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Surface Palatalization of Polish Bilabial Stops: Articulation and Acoustics

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ABSTRACT

Bilabial stops undergoing Surface Palatalization (SP) were analyzed in an EMMA/EPG study. Articulatorily, the point of maximal palatal contact and the labial opening movement were analyzed. The acoustic analysis pertained to stop related timing and the point of the highest F2-value. Results show (i) that SP yields a higher F2 at vowel onset and a lengthened opening gesture and (ii) that morpheme-induced palatalizations are distinguished from word initial ones and sandhi-palatalizations articulatorily and acoustically by a shorter delay of palatal target position with respect to stop production; (iii) no differences are found between 'repalatalized' and plain segments in case of sandhi palatalization.

1. INTRODUCTION

According to phonological approaches, cf. [1,2] Surface Palatalization (SP) in Polish affects all labials before the high front vowel /i/ and the glide /j/ independently of the position they occur in (cf. (1)).

$$[+\text{cons}] \rightarrow \begin{pmatrix} +\text{high} \\ -\text{back} \end{pmatrix} \; / \; \_\_\_ \; ([-\text{seg}]) \begin{pmatrix} -\text{cons} \\ +\text{high} \\ -\text{back} \end{pmatrix} \qquad (1)$$

The goal of this paper is to prove the adequacy of this rule with respect to phonetic facts. Of particular interest are (i) acoustic and articulatory aspects of palatalization depending on their realization position, i.e. (a) root internally, (b) before a morpheme boundary, and (c) across word boundaries.

A related issue we are interested in concerns differences between underlyingly palatalized (/p^jes/ 'dog') vs. plain labials that are palatalized according to SP. (/krab jadalny/ → [krab^j jadalny] 'eatable crab'). The second case also includes labials which undergo palatalization in cases where the trigger is not visible in the output but only in the underlying representation. Most palatalizations of this type occur when a suffix is added to a root (cf. kar[p] vs. kar[p^j]a 'carp' nom.sg./gen.sg). As far as the underlying representations of such words are concerned, there are at least two possibilities. First underlying plain labials are followed by palatalizing suffixes, as shown in (2a) (The palatalizing property of the suffixes is represented by a palatalizing jer [ɨ] that is deleted on the surface). Second, palatalized labials are present underlyingly and are followed by a nonpalatalizing suffix –a, as shown in (2b).

kar/p/ + /ɨ/a	kar[p^j]a	a	(2)
kar/p^j/ + a	kar[p^j]a	b	

There are several arguments in favor of (2b). One of them is that in comparison to other suffixes, the suffix –a does not trigger palatalizations of every root-final labial (e.g. krab vs. [kraba] 'crab' nom.sg./gen.sg.), for other arguments see [2].

In the following we assume the underlying root-final labials, as presented in (2b). They are depalatalized in a word-final position, e.g. kar[p] and 'repalatalized' if (i) the inflection is added, as in (2) or if the following word starts with /j/ or /i/ (e.g. kar[p^j j]adalny 'eatable carp'). For a thorough discussion of Polish palatalization see [3].

In light of these facts we posed the question whether there is an articulatory/acoustical difference between an underlyingly palatalized segment and its plain counterpart in case of sandhi palatalization.

2. EXPERIMENTAL SETUP

2.1. SUBJECTS AND MATERIAL

Four native speakers of Standard Polish (2 female (jb, mr), 2 male (pk, zl), mean age of 30 years) served as subjects. They read the test words embedded in the carrier frame *powiedziałem ... bez pospiechu* ('I said ... without hurry') 6 to 9 times in randomized order as prompted by the screen for stimulus presentation (cf. fig. 1). The test data were constructed according to table 1.

	#_	_+	_#
/plain/		krab+a 'shrimp' gen.sg.	krab jadalny 'shrimp eatable'
/palatal-ized/	białko 'white of egg'	gołębi+a 'pigeon' gen.sg.	gołąb jasny 'pigeon white'

Table 1: Illustration of the categories of test items (only voiced examples given); #_: word initial, _+: at morpheme boundary, _#: at word boundary.

2.2. METHOD

The consonantal articulation was recorded by midsagittal electromagnetic articulography (EMMA, Carstens AG 100, 10 channels) and by electropalatography (EPG, Reading system 3.0 with 62 electrodes in 8 rows; cf. fig. 1) in parallel.

