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PALATALIZATION EFFECTS AS A RESULT OF ARTICULATORY- AND PERCEPTUALLY-DRIVEN MECHANISMS

0. Overview

For the past few decades, in the main stream phonology there has been no place for argumentation referring to perception or acoustic properties of speech. The thesis of the first part of this article is that, in contrast to standard assumptions inherited from the SPE and feature geometry, we do need perceptually defined features organized into perceptual representations for the phonological analysis. In the second part, one theoretical issue that is important in the auditory-oriented approach, namely that of the emergence of the surface contrast will be discussed in more detail. The idea is that auditory representations are controlled by the functional principle of maximal perceptual distinctiveness of speech units. The question is, what formal constraints are involved to deliver surface representations that conform to this principle. The existing approaches to this topic will be reviewed. Finally, I will present my proposal in that I will argue for perceptual cue enhancement constraints, evaluating the difference between surface auditory representations of contrasting forms (words) and selecting those which are most distinct.

1. Palatalization in Slavic and Feature Geometry

The term `palatalization´ is used here to refer to any effect that is produced on the consonant by the adjacency of a front vowel, i.e. not only raising of the tongue towards the hard palate (secondary palatalization) or change the place of articulation to coronal (coronalization), compare (1) and (2). In what follows, I will argue that traditional purely articulatory approach (Feature Geometry) does not account for the whole range of palatalization processes and an alternative approach must be considered.

Palatalization is usually regarded as an assimilation and within feature geometry it is analyzed as spreading of vocalic place features. When we look at the results of palatalization, it is striking, however, that we have to do with a great phonetic variety. Table (1) lists possible phonemic effects of palatalization in the context of a front vowel across Slavic languages. The palatalised segments differ greatly in place and manner of articulation (the phonetic symbols do not reflect all the phonetic variation anyway[1]).

(1)

Results of Palatalization in Slavic
p^j, $p^ś$, p^c, $\widehat{ts}$, t^j, $\widehat{ts^j}$, $\underline{t}^j$, $\widehat{tɕ}$, $\widehat{tš^j}$, $\widehat{tš}$, *c*

One idea to accommodate these facts in feature geometry would be to claim that cross-linguistically we deal with varying across languages phonetic implementations of vocalic features, which are producing so different effects of palatalization. Yet, many Slavic languages may illustrate the fact that this great variety might occur also within one language. Consider the outputs of palatalization in Polish in (2). In (2) results of palatalization-type phenomena taking as the input only voiceless plosives, are listed.

(2)

Results of Palatalization in Standard Polish (alternants of voiceless plosives only)
p^j, t^{j}[2] , $\widehat{ts}$, $\widehat{tš}$, $\widehat{tɕ}$, *c*

Here, of course, it cannot be claimed that the differences are all due to the variation in phonetic implementation. Also, these different palatalization effects have different phonological and morphophonological properties. This can be illustrated by the examples from Polish morphophonology and one such telling example is the behavior of the masculine personal Nom. pl. ending –i,. It surfaces only after labials and coronal stops. On the other hand, the underlying velars when palatalized surface as `hard´ (without secondary raising of the tongue to the palate) alveolars,

[1] *Sawicka and Grzybowski (1999) provide more detail.*
[2] *An effect of Surface Palatalization; non-phonemic.*

which in turn cause a retraction of the [i] (that triggered palatalization in the first place) to [ɨ], as in (3).

(3) chłop - chło[pʲ]i

kat – ka[t͡ɕ]+i

but:

Norwe[g] – Norwe[d͡ʑ]+ɨ ([d͡ʑ] triggering retraction)

On the other hand, other palatalized sounds are incompatible with –ɨ altogether .(It also does not trigger palatalization, and for this reason there are no genuine examples where an effect of a palatalization process is followed by an underlying ɨ.) There are, however, cases where a sequence of an underlying prepalatal is followed by a morpheme starting with an underlying -ɨ, which then surfaces as [i]. For instance, Genitive singular ending for feminine nouns is -ɨ, but when attached to stems ending with underlying prepalatals, it surfaces as [i], see (4):

(4) Fem. Gen. Sing.:

dziewczyn-[ɨ]

but:

Ka[ɕ]+a – Ka[ɕ]+i

Ja[d͡ʑ]+a – Ja[d͡ʑ]+i[3]

Etc.

