Palatalization in Polish

An Interaction of Articulatory and Perceptual Factors

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ERKLÄRUNG

Hiermit erkläre ich, Małgorzata Ewa Ćavar, dass ich die folgende Arbeit vollkomen selbstständig und ohne Hilfe Anderer verfasst habe. Alle verwendeten Hilfsmittel und Quellen sind aufgeführt und entsprechend gekennzeichnet.

Die vorliegende Arbeit wurde an keiner anderen Universität eingereicht. Sie wurde weder von einer anderen Universität angenommen noch abgelehnt.

Bloomington, Indiana, den 10.11.2003

(Małgorzata Ewa Ćavar)

DEUTSCHE ZUSAMMENFASSUNG

Palatalization in Polish: An Interaction of Articulatory and Perceptual Factors

Palatalisation im Polnischen: Eine Interaktion artikulatorischer und perzeptueller Faktoren

In der vorliegenden Dissertation werden Palatalisierungsphänomene im Polnischen untersucht. Die Hauptthese ist, dass Palatalisierung ein durch artikulatorische und auditive Faktoren verursachtes Phänomen ist. Genau genommen wird eine funktionale Perspektive eingenommen, ausgehend von der Annahme, dass Sprache durch zwei generelle Tendenzen geprägt wird. Erstens, die Tendenz zur Minimalisierung des Aufwands beim Sprecher, d. h. die Aussprache und der Sprechaufwand sollten reduziert werden. Zweitens, die Tendenz zur Minimalisierung des Aufwands beim Hörer, d. h. die distinktiven Merkmale der lautlichen Elemente in einer Sprache sollten maximiert werden. Aus dieser Perspektive errscheint Palatalisierung als optimales Resultat der lautlichen Realisierung sprachlicher Ausdrücke auf phonologischer Ebene. In dieser Dissertation werden verschiedene artikulatorische und perzeptuelle (auditive) Faktoren bei der Palatalisierung am Beispiel des Polnischen identifiziert. Des weiteren wird ein erklärungsadäquater Ansatz für Palatalisierungsprozesse im Polnischen ausgearbeitet, der die Zusammenhänge zwischen den einzelnen Prozessen (wie sie in der phonologischen Literatur beschrieben wurden) neu beleuchtet. Dabei werden adäquate Methoden für die Analyse entsprechender Phänomene ausgearbeitet.

Kapitel 1 zeigt die Notwendigkeit einer phonologischer Analyse insbesondere für das Phänomen der Palatalisierung auf, unter Einbeziehung der Perzeption. In Kapitel 1 werden die Hauptannahmen dieser Dissertation formuliert und die funktionelle Perspektive eingeführt.

In Kapitel 2 wird ein Model der Interaktion artikulatorischer und auditiver Faktoren in der Phonologie dargestellt. Die in dieser Dissertation verwendeten Beschränkungen, Prinzipien und Merkmale (mit Akzent auf perzeptuelle Merkmale) werden definiert. In diesem Kapitel wird weiterhin das sogenannte “Derived Environment” diskutiert. Die alte Definition von “Derived Environment” konnte nicht ohne weiteres direkt übernommen werden, da sie sich auf den Begriff der “Derivation” bezieht, der im klassischen “Main-Stream” der Optimalitätstheorie OT keinen Platz mehr hat. Um die Idee auszudrücken, dass die Anwendung einiger phonologischer Regeln auf morphologische Grenzen beschränkt, oder an die Anwendung anderer Regeln gebunden ist, wurden in der phonologischen Literatur bereits einige Lösungen vorgeschlagen. Eine Lösung schlägt spezielle “Faithfulness Constraints” (Treue-Beschränkungen) vor, die sich auf den Stamm beziehen – aber nicht auf ein Suffix, und die universell höher in der Beschränkungshierarchie stehen als die allgemeinen “Faithfulness Constraints”. So kann zwischen Konsonanten im Stamm und Konsonanten im Suffix unterschieden werden, aber nicht, wie im Polnischen notwendig, zwischen Stamm-internen und Stamm-finalen Konsonanten. Daher ist dieses formale Mittel nicht hilfreich in der Analyse von “Derived-Environment” Phenomänen im Polnischen.