The EMMA receiver coils were mounted at the vermilion border of the lower lip, the tongue blade ca .5 cm behind the tongue tip laminally and at distances of 1.5 cm each predorsally and dorsally (cf. fig. 1).

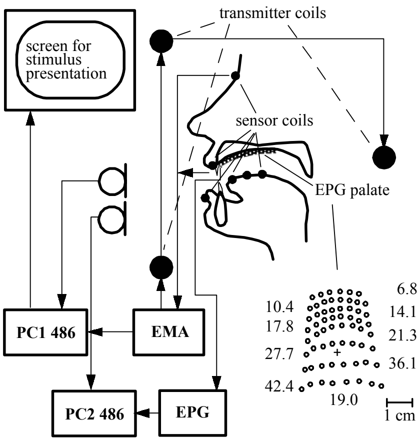

Figure 1: Scheme of the experimental setup and of the electrode placement on a sample EPG palate (male; the numbers besides the palate give the mean distance of the electrode rows from the inner edge of the upper incisors [mm]; the cross marks the highest point of the palate with its distance from the bite plane given below).

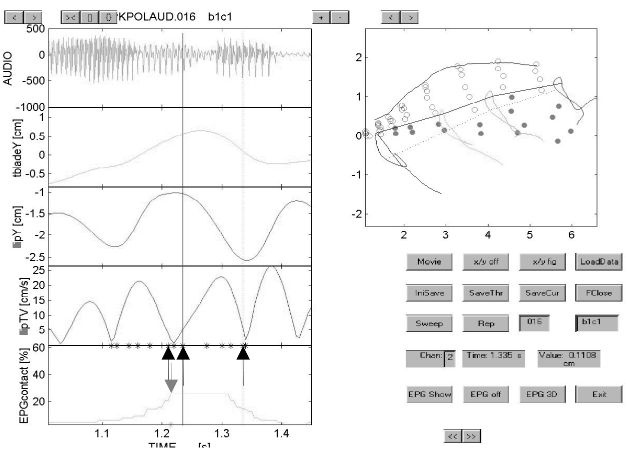

Figure 2: Screenshot of the analysis software; left: articulatory measurement points as defined by lower lip tangential velocity (trace 4): end of closing gesture, beginning and end of opening gesture (black arrows), and (trace 5, grey arrow): point of maximal palatal contact; right: sagittal view of the palate contour, the palate electrodes and the trajectories of the EMMA coils (lines connecting the coil positions represent the cursor positions of the left panel; filled circles: EPG contacts at left cursor's time point).

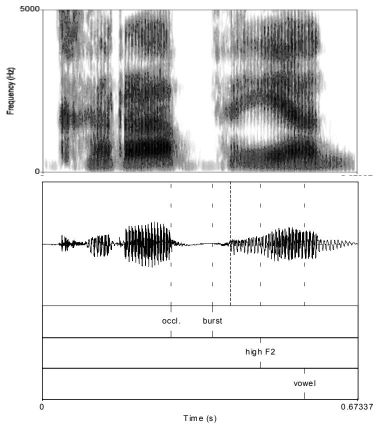

Figure 3: Acoustical measurement points.

The palatographic data were analyzed with respect to the timing of the point of maximal palatal contact. The beginning and the end of the labial opening gestures was determined by applying a 20 percent threshold criterion to the EMMA tangential velocity signal of the lower lip sensor (cf. fig. 2). Parallel, in the acoustic signal the point of occlusion onset, the burst, the first pitch period with clearly detectable formant structure, the highest F2-value and the target vowel position were measured. Additionally, formant frequencies (F1, F2) were measured at the latter three time stamps (cf. fig. 3).