To summarize, one group of palatalized sounds patterns exclusively with front tense [i], the other with centralized [ɨ]. How come that spreading from one and the same vowel produces so different effects?

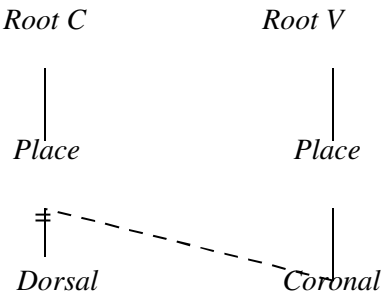
One conclusion is that all these results of the interaction with a front vowel in Polish cannot be accounted for by spreading of one and the same feature. Purely articulatory approach offered by Feature Geometry operating with feature [-back] or with the Coronal node has not enough explanatory power to account for the whole variety of palatalization processes. Thus, within Feature Geometry, one has to propose a very complex place feature specification for the front vowel (Szpyra, 1995, Rubach, 1993, Cavar, 1997, assumed Coronal and Dorsal[-back] ; Lahiri and Evers, 1992 – Dorsal [-back][+high]). The authors who do assume a technical

[3] *The examples `Kasia´, `Jadzia´ do not exhibit alternation between the plain sound and the prepalatal within related forms – thus, the assumption is that prepalatal is underlying.*

solution with double specification of the front vowel as Coronal and Dorsal[-back] cannot deliver unified definitions for their features. This is because front vowels are claimed dorsal because the constriction is produced actively through the movements of the back part of the tongue (the active articulator model by Halle, 1995), and the definition of front vowel as coronal rests upon the assumption that it is not active articulator but the place of constriction that is of relevance(constriction model by Clements and Hume, 1995). Thus, it is unclear why assimilation actually happens – whether it is for the sake of not changing the active articulator, or whether it is about not changing the configuration of articulators. Lahiri, and Evers approach is unsuccessful for the very reason that it predicts that only high front vowels should cause secondary palatalization, which is not true (Bhat, 1978). On the other hand, high back vowels should trigger secondary palatalization on equal terms with front vowels, which is also not born out. Finally, even these complex approaches do not cope with the affrication issue.

Affrication problem is illustrated in (5), where palatalization is expressed as a spreading of the Coronal node with a subsequent delinking of the original Dorsal node of the consonant (following a.o. Hume, 1992)

(5)



However, what is often overlooked, the result of the operation in (5) is a consonant with the coronal place of articulation , see (6), and the manner of articulation should not change.

(6) *k → t̲ /__ V[Coronal] (expected result)*

vs.

k → tš / __V[Coronal] (actual result)

Yet, the change of the consonantal place of articulation in the vicinity of a front vowel comes usually together with the change of the manner of articulation: stops turn up as affricates or fricatives. What is more, there are cases where the affrication appears alone, without any change in the place of articulation, like for instance in Japanese, as described by Lahiri and Evers (1992). The relation between the change of the place and the manner of articulation has not received a satisfactory

account under classical Feature Geometry. What is predicted by articulatory approach is the assimilation in the place of articulation. The fact that some results of palatalization differ from the underlying segment in the manner of articulation is mysterious under the Feature Geometry approach.

