Allophonic variation of Polish vowels in the context of prepalatal consonants

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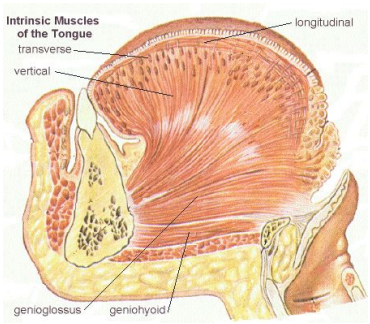
Introduction

- Phonetic studies of Polish mention allophonic variation in vowels, a systematic effect of tongue fronting and raising in the prepalatal consonant context (Sawicka1995:122ff, Wiśniewski 1997:71ff).
- Similarly, phonemic [i] is excluded after non-palatalized consonants, and the phonemic [ɨ] does not occur after prepalatals.
- We assume that the difference between the two sets of vowels is based on the same mechanism for both phonemic and allophonic effects.

Neutral consonants [p b f v t d s z t͡s d͡z ʂ ʐ t͡ʂ d͡ʐ k g x] context	Prepalatal consonants [ɕ ʑ t͡ɕ d͡ʑ] context
Phonemic	
ɨ	i
Allophonic	
u	ʉ
ɛ	e
ɔ	ɵ
a	ą

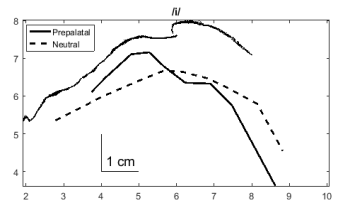
- Although X-ray data for Polish speech production exists from the 50's and 60's (Koneczna & Zawadowski 1951, Wierzchowska 1967) no X-ray images are available of the contextual variants of vowels adjacent to prepalatal consonants.
- 5 speakers in the study show all allophonic variation with some degree of fronting **and/or** raising of the tongue body combined with the fronting of the tongue root for the vowels in the context of prepalatals as opposed to the vowels in the neutral (non-palatalized) consonant context.

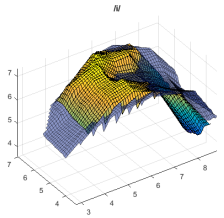


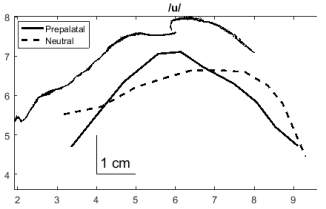
Method

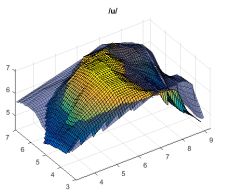
- 5 Polish native speakers (3 women, 2 men) participated in the recordings, some of them in multiple sessions. Participants read word lists consisting of 2-syllable nonce words of the shape $C_iV_jC_iV_jC_i$. The consonantal contexts: /p, t, k, tɕ/ The vowels: /i, ɨ , u, e, o, a/
- Palate impressions were made using dental alginate & digitized with a NextEngine3D laser scanner; data were saved in binary STL format.
- Ultrasound images were recorded with a Philips EpiQ7G system using an xMatrixx6-1 digital3D transducer secured under the chin using an Articulate Instruments ultrasound stabilization headset.
- Fully uncompressed DICOM ultrasound files were transferred to a Windows 7 computer.
- Ultrasound/palate files were analyzed w/ a custom MATLAB toolbox, called "WASL".
- Palates were manually registered with the tongue data.
- Audio was recorded with a SHURE KSM32 microphone placed approximately 1 meter in front of the participant, at 48kHz sampling rate.