3. RESULTS

3.1. ACOUSTICAL MEASUREMENTS

The results of the formant measurements for the first pitch period after plosive release are depicted in table 2.

jb

item		F1	signif.		F2	signif.	
b/p	_+	531.685 32.123	***		1080.878 63.130	***	
	_#	390.767 30.013			2102.926 90.268		
b'/p'	#_	408.097 54.638	n.s.	n.s.	2151.403 92.681	*	n.s.
	_+	431.211 52.280	n.s.		2034.556 130.696	n.s.	
	_#	403.399 39.684			2134.919 146.672		

mr

item		F1	signif.		F2	signif.	
b/p	_+	643.958 127.633	***		1248.694 380.449	***	
	_#	412.818 19.507			2040.679 73.034		
b'/p'	#_	387.163 26.116	n.s.	n.s.	2081.645 122.357	*	n.s.
	_+	401.704 43.499	n.s.		1988.314 87.590	n.s.	
	_#	388.697 22.341			2061.130 75.193		

pk

item		F1	signif.		F2	signif.	
b/p	_+	504.337	***		1144.369	***	
		36.036			160.183		
	_#	346.505			1868.815		
		23.375			58.352		
b'/p'	#_	345.933		n.s.	1949.984		*
		15.745	n.s.		57.291	**	
	_+	363.209			1780.529	*	
		35.208	n.s.		90.122	**	
	_#	346.204			1871.708		
		22.894			88.140		

zl

item		F1	signif.		F2	signif.	
b/p	_+	553.834	***		1290.833	***	
		36.284			157.537		
	_#	373.071			2127.731		
		42.890			105.218		
b'/p'	#_	378.345		n.s.	2159.518		n.s.
		32.976	n.s.		67.176	n.s.	
	_+	355.048			2076.739		
		31.043	n.s.		103.976	n.s.	
	_#	345.924			2117.967		
		40.709			129.043		

Table 2: Results of the formant measurements at plosive release (means and standard deviations) for the four subjects and ANOVA results (*: p < .05, **: p < .01, ***: p < .001).

Single ANOVA analyses for the single subjects showed that test items with underlyingly plain labials exhibit a highly significant (p < .001) shift of formants in the direction of [i] under the condition of sandhi palatalization (cf. upper panels in table 2).

For the underlyingly palatalized segments (with formant values already in the direction of [i]) there are still some significant differences in F2 depending on position (jb: p < .05, mr: p < .05, pk: p < .001, zl: n.s.). Results of post-hoc Scheffe's comparisons are show in the lower panels of table 2. No significant differences could be found between underlyingly plain vs. palatalized stops in the case of sandhi palatalization. These positional differences (together with differences due to voicing) become clearer when analyzing the acoustic timing parameter of the lag of the point of the highest F2-value behind plosive release (cf. fig. 3) as shown in figure 4: The general tendency seems to be a shorter lag of the highest F2-value in case of the morpheme boundary condition. Subjects jb and pk showed a marginal effect of underlyingly plain vs. palatalized stops (p < .05) in the case of sandhi palatalization with respect to this parameter, i.e. longer lags for phonemically palatalized stops.