These all facts suggest that palatalization is a phenomenon which cannot be reduced to pure articulation place feature spreading. If only articulatory facts were involved, only one output would surface in all cases, the one which would be best articulatory accommodated to the front vowels. The articulatory assimilation approach does not explain why we make the effort to keep the effects of different palatalization processes distinct, e.g. in Polish between palatalization of coronals and velars, see (7):

(7) Effects of palatalization of coronals and velars are distinct

	Coronal Palatalization	*1st Velar Palatalization*
Input	*bł o[t]+o ` mud´*	*kro[k] ` step´*
Output	*za+bł o[t͡ɕ]+i+ć ` to make dirty with mud´*	*kro[t͡ʃ]+y+ć ` to walk´*

If it would be only for articulatory reasons, in both cases we would expect a maximal assimilation to prepalatal, where the tongue assumes the position very close to that of the front vowel. Yet, in the alternants of velars, though the place of constriction is as expected, post-alveolars lack the characteristic raising of the tongue towards the hard palate. Thus, assimilation is not complete. The answer would be that we want to preserve the perceptual contrast, but how shall we express this concept without perceptual features?

Another unanswered question is why the change of the primary articulation before front vowels is common, whereas the change of the primary articulation place in the context of back vowels, as in (8) is hardly heard of.

(8) *ki* → *tʃi*

tʃ → *ka*

And why do we have the asymmetry in the behavior of consonants in different places of articulation: velars are cross-linguistically more often turned into Cor[-anterior] in the adjacency of front vowels than coronals themselves, and coronals, in turn, are more apt to primary place palatalization than labials.

An alternative to articulatory grounded Feature Geometry, that might offer some answer to the questions above, appears to be an approach involving both articulatory and auditory factors. Guion (1998), demonstrated that the sequences [ki] – [tʃi] are acoustically and perceptually very similar. On the other hand, no such results have been obtained when the sequences with back vowels have been tested. Thus, perceptual similarity corresponds tightly to well-known tendencies in phonological behavior of sounds. Similarly, the above mentioned asymmetry between the places of articulation of consonants and their immunity to the primary place palatalization might have to do with their perceptual qualities, though I am not aware of any phonetic or perceptual experiments carried out on this topic (but compare Flemming, 1995). Thus, it seems that we will not get any further in research on palatalization if we do not accept perceptual features as a formal device.

2. Arguments against pure articulatory approach outside palatalization

It is not only palatalization that requires auditory/perceptual features/representations in order to be accounted for. In the literature, we find many more examples of phenomena which cannot be fully explained by purely articulatory approach. (9) gives just a short list of problems which could be probably stop being problems when we consider perceptual factors involved.

(9)

(a) A number of processes seem to refer a class of sounds involving both labial and dorsal sounds (see Hall, 1997 for a list of examples). Labials and velars in Jakobsonian terms are [grave], and this traditional feature has been adopted by researchers working on feature geometry although [grave] or [peripheral] has no articulatory bases.(e.g. Avery and Rice, 1989; Dogil, 1988; Hall, 1997)

(b) Feature [continuant] can be implemented by many articulators, in other words, there is no one common articulator involved in the production of all fricatives. On the one hand, one needs to express the fact that [continuant] is a natural class independently of the particular places of articulation, on the other hand one needs to express the fact that [continuant] undergoes spreading together with place features.(e.g. Clements, 1987, Padgett, 1994), which leads to the unresolvable conflict. In acoustic terms, in contrast, there is a clear correlate of a fricative: presence of noise in the spectrogram.

(c) Feature [strident] cannot be defined otherwise as by reference to perception.

(d) Spontaneous voicing, used to define a natural class of sonorant sounds, does not involve a single active articulation but rather requires a certain vocal tract configuration that can be achieved by several different muscular implementations (Boersma, 2001), and the constant is the radically different from non-sonorous sounds properties of the acoustic signal.

