	9.6	1.9	10.6	2.1
S5	9.9	2.2	12.5	2.7

Tempo data of spontaneous speech display a moderate level comparing to the average Hungarian speech tempo which is 15.5 sounds/s for articulation tempo and 12.5 sounds/s for overall speech tempo (Gósy 1991). Table 3 summarises the VOT values of the three measured voiceless plosives in syllables and words in isolation.

Table 3. VOT data for syllables and words in isolation

Tablica 3. Podaci o vremenu uključivanja glasa u slogovima i izoliranim riječima

Voiceless stops Bezvučni okluzivi	Duration of VOT Vrijeme uključivanja glasa					
	In syllables (ms) / u slogovima (ms)			In words (ms) / u riječima (ms)		
	Mean Prosjek	Range Raspon	SD	Mean Prosjek	Range Raspon	SD
p	24.05	14.0 - 38.4	11.34	24.64	13.2 - 34.8	11.95
t	25.42	18.8 - 40.2	8.06	23.30	15.4 - 37.6	8.18.
k	50.60	37.2 - 64.6	15.15	50.17	32.6 - 65.8	18.71

Significant difference was found neither across speakers nor according to speech samples. The five female subjects' VOTs show very similar values within the same vowel category both in syllables and in words. However, significant differences were found according to various vowel qualities in both speech material (significance level: $p<0.001$). VOTs of bilabial and velar plosives in all occurrences show almost the same value, i.e. around 24 ms duration for bilabials and around 50 ms for velars. Dental voiceless plosives' VOTs are in between with a tendency to being shorter in words (around 23 ms) and longer in syllables (around 25 ms). There is a significant difference among the VOTs of the velars and the bilabials, and dentals (at a $p<0.0001$ level) while no such difference was found between the labials and the dentals. Data from multiple speakers of 17 languages show different VOT values from the Hungarian data with the only exception of Yapese (where the appropriate mean VOT values are similar: 20 ms for bilabials, 22 ms for dentals, and 56 ms for velars, cf. Cho–Ladefoged 1997:29).

There are indications in the literature that the place of articulation of stops will affect the VOT, i.e. fronter articulations will have a shorter lag if voiceless (Henton *et al.* 1992:79). This may be a language-specific phenomenon rather than some sort of rule coming from the articulation gestures of plosives. For example, Japanese VOT data seem to support the claim showing a VOT value of 7.7 ms for the bilabial, a 12 ms VOT value for the dental and a 17.9 ms value for the velar plosives (on the basis of ten subjects, cf. Han 1992). Hungarian data for careful speech, however, have partly supported this claim because no difference was found in the VOT values according to the place difference of the bilabial and dental stops. The VOTs of bilabial and dental Nepali stop consonants seem to contradict the claim. The mean value obtained for their VOTs with the bilabial stops is 69.43 ms contrasted to 59.31 ms for dental ones (Poon and Mateer 1985).

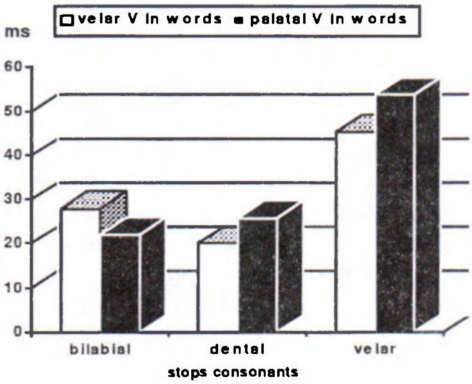
Articulation gestures of vowels followed by appropriate acoustic properties seem to define the VOT. Hungarian vowels can be categorised according to the tongue movements (front and back as well as low, mid and high vowels), according to the lip movements (illabials and labials) as well as according to their duration (short and long vowels). So, out of the fourteen vowels there are 6 back and 9 front, altogether 3 low, 5 mid and 6 high vowels, 9 of them are labials, 5 illabials, and 7 phonemically long and 7 phonemically short vowels. Analysis of VOTs was carried out according to these vowel categories both with the syllables and the words. Since there was no significant difference between the syllables and the words, the effect of the vowels will be discussed concerning the words.

