Human Language Technologies - THE BALTIC PERSPECTIVE

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Remarks on the Duration of Lithuanian Consonants in a Continuous Speech

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The aim of the research

- to investigate the quantity of consonants in a corpus of continuous speech of Standard Lithuanian,
- to qualify spontaneous duration of the analyzed sounds considering qualitative (articulatory) features and ignoring other factors like:
  - the length of the segment
  - the sound's position in a word or
  - adjacent sounds.

The data

- A fragment from V. Mykolaitis-Putinas' novel "Altorių šešėly" read by an actor V. Širka (almost 1 h and 40 min. of records with approx. 60.000 sounds);

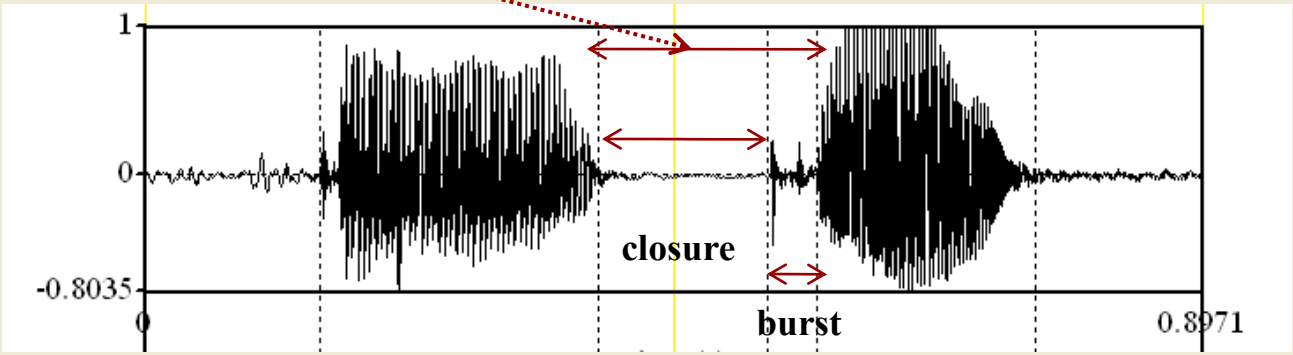
- Analyzed**:**
  - More than 14.000 of **sonorant** consonants;
  - Approximately 11.000 of **plosive** consonants;
  - Approximately 6.000 of **fricative** consonants.

The method

- Automatic annotation of sound records with the HTK speech recognition toolkit;
- Subsequently phone boundaries were manually corrected with the acoustic analysis program Praat;
- Results were processed statistically (duration was measured in seconds (s), mean, standard deviation, confidence interval (95 %)).

The method (2)

- Sonorant and fricative consonants were analyzed in all word positions;
- Plosive consonants, appearing in an initial word positions, were ignored. Closure and burst considered as a single segment.



[k]

- Affricates are not covered by this paper.

Results

Articulatory features:

- place of articulation;
- manner of articulation;
- voicing;
- palatalization.

The place of articulation and VOT patterns

PLOSIVES: VOT duration varies with place of articulation (Cho & Ladefoged)

VOT depends on a number of factors:

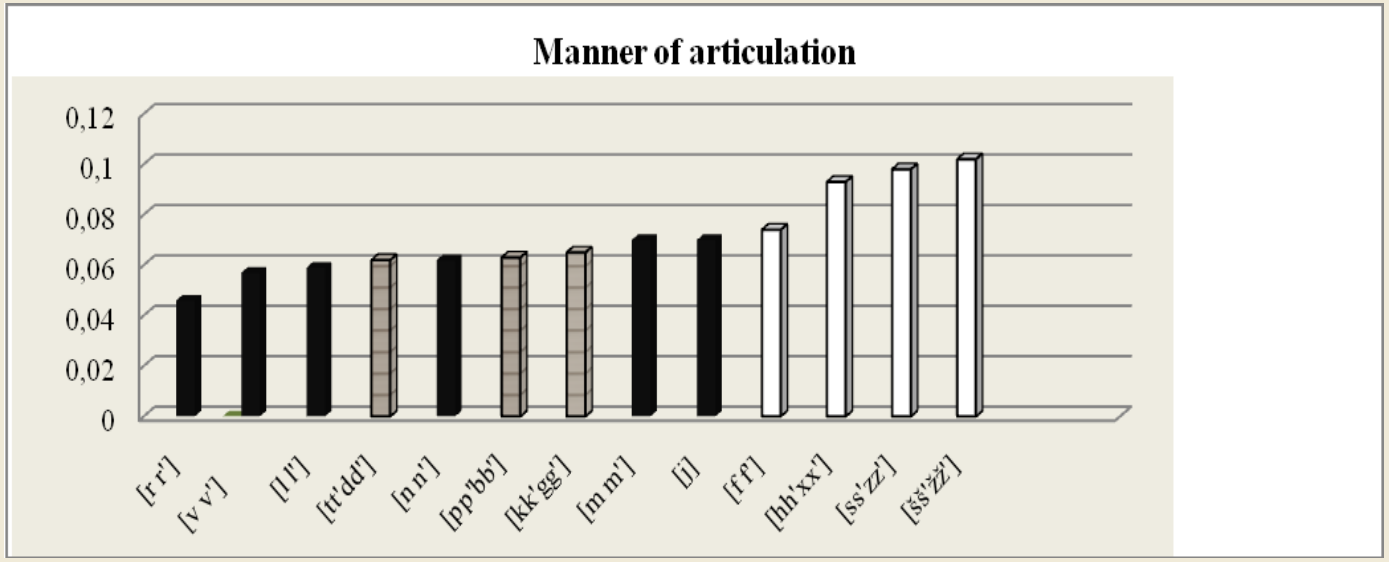
- laws of aerodynamics (Hardcastle, 1973; Maddieson, 1997; van den Berg, 1958);
- articulatory movement velocity (Kuehn & Moll, 1976; Hardcastle 1973; Maddieson 1997);
- differences in the mass of the articulators (Ladefoged & Maddieson, 1996; Stevens 1999);

RESULTS: *The place of articulation*

- Duration results of Lithuanian plosives correspond to the tendency to pronounce longer the sounds that are uttered in the back part of the cavity to pronounce longer.
- This also applies to fricatives (*[ff'']-> [ss''] -> [šš'']*) and sonorants (*[rr''] -> [vv'']-> [ll''nn''*
- Bilabial and dental / alveolar consonants (front part of the mouth) ? (*the velocity of the tongue* and the *mass and movements of the articulators ??)*

	Consonants	Sample size	Mean (s)	Stand. deviation	Confidence interval (95 %)
Plosives	*[pp'bb']*	2649	**0,063**	0,023	0,062÷0,064
	[tt'dd']	4876	**0,062**	0,025	0,062÷0,063
	[kk'gg']	3860	**0,065**	0,025	0,064÷0,066
Fricatives	*[f f']*	52	**0,074**	0,03	0,065÷0,082
	[hh'xx']	14	**0,093**	0,23	0,081÷0,105
	[ss'zz']	4498	**0,098**	0,03	0,097÷0,099
	[šš'žž']	1353	**0,102**	0,03	0,100÷0,103
Sonorants	*[r r']*	2036	**0,046**	0,019	0,045÷0,047
	[v v']	2036	**0,057**	0,027	0,056÷0,058
	[l l']	1627	**0,059**	0,028	0,057÷0,060
	[n n']	2116	**0,062**	0,028	0,061÷0,063
	[m m']	1726	**0,070**	0,023	0,069÷0,071
	[j]	1796	**0,070**	0,038	0,068÷0,071

RESULTS: *The manner of articulation*



- Sonorants are almost 1,5 times shorter but are more similar to plosives (~ 0,62 s).
- The duration differs in distribution of the consonants according the voicing: voiceless plosives and fricatives are the longest, the voiceless ones shorter and sonorants are the shortest in duration.

RESULTS: *The manner of articulation*

The fricative [s]

Consonant	***s***	***s + sp***	***s***	***s + sil***
Sample size	2062	570	2062	228
Mean (s)	**0,102**	**0,182**	**0,102**	**0,182**
St. deviation	0,04	0,05	0,04	0,03
Confidence interval (95 %)	0,100 ÷ 0,104	0,178 ÷ 0,186	0,100 ÷ 0,104	0,178 ÷ 0,186
The duration rates	1 : 1,8		1 : 1,8	

The symbol [*s*] marks here the duration of the fricative in the middle of the word;

s+sp – the [*s*] in the final position of the word before the pause in the middle of the phrase (*vaikas verkia*);

s+sil – the [*s*] in the final position of the word before the pause at the end of the phrase (*verkia vaikas*).