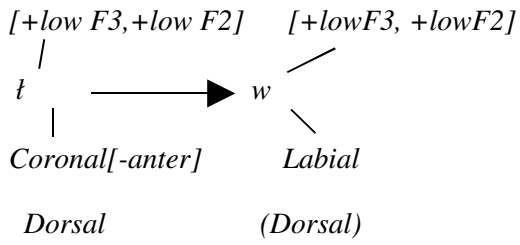
(e) Steriade (2001) observes that in the intervocalic clusters of consonants, place assimilation proceeds regressively, with an exceptions of clusters composed of retroflexes and alveolars, where assimilation is progressive. Steriade accounts for this asymmetry by reference to the location of the place cues in the signal: whereas the basic cue for the perception of the place in consonants is usually the transition from the consonant into the following vowel, for retroflexes holds the opposite. It seems the that it is always a consonant where the transition cannot be perceived, which is being neutralized.

(f) Nasal assimilation directionality seems to follow from the perceptual properties of the consonant clusters involving the nasal (Boersma, 1998).

(g) Rhotics produced by different articulators still form a natural class (Ladefoged, 1975; Lindau, 1985, for an overview and discussion, see Hall, 1997)

(h) Some alternations require a bilateral context. As pointed out by Flemming (1995) from the point of view of Feature Geometry such a requirement is irrational; it should not make any difference whether the spreading comes from one or two sources. However, place cues might appear in the transition from the vowel to the consonant, and from the consonant to the vowel – if both environments are illegible (through the influence of the vowel), the cues for the original place are not available any way, and articulatory assimilation may take place.

(i) Dark l vocalization in Polish – a change where the historic dark [ɫ] has started being realized as [w]. From an articulatory perspective, the change from a velarized coronal to a labial glide is quite arbitrary. Yet, when we consider also acoustic properties of the involved sounds, it becomes clear that the two sounds are similar perceptually and this fact allows for the substitution of articulatory more complex dark l to a simpler [w].



All these cases are to show that we are not able to capture certain regularities in terms of articulation alone, and the arguments above are probably not all arguments that can be called in to support the relevance of the auditory factors in phonology.

The last argument for involving perception into phonological explanation that will be mentioned is of theoretical nature. When looking for explanations in phonology, one can assume that a particular patterning of sounds is due to structures and constraints within grammar. So to speak, adopt "internal explanations". Another approach, that is adopted here, is to assume that external, extra-grammatical factors are ultimately responsible for phonological regularities. To quote Myers (1998):

"In seeking insight into why phonological patterns are the way they are, it makes sense to adopt the general strategy in science of maximizing the generality of our explanations and seeking explanations based on independently motivated factors."

Many scholars referred in the history of linguistics to functional principles governing language (Passy, 1891, Martinet, 1955; Lindblom, 1986; Flemming, 1995, and references therein; Boersma 1998). These are given in (10):

(10) *(a)* *Principle of minimization of effort. The less movement, the less complex movement, the closer distance of movement, etc. the better. Examples here might be articulatory assimilations, simplification of complex articulation.*

(b) *Principle of minimization of confusion; the speaker wants to be understood, thus, the perceptual output has to be as distinct and clear as possible. For instance, OCP can find its explanation in terms of this principle – adjacent segments that are too similar cannot be distinguished from one another and are avoided. Dissimilation enhances the distinctiveness of adjacent segment. Similarly, spreading of particular perceptual features has the positive effect of prolonging the time in which a given feature can be perceived, and thus making this particular feature more distinct.*

The two principles interact; sometimes it is more advantageous to make more effort in order to be better understood, sometimes saving the articulatory effort has the priority.

It seems that the functional approach referring to the principles of minimization of effort and of maximization of distinctiveness exhibits some advantages over the structuralist view. It is, first, more general, as it refers to principles which are common to all human motor behavior and perception, and second, it offers external motivations, as the phonological behavior is motivated by articulation and perception, and not by other portions of grammar.