VOTs preceding front vowels are shorter than those preceding back vowels in the case of bilabial stops while they are longer in the case of dental and velar stops (Figure 2). The data suggest that the horizontal movement of the tongue in vowel articulation is a definitive factor for VOT values of voiceless stops.

VOT values show specific distribution depending on vertical movements in vowel articulation. The higher the tongue position the longer the VOT of the preceding voiceless stops (Figure 3).

Figure 2. The effect of the vowels' horizontal movements on the stops' VOT values

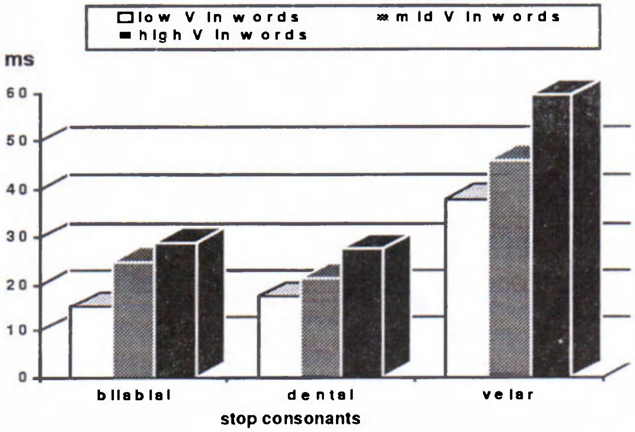
Slika 2. Utjecaj promjene samoglasnika na vodoravnoj osi na vrijeme ukjučivanja glasa



Acoustically, the lower the first and the higher the second formant of the vowels the longer the VOT. Considering the tongue position of vowels across the place of stop articulation, it can be seen that bilabials require the shortest and velars the longest VOT with the exception of dental stops preceding mid vowels.

Figure 3. The effect of the vowels' vertical movements on the stops' VOT values

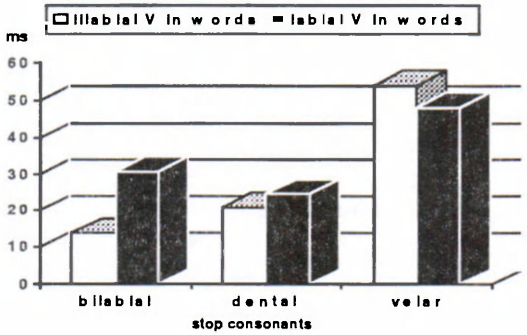
Slika 3. Utjecaj promjene samoglasnika na okomitoj osi na vrijeme uključivanja glasa



Lip movements of the vowels seem to be also definitive for the VOT values. In the case of bilabial and dental stops the VOT is longer preceding labial vowels while in the case of velar stops the VOTs are shorter preceding labial vowels. Acoustically it means that the second formant frequency influences the VOT duration. VOTs vary also according to the place of stop articulation: the longer the VOT the further the place of stops is in case of illabials. Preceding labial vowels dental stops' VOTs are shorter than those of bilabials and velars (Figure 4).

Figure 4. The effect of the lip movements of vowel articulation on the stops' VOT values

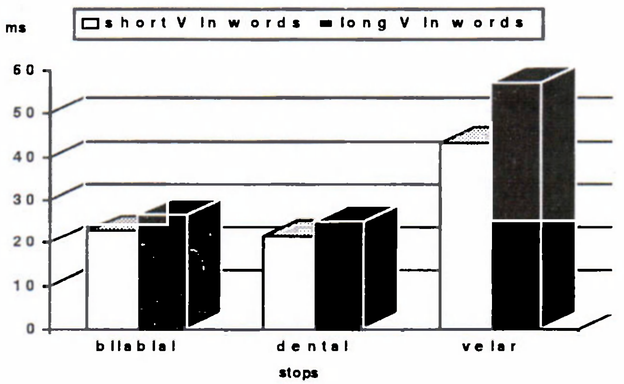
Slika 4. Utjecaj pokretanja usana tijekom izgovora samoglasnika na vrijeme uključivanja glasa