In der OT-Literatur wurde weiterhin vorgeschlagen, die Umgebung der Morphemgrenze mittels “Local Conjunction” von Beschränkungen zu definieren, die Palatalisierung hervorrufen, und sog. “Allignment Constraints”, die verlangen daß der rechte Rand des Stamms mit dem rechten Rand einer Silbe korrespondiert (Łubowicz, 1998). In Kapitel 2 werden einige Probleme angesprochen, die im Zusammenhang mit diesem Ansatz diskutiert werden. In Kapitel 6 werden die Daten diskutiert, die dieser Ansatz nicht erklären kann. In Kapitel 2 wird eine Analyse vorgeschlagen, die auschliesslich die Relationen zwischen Oberflächenrepräsentationen ausnutzt, ohne sich auf die zugrundeliegenden Repräsentationen zu beziehen. Dabei wird zwischen paradigmatisch alternierenden und uniformen Umgebungen unterschieden. Es wird angenommen, dass einige Palatalizierungsprozesse im Polnischen nur in paradigmatisch alternierenden Umgebungen auftreten, d. h. da, wo man die Alternationen (von den relevanten Reihenfolge der Laute) zwischen Formen in einem Paradigma auf der Oberfläche feststellen kann. Diese Analyse ist mehr funktional in dem Sinne, dass sie eine Erklärung in externen Faktoren zu finden versucht, d. h. z. B. in generellen Lernstrategien. Die vorgeschlagene Analyse weist nicht die mit vorherigen Ansätzen verbundenen Probleme auf, und, wie in Kapitel 6 gezeigt wird, deckt sie auch die Daten ab, die in der Analyse von z. B. Łubowicz unabhängig analysiert werden müssten.

Kapitel 3 beschreibt die Fakten, die für die weitere Diskussion notwendig sind. Die Alternationen im Polnischen, die als Palatalisierung gelten, werden aufgelistet. Die Phonetik der Laute, die in Palatalsierungsalternationen vorkommen, werden diskutiert – aus einer artikulatorischen Perspektive, anhand früherer Studien von Koneczna und Zawadowski, Wierzchowska, Biedrzycki, und anderen, wie auch aus einer akustischer Perspektive heraus. Die akustische Beschreibung basiert teilweise auf früheren Studien, teilweise entspricht sie den Resultaten eigener Messungen. Aufgrund der phonetischen Beschreibungen wird für ein konkret zugrundeliegendes Inventar von Lauten im Polnischen aurgumentiert und das Merkmalsinventar derselben spezifiziert. Die phonetischen Messungen begründen die Spezifikation der Segmente durch perzeptuelle Merkmale, die für die polnischen Laute nie vorher vorgeschlagen wurden. Zusätzlich werden einige Behauptungen zur artikulatorischen Spezifikation gemacht, die im Gegensatz zu früherenen Annahmen von z. B. Rubach (1984) stehen. Z. B. wird angenommen, dass der polnische Vokal, der als [ɨ] transkribiert wird, ein vorderer (Coronal[-anterior]) Vokal ist. Es stellts sich jedoch heraus, dass, aufgrund der phonetischen Beschreibung und entgegen vorheriger Annahmen, dieser Laut ein hinterer Vokal ist. [l] war von Rubach (1984) als [+anterior] spezifiziert worden. Bei genauerer Betrachtung ergibt sich jedoch, dass es sich um einen Laut handelt, der hinter dem alveolaren Kante artikuliert wird, d. h. der Laut sollte als [–anterior] spezifiziert sein. In der artikulatorischen Beschreibung der polnischen Laute wurde in der vorliegenden Arbeit besondere Aufmerksamkeit dem bis jetzt nicht betrachteten Kriterium der Position der Zungenwurzel geschenkt. Die Spezifizierung der Position der Zungenwurzel bei Lauten erlaubt einerseits die Unterscheidung von zwei Gruppen von Palatalizierungsprozessen, die bislang immer einheitlich behandelt wurden (die eine Gruppe wird durch perzeptuelle Faktoren bedingt, die andere durch ATR Merkmale). Andererseits erlaubt sie eine generelle Analyse von mehreren, bislang als beziehungslos bzw. nicht zusammenhängend analysierten Prozessen, die sich auf ATR-Agreement beziehen (s. Kapitel 6).