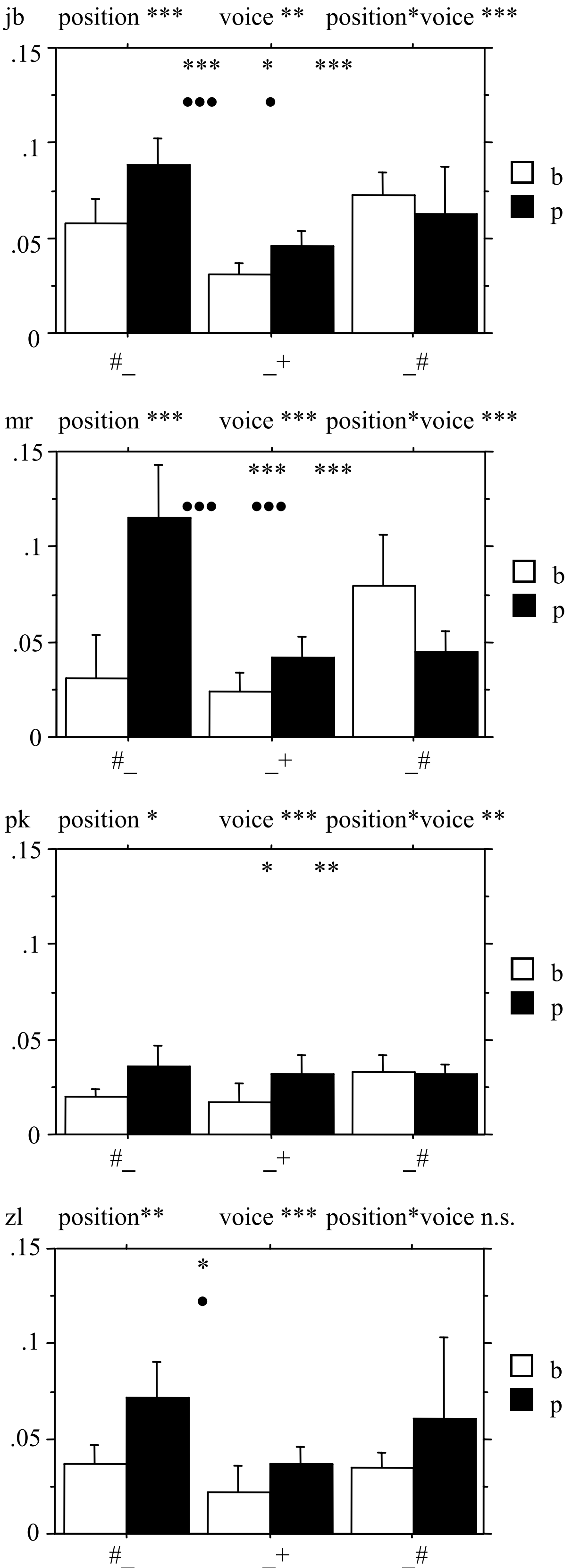

Figure 4: Time lag [s] of point of highest F2 value relative to plosive burst under the different conditions of position and plosive voicing (ANOVA results for these variables above the panels; post-hoc Scheffe's comparisons inside panels; * for [b], • for [p], as in table 2).

3.2. ARTICULATORY MEASUREMENTS

In the light of the acoustical results our articulatory analysis again focussed on timing behaviour. Here single ANOVAs for our subjects showed a positional effect paralleling the acoustical results when looking at the time between the beginning of the labial opening gesture and the point the tongue is reaching its maximal palatal contact as depicted in figure 5 (jb: $p < .01$, mr: $p < .001$, pk: n.s., zl: n.s.).

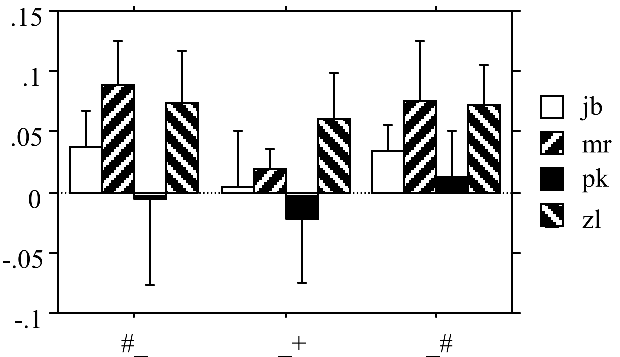

Figure 5: Time lag [s] of point of maximal palatal contact with respect to the beginning of the labial opening gesture.

Again this lag is shorter in case of the morpheme boundary condition. Post-hoc comparisons for our two female subjects showed significant differences between morpheme boundary condition and initial as well as word-final position (jb: $p < .05$ both; mr: $p < .001$ both) but not between the latter two.

Only subject jb showed an effect of underlyingly plain vs. palatalized stops ($p < .001$) in the word-boundary condition with respect to this parameter, again resulting in longer lags for phonemically palatalized stops.

4. CONCLUSIONS

Despite strong intersubject variability in our data surface palatalization of Polish bilabial stops followed by /a/ can be (i) acoustically characterized by formant shifts in the direction of [i]. The tongue fronting during the bilabial opening gesture producing these shifts furthermore (ii) is differently timed in the different positional variants of the palatalization: Root-internal palatalization and sandhi palatalization across word boundaries seem to be similar to each other and different from palatalization applying at morpheme boundaries.

This asymmetry is problematic for phonological accounts of palatalization, see introduction, which treat surface palatalization in a homogeneous way independently of the position it occurs in. This also suggests that there might be different processes at work with respect to boundary conditions. Therefore phonological rules should be evaluated with respect to their adequacy. This difference between true palatals/sandhi palatalizations and repalatalizations occuring at morpheme boundaries in Polish is also in some ways in contrast to the findings that labial palatalization in Russian is more prone to neutralization in (preconsonantal) coda position (cf. [4]).

Our results also show that there seems to be no phonetic difference in palatalization across word boundaries between segments that are underlyingly palatalized and those that are only palatalized on the surface.

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