Taking into consideration careful speech when producing word lists, phonemically short and long vowels show different objective temporal values without any overlapping. Therefore, short vowels have really shorter physical duration than long vowels. Duration has a significant effect on VOT values with all voiceless stops. The longer the vowel duration the longer the duration of the VOT (Figure 5).

Figure 5. The effect of vowel duration on the stops' VOT values

Slika 5. Utjecaj duljine samoglasnika na vrijeme uključivanja glasa



Spontaneous speech data show – as expected – a somewhat different picture concerning the VOT values. Table 4 summarizes the mean values and the ranges.

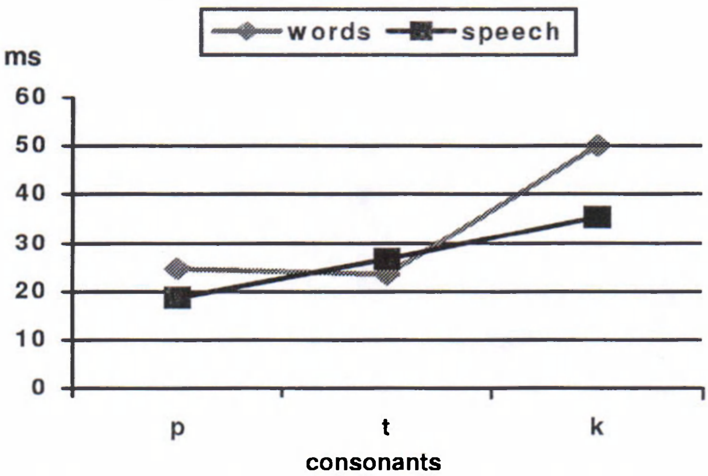
Table 4. VOT data of spontaneous speech of 5 subjects
Tablica 4. Podaci o vremenu uključivanja glasa u spontanome govoru pet ispitanica

Stops / Okluzivi	Duration of VOTs (ms) / Vrijeme uključivanja glasa		
	Mean / Prosjek	Range / Raspon	SD
Bilabials / Bilabijali	18.51	9.1 - 28.8	5.92
Dentals / Dentali	26.59	14.3 - 38.4	6.46
Velars / Velari	35.31	22.2 - 68.6	10.78

Comparing these values to those which occurred in syllables and words, a significant shortening is obviously seen in VOTs with bilabial and velar stops but no change – if not some tendency for increase – in the case of the dental plosives. The difference of average VOT values between isolated words and those occurring in spontaneous speech is more than 6 ms for bilabials and more than 15 ms for velars. The differences in the French stops' VOT values between careful and spontaneous speech were not significant while our values for the velars turned out to be significantly different ($p<0.001$).

Figure 6. Differences of VOT values of voiceless stops depending on speaking style

Slika 6. Razlike među vrijednostima vremena uključivanja glasa ovisno o tempu govoru



The ranges of the VOTs do show greater values in spontaneous speech than those obtained in the words or in the syllables. Dental stops' VOTs seem to be more stable across the various speech styles than the bilabials' and velars' values. This can presumably be explained by the articulatory gestures for the dental plosives that appear between the labials and the velars in the mouth cavity (Figure 6).

Further analysis was carried out according to the vowel categories as it had been done in the case of syllables and words. VOTs preceding front and back vowels showed the very same tendency that was found in careful speech. VOTs are shorter in the case of a front vowel context with the exception of dental stops. Tongue height and the lip movement seem to be definitive factors also in spontaneous speech: the higher the tongue position in the mouth cavity the longer the VOT of the preceding voiceless stops. The VOTs are longer preceding labial vowels with the same exception of velars as was found in careful speech. Needless to say, the actual values are shorter than those measured in syllables and in isolated words. As predicted, there is no difference among the VOTs according to the quantitative categories of vowels. Since the phonemically short and long vowels show various types of overlapping in their actual physical duration in spontaneous speech, no significant difference had been assumed or was found in VOTs.