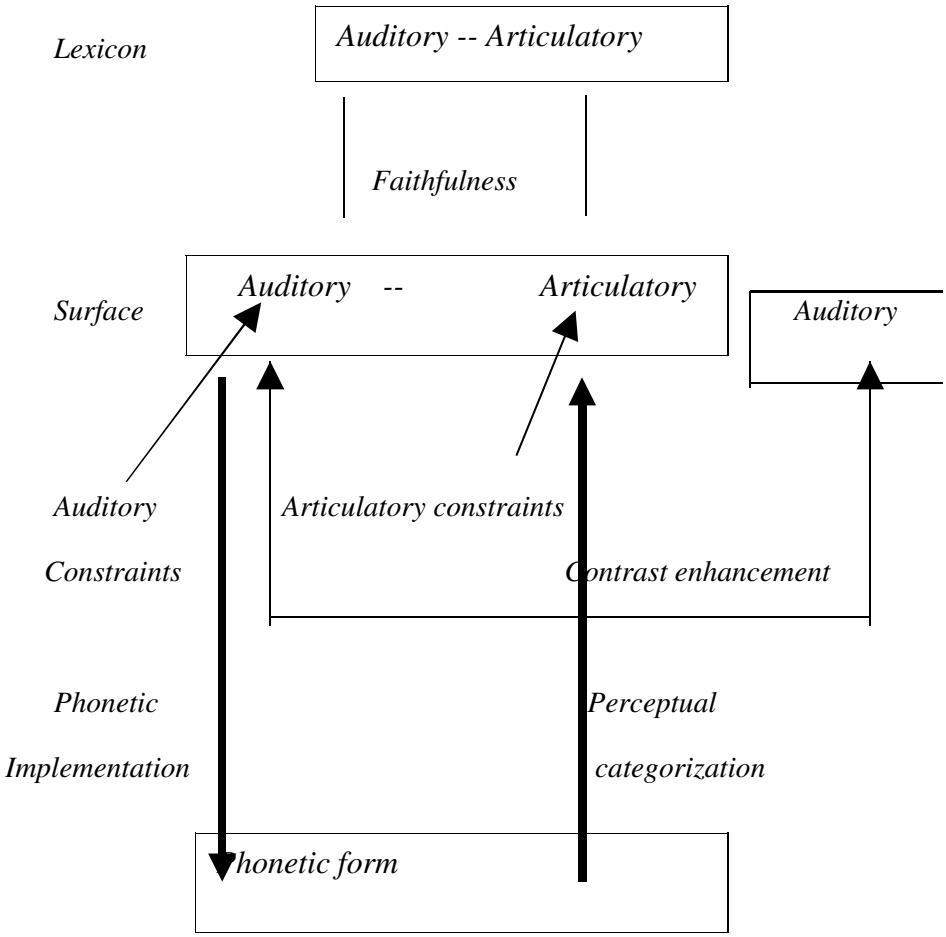
To summarize, if we want to adopt a functional approach, we have to admit that certain phenomena are governed by auditory needs, thus, the formal constraints to express them have to refer to auditory/perceptually grounded features.

3. Theoretical assumptions

*In section 2 arguments have been presented for the presence of auditory representations in phonology. On the other hand, it is clear that things happen in phonology for articulatory reasons, and thus, we need to assume that both the underlying and the surface representations include articulatory and auditory information (features and information about their mutual relations). In (11) a model that is assumed in here is schematized[4]. Between the underlying and surface representations, faithfulness relationships hold in the sense of OT – the only difference being that we have to distinguish between faithfulness in terms of articulatory and those in terms of auditory features. The surface auditory representation is evaluated by the auditory constraints favoring the sequences resulting in maximal perceptual distinctiveness. Here, some OCP effects can be aptly accounted for. For instance, a constraint on sequence *ji would be motivated by the fact that [j] and [i] are to close perceptually and are not likely to be perceived as two segments. The articulatory constraints evaluate the surface articulatory representations in terms of articulatory ease. Finally, another family of constraints, Contrast Enhancement family, is proposed here and a case of its application will be described at lengh in the second part of the article. The idea is that any user of a language is also evaluating auditory representations standing in paradigmatic relations to each other.*

[4] *For further argumentation and the discussion of the architecture of the model: Ćavar (in progress)*

(11)



The surface phonological representation is phonetically implemented, producing phonetic form, a string of non-categorical acoustic signal.