In der vorliegenden Dissertation werden alle "Outputs" (Generierungen bzw. Ausgaben) von Palatalisierung als Effekte von zwei Hauptprozessen betrachtet. Im Kapitel 4 wird Palatalisierung als Effekt der Verlängerung des perzeptuellen Merkmals [+Pal] diskutiert. Diese Gruppe der Palatalisierungsprozesse kommt an Morphemgrenzen vor, und – im Kontext von den gleichen Morphemen, unabhängig von der Artikulationsstelle des "Targets" (Ziel). In dieser Gruppe der Palatalisierungsprozesse (Coronal Palatalization, First Velar Palatalization und Labial Palatalization) kommen grobe Veränderungen in der Artikulationsstelle für koronale and velare Laute vor, d. h. Einfügen von [j] nach Labialen. Die These ist, dass der Kern des Prozesses "Spreading" des Merkmals [+Pal] ist. Dies hat den Vorteil, dass die Distinktion in der Dimension "Palatalität" deutlicher gemacht werden kann. Diese Distinktion kann sowohl durch Einfügen der Friktion (wie in Coronal and Velar Palatalization), wie durch Einfügen des Segments [j] nach den Labialen verstärkt werden. Das Nichtvorkommen von Palatalizierung der Labiale in einer Umgebung von palatalisierenden Vokalen, wird durch eine Beschränkung erklärt, die sich auf die Perzeptabilität der Merkmale (Cues) für Palatalizierung bezieht. Weiterhin kommt kein Einfügen von [j] und keine sekundäre Palatalizierung von Labialen vor einer Pause oder vor einem anderen Kosonant vor, weil in diesen Positionen keine Vokaltransitionen zu hören sind und die Perzeptabilität der Merkmale (Cues) für Palatalisierung zu niedrig ist. [j] -Einfügung kommt auch nur vor [e] vor, nicht vor [i], weil [j] vor [i] nicht ausreichend distinktiv ist und nicht dem Zweck dienen kann, den Palatalisierungskontrast auf dem Konsonant zu verstärken.

Die Palatalisierungsprozesse sind generel auf verschiedene Weise durch artikulatorische und auditive Faktoren beschränkt. Das ist im Folgenden zusammengefaßt:

1. Der “Output” von Palatalisierung muss treu zu den perzeptuellen Merkmallen der zugrundeliegender Repräsentation sein.

2. Die perzeptuellen Veränderungen müssen aus artikulatorischer Sicht von Vorteil sein (d. h. perzeptuelle Palatalisierung verursacht auch artikulatorische Harmonie).

3. Der zugrundeliegende Kontrast muss auf der Oberfäche erhalten bleiben. Dieser Faktor verbietet die Verschmelzung (Merging) von “Outputs” von Palatalisierung von Labialen, Koronalen und Velaren im Polnischen.

4. Der “Output” der perzeptuellen Palatalisierung muss die generel höcher gestuften Beschränkungen erfüllen, z. B. Markiertheitsbeschränkungen in der jeweiligen Sprache. In dieser Dissertation wird behauptet, dass die Effekte der perzeptuellen Palatalisierung die Bedinung von [ATR]-Harmonie erfüllen müssen.

Die andere Gruppe der Prozesse, die sekundäre Palatalisierung von Konsonanten und Modifikation der Qualität der Vokale nach palatalisierten Lauten beinhaltet, wird in Kapitel 6 diskutiert. In diesen Prozessen werden nur kleine Veränderungen der Artikulation im Vergleich zur zugrundeliegenden Form vorgenommen. Meistens sind die perzeptuellen Modifikationen auch insignifikant. Die artikulatorischen Effekte können der Bedingung für ATR-Harmonie zugeschrieben werden, und im Fall von velaren Konsonanten – zusätzlich der Bedingung von Place-Harmonie. Dadurch, dass zwischen zwei Gruppen von Palatalisierungsprozessen unterschieden wird (perzeptuellbedingte Palatalisierung, und die hauptsächlich ATR-bedingte Palatalisierung), finden mehrere früher als unabhängig betrachtete Prozesse eine gemeisame Erklärung. Die Analyse bezieht sich auf generelle “Cooccurrence Constraints”, die von Beschränkungen der ATR-Harmonie hervorgerufen werden:

(1) Agr (C, V)(ATR)

Die Beschränkungen vom Typ (1), die sich auf velare Plosive oder auf alternierende Umgebungen beschränken, sind höherwertig, als die allgemeinen ATR-Harmonie Beschränkungen. Sie produzieren ein Netzwerk von Effekten, die im Detail in Kapitel 6 beschrieben und analysiert werden. Die Hierarchie (Ranking) von spezifischeren Beschränkungen in Relation zu allgemeineren Beschränkungen ist extern motiviert, durch die relative Schwierigkeit der Artikulation und die relative Salienz der wahrgenohmenen Sprache.