In the final word position fricative [s] is usually uttered longer (almost twice).

RESULTS: *The manner of articulation*
Process of degemination

Consonant	***s***	***ss***	***s'***	***ss'***
Sample size	499	145	499	79
Mean (s)	**0,100**	**0,108**	**0,098**	**0,104**
St. deviation	0,04	0,03	0,03	0,03
Confidence interval (95 %)	0,097 ÷ 0,104	0,103 ÷ 0,112	0,095 ÷ 0,101	0,098 ÷ 0,110
The duration rates	1 : 1,1		1 : 1,1	

- The sequence of two identical adjacent consonants (occurring only at the morpheme boundary) undergoes degemination (*pusseserė*);
- The possible geminates are only 1,1 times longer than unambiguously non-geminates;
- Synthesizing a combination of words like *vaikas serga* at normal speech rate would require longer pause between them in order to obtain two separate sounds.

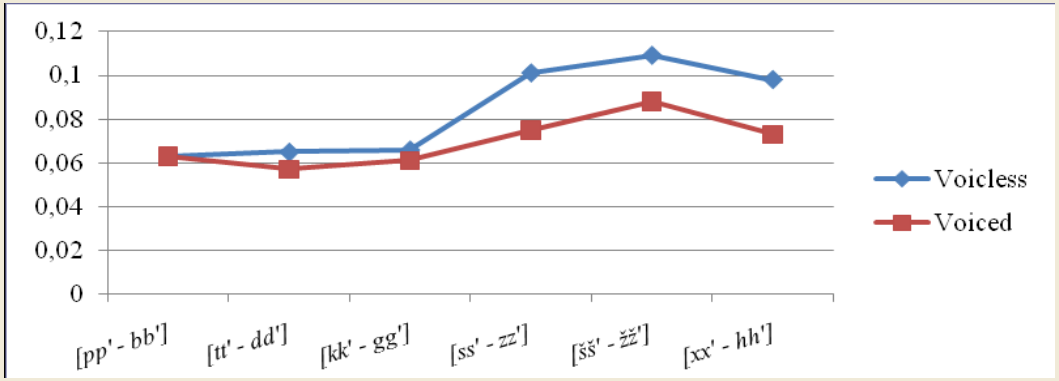
RESULTS: *The manner of articulation*

Sonorants in monophthongs and diphthongs. Stressed / unstressed

Consonant	**V/C–V/C** [*m m'*]	**V–C** [*m m'*]	**V/C–V/C** [*r r'*]	**V–C** [*r r'*]	**V/C–V/C** [*n n'*]	**V–C** [*n n'*]	**V/C–V/C** [*l l'*]	**V–C** [*l l'*]
Sample size	1726	269	2036	1164	2116	344	1627	228
Mean (s)	**0,070**	**0,088**	**0,046**	**0,057**	**0,062**	**0,075**	**0,059**	**0,083**
St. dev.	0,023	0,027	0,019	0,025	0,028	0,023	0,028	0,032
Confidence interval (95 %)	0,069÷0,071	0,085÷0,091	0,045÷0,047	0,055÷0,058	0,061÷0,063	0,073÷0,078	0,057÷0,060	0,079÷0,087
Duration rates	1:1,3		1:1,2		1:1,2		1:1,4	

- In diphthongs uttered sonorant consonants are 1,3 times longer in comparison to monophthongs.
- A diphthongal circumflexed (rising) allotone is produced by emphasizing and lengthening the second element of a biphonemic diphthong and by reducing its first element (for example, *ka̲ltas, kal̲tas)*.
- If the sonorant is a part of the diphthong and is stressed – it is approx. 1,25 times longer.