All the abstract features and representations I am talking about are phonetically grounded, that is they have either articulatory or auditory correlates.

As soon as we adopt a functionalist view, it is necessary to consider ways of formalizing the functional principles in (10). Functional principle of minimization of articulatory effort can be expressed by constraints on the surface articulatory representation. In case of the principle of minimal confusion, or, the issue of the emergence of contrast, however, there is some disagreement. In the following, the approaches of Flemming (1995) and Boersma (1998) will be scrutinized.

4. The approach of Flemming (1995)

Flemming evaluates contrasts through constraints on inventories. He refers to two functional principles of:

(A) maximizing the number of contrasts, and

(B) maximizing the auditory distinctiveness between contrasting elements.

According to (A), inventories with bigger number of members are more optimal (because, for example, they can pass over more information within a unit of time). It is expressed in Flemming by a family of Maintain Contrast constraints. According to (B), all members of a given contrast need to perceptually differ from each other to the maximal extent, by means of the maximal number of perceptual features, which is achieved by Minimal Distance constraints.

Flemming's example was an evaluation of a vocalic inventory in terms of one only perceptual dimension, that of the value of F1.[5]

(12) Perceptual features (F1 dimension) of vowels in Flemming (1995:15)

F1 dimension	***i***	ɪ	***e***		***a***
Lowest F1	+	-	-	-	-
Low F1	+	+	-	-	-
High F1	-	-	-	+	+
Highest F1	-	-	-	-	+

Assuming the featural make-up as in (12), consider the constraint ranking in (13). The inventory with just two members [i – a] fails on Maintain 2 Contrasts, and the winner is the inventory of three members, which not only keeps sufficient number of contrasts but also, unlike the remaining candidate, does maintain enough perceptual distance between its members.

(13) Evaluation of vowel inventory; high ranked Maintain 2 Contrasts. (Flemming, 1995:22)

	Maintain 1 F1 contrast	***MinDist F1 = 2***	***Maintain 2 F1 contrasts***	***MinDist F1 = 3***	***Maintain 3 F1 contrasts***
i – e – a				**	*
i – a			*!		
i – ɪ – e – a		*!*		***	

[5] *The value of F1 is a correlate of the vowel height.*

If we exchange the ranking of Maintain 2 Contrasts and MinDist 3 (tableau 14), the winner from (13) fatally violates MinDist 3, and the inventory with just two vowels turns out to be the optimal.

(14) Evaluation of vowel inventory; high ranked MinDist F1 = 3 (Flemming, 1995:23)

	Maintain 1 F1 contrast	***Mindist F1 = 2***	***Mindist F1 = 3***	***Maintain 2 F1 contrasts***	***Maintain 3 F1 contrasts***
i – e – a			*!*		*
i – a				*	*
i – i – e – a		*!*	***		

An evaluation of inventories of consonants is admittedly much more complex, as we have to refer to many different phonetic dimensions that are crucial for the perception of the contrast. Let us make an attempt to generate an inventory contrasting palatalized versus non-palatalized segments. I assume palatalization is a perceptual dimension which can be marked by different perceptual features, see (15):

(15) Perceptual features of palatalization

[PAL] - higher F2 and F3 transitions like in palatalized segments,

[VEL] - relatively lowered F2 and F3 like in velarized segments,

[FRICTION] – burst of noise characteristic of affricates and fricatives

Below, the evaluation of the inventory of Polish non-fricative obstruents follows. The symbols in the candidate column stand for the pair of representations: articulatory and perceptual. The assumed feature values are given in (16).