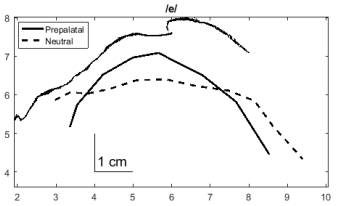
Results

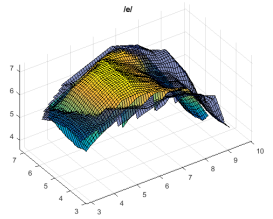


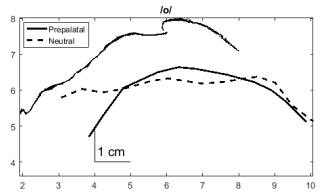


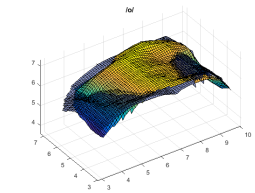


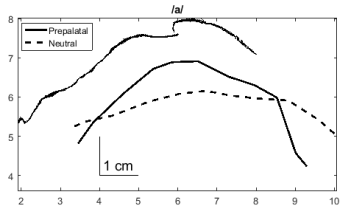


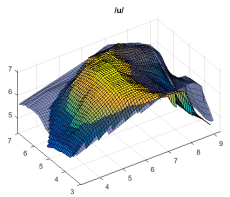










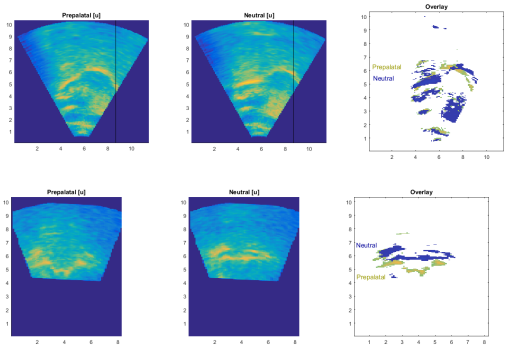


Observations

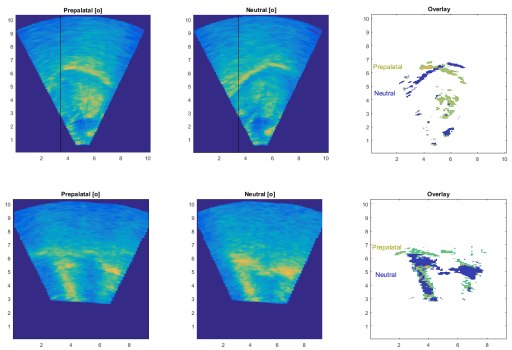
Speaker	Observation		Hypothesized Articulatory Mechanisms
	Prepalatal context vowels	Neutral context vowels	
Speaker 1 (female)	Tongue root advancement, a groove in the back of the tongue. Genioglossus tendon is elevated.		Contraction of posterior genioglossus (GGp) in pre-palatal context.
Speaker 2 (male)	Some tongue root advancement (more for high and front vowels), posterior genioglossus pushing hyoid bone down.	Prominent groove in the front of the tongue (activation of anterior genioglossus GGa), geniohyoid muscle (GH) compressed downwards	Contraction of GGp in pre-palatal context. Contracted GGp pushes hyoid bone down. Contraction of anterior genioglossus (GGa) in neutral context. Contracted GGa pushes hyoid bone down.
Speaker 3 (female)	Variable: Groove in the back part of the tongue, tongue tip pulled back which elevates the tongue body. Genioglossus tendon is elevated in some realizations, and geniohyoid muscle is thicker.		Contraction of inferior longitudinal muscle (IL) in pre-palatal context. Contraction of geniohyoid (GH) in pre-palatal context. Contraction of GGp in pre-palatal context.
Speaker 4 (female)	Prominent groove in the back part of the tongue.	Prominent groove in the front part of the tongue.	GGp or GGm contraction in pre-palatal context. GGa contraction in neutral context.
Speaker 5 (male)	The geniohyoid muscle pulls the hyoid bone forward and up. Genioglossus tendon is angled. Groove in the back of the tongue.		GH and GGm/GGp contraction in pre-palatal.

Results

Tongue root mechanism

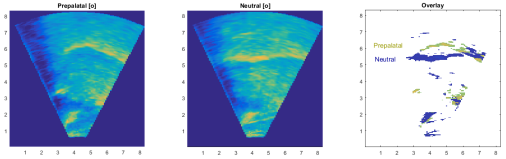


Tongue tip expanding the oral cavity

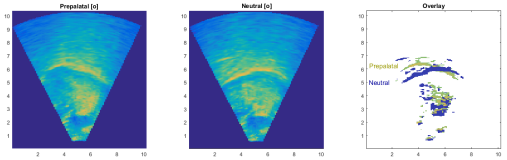


Articulatory Mechanism	Tongue Shape	Tract Configuration
Prepalatal consonant context		
Posterior genioglossus contraction	Groove in the back part of the tongue	Expansion of the upper pharynx
	Pushing hyoid bone down and the tongue body up	Narrowing of the oral cavity
Medial genioglossus involvement	Pulling the dorsum down/forward	Expansion of the upper pharynx
Geniohyoid contraction	Relative raised and advanced position of the hyoid bone resulting in the advancement of the tongue root	Expansion of the lower pharynx
Inferior longitudinal muscle contraction	Tongue tip pulled back and down and the tongue body pushed upward/forward	Narrowing of the oral cavity
Neutral consonant context		
Anterior genioglossus	Groove in the blade of the tongue	Expansion of the front part of the oral cavity

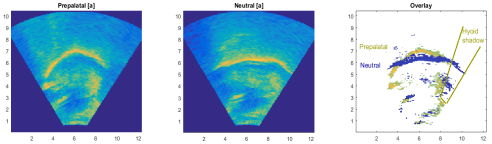
Tongue tip narrowing the oral cavity



Medial genioglossus involvement



Geniohyoid involvement



Discussion

Idealized neutral vowel configuration with the expansion of the oral cavity and/or narrowing of the pharyngeal cavity

Idealized prepalatal context configuration with the expansion of the pharyngeal cavity and/or narrowing of the oral cavity

Conclusions/Future Directions

- The images of the prepalatal context vowels show fronting of the hyoid bone (thus advancement of the tongue root), a deep groove in the back part of the tongue, but also activation of the posterior genioglossus and geniohyoid muscle.
- There is a lot of inter- speaker variation and some intra-speaker variation, however, in all cases the combined effect is that of relative expansion of the pharyngeal cavity for the prepalatal context and enhancing the oral cavity for the neutral context.

Further questions:

- Speaker-specific variation or dialectal variation?
- Do female – male anatomic distinction (pharynx size) favor one or the other implementation strategy? (Vorperian et al., 2009)
- Does split tendon influence the choice of strategy? (presence/absence of the groove in the back of the tongue)

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Acknowledgements

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