CONCLUSIONS

This paper was aimed at a systematic investigation of the Hungarian voiceless stop consonants that had not been done before. Acoustic measurements showed a specific pattern of these consonants. Although the Hungarian voiceless stops belong to the most common group of plosives of the world's languages, they seem to differ to a certain extent from the behaviour of all the measured plosives reported in the literature.

Acoustic analysis of the VOTs of voiceless stops shows a clear difference between careful and spontaneous speech. Bilabilas and velars are significantly shorter in fluent speech while dentals seem to be unchanged. Therefore, the actual duration of VOT is characteristic of the place of the articulation of stops in spontaneous speech while VOTs of bilabials and dentals do not differ from each other in careful speech. Vowels following the stops influence them more in careful than in spontaneous speech which can also be explained by the experimentally confirmed phenomenon of the changing quality of the present-day Hungarian vowels into the neutral sounds (Gósy 1997). The influence of the vowels decreases in spontaneous speech because of this neutralisation process.

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Mária Gósy
Mađarska akademija znanosti, Budimpešta
Mađarska

VRIJEME UKLJUČIVANJA GLASA U MAĐARSKIM BEZVUČNIM OKLUZIVIMA U POLAGANOM I SPONTANOM GOVORU

Mnogobrojne tehnike primijenjene u eksperimentalnoj fonetici i istraživanje jezičnih inventara omogućavaju sve više znanja o prirodi okluziva u različitim jezicima svijeta. Okluzivi se javljuju u svim jezicima, s time da su oni bezvučni neaspirirani najčešći. Ovisno o posebnostima pojedinih jezika ti se suglasnici međusobno razlikuju na temelju različitih akustičkih znakova. Vrijeme uključivanja glasa definira se kao vrijeme između otpuštanja prekida zračnoj struji i početka fonacije u vokalnom traktu.

Do sada nije provedena sustavna analiza okluziva u mađarskom jeziku. Cilj je ovoga rada bio proučiti (s pomoću CSL 50) akustička svojstva vremena uključivanja glasa u tri mađarska bezvučna okluziva u izolaciji (u slogovima i riječima) i u spontanom govoru, na uzorku pet nastavnica.

Akustička analiza pokazala je jasne razlike između polaganog i spontanoga govora. Bilabijalni i velarni okluzivi bili su značajno kraći u spontanom govoru, dok između dentala nije bilo velike razlike. Srednje vrijednosti za bilabijale bile su: 24,05 ms u slogovima; 26,64 ms u riječima, 18,51 ms u spontanom govoru. Srednje vrijednosti za dentalne okluzive bile su: 25,42 ms u slogovima; 23,30 ms u riječima i 26,59 ms u spontanom govoru. Za velarne okluzive nađene su sljedeće vrijednosti: 50,60 ms u slogovima; 50,17 ms u riječima i 35,31 ms u spontanom govoru. Dakle, stvarno vrijeme uključenja glasa ovisi o mjestu artikulacije okluziva u spontanome govoru, dok se bilabijali i dentali ne razlikuju međusobno po vremenu uključenja glasa u polaganome govoru. Samoglasnici koji slijede okluzive imaju veći utjecaj na njih u polaganome nego u spontanom govoru, što se također može objasniti eksperimentalno potvrđenom promjenom kvalitete samoglasnika u neutralan samoglasnik u mađarskom. Vrijeme uključivanja glasa specifično je svojstvo mađarskih okluziva i njegove se vrijednosti značajno razlikuju od većine jezika svijeta.

Ključne riječi: *mađarski jezik, suglasnici, analiza govora*