(16)

		t	*t^j*	*t^ɣ*	*t͡ɕ*	*t͡ʂ*	*t͡ʂ^j*	*k*	*k^j = c*	*k^ɣ*
Articulatory features		*Cor*	*Cor*	*Cor*	*Cor*	*Cor*	*Cor*	*Vel*	*Vel*	*Vel*
Auditory features	*PAL*		+		+		+		+	
	VEL			+						+
	FRICTION				+	+	+			

For the evaluation in tableau (18), constraints which are defined in (17) are relevant.

(17) Constraints:

Maintain X Pal Contrasts – maintain X contrasts within palatal dimension

MinDist X Cues – the minimal perceptual distance between members of the contrast on the particular dimension is equal or bigger than X

**Velarization – articulatory constraint militating against secondary velarization on segments*

The objective is to maintain as many contrasts as possible, however, the contrasts should be also marked by as many cues as possible. Candidate (b) in (18) corresponds to the Russian inventory and is excluded in Polish by the articulatory constraint on velarization. Candidates (a) and (c) are eliminated by MinDist 2 Pal Cues: in (a) alveolar [t] and its palatalized counterpart differ only in one feature namely in [PAL], in (c) the effects of palatalization of coronals and of velars ([t͡ɕ] and [t͡ʂʲ]) are too similar. The last candidate neutralizes the difference between palatalized members of the inventory altogether and falls off on Maintain 3 Pal Contrasts.

(18) The emergence of palatality contrasts

	Maintain 1 Pal Contrast; Maintain 2 Pal Contrasts	***Maintain 3 Pal Contrasts***	***MinDist 2 Pal Cues***	****Velarization***
(a) t – tʲ – tʃ – k			**!*	
(b) tˠ – tʲ – tʃ – k				**!*
(c) t – tʃ – tʃʲ – k			**!*	
☞ ***(d) t – tʃ – k***				
(e) t – tʃʲ – k		**!*		

This approach seems to work, yet it appears to be problematic for some reasons. Boersma (1998: 360ff) criticizes Flemming's approach for adding an extra module of phonology: inventory grammar where constraints operate which are not applicable elsewhere in phonology. He also remarks that: "[i]nventory grammars (…) do not explain how a random input is filtered into a well-formed utterance." You need to evoke an additional mechanism to establish a relationship between the possible candidates, generated by the general phonological module, and the winning inventory. Yet another problem for this approach appears to be the fact that the availability of a given member of the inventory depends in fact on the context (see Kirschner, 1997). For instance, within one language, the inventory of sounds appearing in onsets is different from the inventory of segments word-finally.

5. Boersma (1998)

Boersma implements the underlying contrast through faithfulness constraints; the underlying forms are rendered most faithfully on the surface, thus the underlying contrast has good chances to emerge on the surface as well.

Let us consider again the same palatalization contrast in Polish. The crucial constraint here is :

IdentPercPl – faithfulness constraint operating between underlying and surface perceptual representations.

(19) Emergence of the palatal contrast in Boersma's approach

ti – ta – ki - ka	***IdentPercPl***
☞***(a) ti – ta – ki - ka***	
(b) tʲi – tˆa – tʃˇʲi - kˋa	**!*
(c) tʃzi – ta – tʃˇ - ka	** !*

The most faithful candidate is not the one that in fact surfaces. The surfacing candidates are not the faithful ones, yet the contrast is preserved, or even enhanced. The underlying (and also the historical) contrast has relied on one cue – namely formant transition. In modern Polish, the surface terms contrast relies on formant transitions and affrication (candidate c), in Russian the contrast is enhanced by extreme difference in formant transitions between palatalized and velarized segments (candidate b).

Faithfulness to the underlying representation alone does not cope with cases of cue enhancement.

6. An alternative

The proposal here is to evaluate the contrast between surface perceptual representations, the difference to Flemming's proposal being the fact he evaluates inventories of segments and I propose to evaluate the contrast between pairs/triples of words that could potentially be confused. The proposed constraints evaluating the contrast between the surface perceptual representations are in a way similar to well-known Output-Output constraints, yet their effect is reverse. The most similar representations are disfavored.