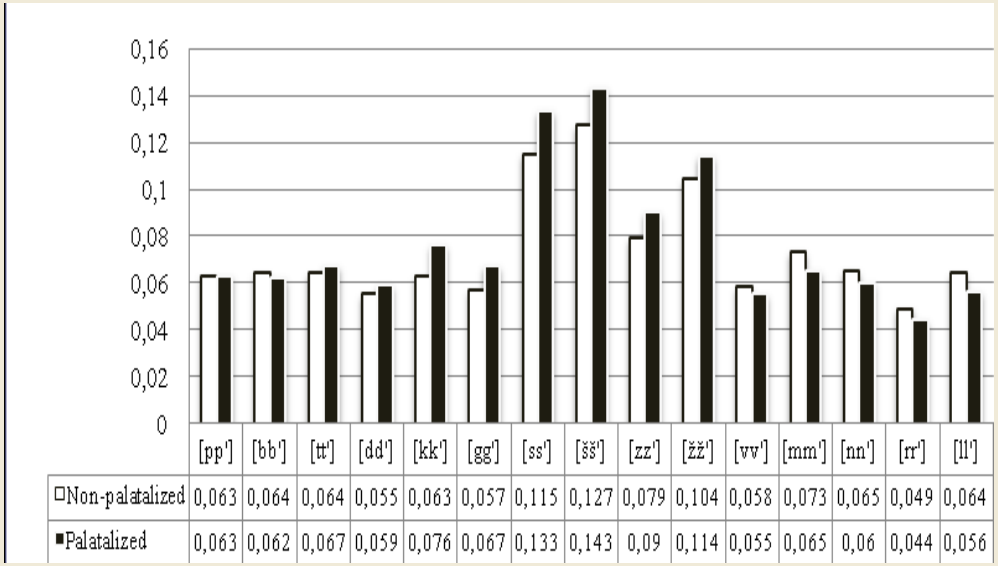
RESULTS: *Voicing*



- The quantity of plosive consonants which are articulated with a closed mouth (bilabials) is similar regardless if they are voiced or voiceless;
- Voiceless dental and velar consonants are slightly longer (1,1 time as long) than corresponding voiced ones. Small differences, but statistically significant;
- Vibration of vocal folds while uttering voiced consonants causes the shorter duration: when the articulation process requires the activity of more articulators, the production of sounds gets more complex and shorter;
- Why then the duration of the voiceless and voiced bilabial consonants is the same?
- Voiceless fricative consonants are 1,2 times longer than the voiced ones.

RESULTS: *Palatalization*

PLOSIVES



	[pp']	[bb']	[tt']	[dd']	[kk']	[gg']	[ss']	[šš']	[zz']	[žž']	[vv']	[mm']	[nn']	[rr']	[ll']
□Non-palatalized	0,063	0,064	0,064	0,055	0,063	0,057	0,115	0,127	0,079	0,104	0,058	0,073	0,065	0,049	0,064
■Palatalized	0,063	0,062	0,067	0,059	0,076	0,067	0,133	0,143	0,09	0,114	0,055	0,065	0,06	0,044	0,056

- Correlation between the consonant duration and its palatalization can partly prove that the duration can be influenced by the articulation's complexity (additional raise of the tongue).
    - Plosive dental palatalized consonants and palatalized consonants articulated in the depth of the mouth articulated (velars) are 1,1 times longer on the average than their non-palatalized counterparts;
    - The durations of both palatalized [p' b'] and non-palatalized [p b] plosive bilabials do not differ;

RESULTS: *Palatalization*

FRICATIVES and SONORANTS

- **Fricative** palatalized consonants are slightly longer (1,1 times) than the non-palatalized ones;

- This phenomenon does not follow the effect of Bernoulli (the airflow passing through narrower gap (in the case of palatalized fricatives) should pass faster);

- Only the palatalized **sonorant** consonants are shorter (1,1 times) in all classes than their respective non-palatalized counterparts.

FINAL REMARKS

- Fricatives (except [*f f'*]) are almost one and a half times longer than plosives. Sonorant consonants are more similar to plosives considering their duration.
- Not the place of articulation but the way how the air penetrates determines some duration regularities.
- Palatalization appears to have no significant impact on the quantity of the consonants: only few palatalized plosive and fricative consonants are longer than the non-palatalized ones. On the contrary, only non-palatalized sonorant consonants are longer than the palatalized ones.
- The most significant feature to impact the duration of consonants is their voicing and the manner of articulation.

FINAL REMARKS

Additional factors should be considered:

- how the duration of the consonants depends on the position in a word,
- the adjacent sounds,
- or the phrase length.

The speech rate, intonation changes, different speakers also should be considered in further researches.

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