The best candidates have to be, on the one hand, maximally distinct from each other, on the other hand, relatively most faithful to the underlying representations and the corresponding articulatory representations have to be most economic in terms of effort. The winning candidate is the one that can best reconcile the three driving forces. In tableau (21) following constraints are of relevance:

(20) PlAgr – articulatory constraint inducing place assimilation between front vowel and the adjacent consonant in the onset

IdentArtPl – faithfulness constraint on the articulatory representations

Maintain X Pal Contrasts – maintain X contrasts within the palatal dimension[6]

Mindist X Pal Cues – the minimal perceptual distance between corresponding members of contrast within the palatal dimension is equal or bigger than x[7]*.*

*In (21) the faithful candidate (a) does not satisfy the Place Agreement. Candidates (b) and (e) are eliminated by MinDist 2 Pal Cues: in (b) it is the difference between palatalized and non-palatalized members of the set that is too small, in (e) it is the difference between the palatalized members of the set themselves that is critical. Candidate (c) is excluded by *Velarize constraint, and the last candidate (f) does not satisfy Maintain 3 Contrasts.*

The winning contrast set obeys PlAgr and maintains maximal number of contrasts that are distinct enough.

(21) Palatal contrast – an alternative proposal

ti – ta – ki – ka	***PlAgr***	***Maintain 3 Contrasts***	***MinDist 2 Pal Cues***	****Velarization***	***IdentArtPl***
(a) ti – ta – ki – ka	**!**		**		
(b) tʲi – ta – ci – ka			**!**		
(c) tʲi – tˠa – tʃʲi - kˠa				**!**	
☞***(d) tʲzi – ta – t͡ʃ – ka***					**

[6] *Adopted from Flemming but applied to surface representations of lexical items and not to the inventories.*

[7] *As above*

(e) tʲʑi – ta – tʲʂʲi – ka			*!		
(f) tʲʂʲi – ta – ka		*!			

The proposed solution is devoid of the faults of the other proposals. The constraints are integrate part of the phonology module of grammar, and the role of context is not overlooked.

There is one more outstanding problem. Consider the underlying set of contrasts as in the previous example [ti – ta – ki – ka] in (22): it is not only set [t͡ɕi – ta – t͡ʂʲi – ka] that is optimal given the constraints above, where /ti/ surfaces as [t͡ɕi] with a prepalatal, and /ki/ surfaces as [t͡ʂʲi] with a post-alveolar. The constraints above do not exclude a surface set of contrasts, where /ti/ would surface as [t͡ʂ] with a post-alveolar, and /ki/ would surface as [t͡ɕi] with a prepalatal.

(22)

UR	***ti***	***ta***	***ki***	***ka***
☞ ***SR***	*t͡ɕi*	*ta*	*t͡ʂʲi*	*ka*
☜ ***SR***	*t͡ʂʲi*	*ta*	*t͡ɕi*	*ka*

However, the alternating pairs are fixed, and the hypothesis is that this happens due to the relative perceptual similarity between the alternating segments: [t͡ʂ] is supposed to be more similar to [k] than to [t], and [t͡ɕ] – more similar to [t] than to [k], and the similarity between the representations is to be expressed by a faithfulness in terms of some perceptual feature (This way we come back to the proposal of Boersma). This claim will be checked experimentally (Ćavar and Hamann, in preparation).

7. Conclusions

The goal of this paper was twofold. First, I have argued for the existence and relevance of auditory representations in phonology. The second goal was to take a closer look at the mechanisms ruling the emergence of contrasts. The alternatives have been closer examined and applied to the Polish data and the conclusion is that the surface contrast emerges as a result of the interplay of many factors, first, constraints reducing articulatory effort, second, constraints favoring large perceptual

differences between different contrasting segments, and third, as hypothesized, constraints on the perceptual faithfulness to the underlying representation.

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