Die Vorteile der Vorgeschlagenen Analyse werden in Kapitel 5 anhand der Zusammenfassung früherer Theorien der Palatalizierung diskutiert. Keine der früheren Arbeiten zur Palatalizierung im Polnischen hat die perzeptuellen Faktoren in Betracht gezogen. Sie konnten auch keine explanatorische Analyse anbieten. Die vorherigen Ansätze konnten nicht erklären, wodurch determiniert wird, welche artikulatorischen Angleichungen möglich sind, und welche nicht – in dieser Dissertation wird dies durch durch die perzeptuelle Ähnlichkeit zwischen dem "Output" und dem "Input" erklärt. Die früheren Ansätze haben die Assibilation (Affrication), wenn überhaupt, dann nur vage und nicht formal erlärt. In der vorliegenden Dissertation wird Assibilation als Mittel betrachtet, das der Verstärkung der "Palatalität"-Distinktivität dient. In bisherigen Analysen ist es nicht klar warum im Kontext von vorderen Vokalen drei verschiedene Serien von "Outputs" vorkommen, unteschiedlich für Labiale, Koronale und Velare. Wenn nur die artikulatorischen Faktoren im Spel wären, würde man erwarten, dass der optimale "Output" immer maximal dem Auslöser (Trigger) ähneln sollte. In der vorliegenden Arbeit wird diese Frage durch Erhaltung des Kontrasts beantwortet: der zugrundeliegende Kontrast zwischen Koronalen, Labialen und Velaren muss auf der Oberfläche zum Ausdruck kommen. Schließlich können bisherige Analysen nicht erklären, warum und wann Prepalatale and Postalveolare überhaupt vorkommen können. In dieser Dissertation biete ich eine Antwort an, die sich auf optimale Oberflächekontraste bezieht.

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GLOSSARY OF PALATALIZATION

- **Palatalization** – phonetically, phonologically and morphologically – all kinds of alternation of consonants in the context of front vowels.
- **Coronal Palatalization** – 1. earlier accounts: rule targeting [+anterior] coronals, cf. e. g. Rubach (1984); 2. here: the palatalization of coronal sounds; no claim is made that it is a separate process from 1st Velar and from Labial Palatalization.
- **1st Velar Palatalization** – 1. earlier accounts: rule targeting velar consonants exclusively, and turning them into post-alveolar sounds; 2. here: the palatalization of velar consonants. Compare Coronal Palatalization and Labial Palatalization.
- **Labial Palatalization** – 1. earlier accounts: rule targeting labial consonants; 2. here: the palatalization of labial consonants. Compare Coronal Palatalization and 1st Velar Palatalization.
- **Iotation** – historical palatalization before [j], the reflexes of which are present in Modern Polish.
- **2nd Velar Palatalization** – historical palatalization of velar consonants, the reflexes of which ([ts], [dz]) are present in Modern Polish.
- **Secondary palatalization** – in phonology and phonetics – raising of the tongue towards the hard palate.
- **Palatalization with the change of the major place of articulation** = Coronalization.
- **Coronalization** – alternation between non-coronal and coronal (usually non-anterior) sounds triggered by the context of front vowels.
- **Palatal sounds** – pronounced with the major constriction at the hard palate.

- **Prepalatal sounds** – pronounced with the major constriction in the prepalatal area.
- **Palatality** – here: dimension of contrast in terms of perceptual features like [high F2/F3], [low F2/F3], [Friction] or perceptual feature [Pal], as defined in chapter 2, section 2.3.2.
- **[Pal], [Palatal]** – here: perceptual feature cued by combination of sub-features [high F2/F3], [highest F2/F3], [Friction], as defined in chapter 2.
- **PALATALIZATION, PAL** – here: constraint effecting in spreading of perceptual [Pal], as defined in chapter 2, section 2.8.1.

SELECTED IPA SYMBOLS VERSUS POLISH ORTHOGRAPHY

IPA	**Symbols used (if not IPA)**	**Polish orthography**
p^{j}		pi
b^{j}		bi
f^{j}		fi
v		w
v^{j}		wi
m^{j}		mi
w		ł
t^{j}		ti
d^{j}		di
s^{j}		si
z^{j}		zi
t͡s	ts	ts
d͡z	dz	dz
t͡s^{j}	ts^{j}	c
d͡z^{j}	dz^{j}	dzi
l^{ɣ}		ł
l		l
t͡ɕ	tɕ	ć, ci
d͡ʑ	dʑ	dź, dzi
ɕ		ś, si
ʑ		ź, zi
ɲ		ń, ni
t͡ʂ	tš	cz
d͡ʐ	dž	dż
ʂ	š	sz
ʐ	ž	ż, rz
t͡ʂ^{j}	tš^{j}	czi

IPA	Symbols used (if not IPA)	Polish orthography
$\widehat{\text{dʐ}}^{\text{j}}$	dž$^{\text{j}}$	dżi
ʂ$^{\text{j}}$	š$^{\text{j}}$	szi
ʐ$^{\text{j}}$	ž$^{\text{j}}$	żi
c		ki
ɟ		gi
ç		chi
x		ch, h
i		i
ɨ		y
e		e
ɛ		e
ɜ̃		ę
ɔ̃		ą
u		u, ó

Transcribing Convention

In general, parts of words are transcribed (and put in square brackets) which are relevant to the analysis. The remaining parts of the words are spelt according to Polish orthography, unless the original spelling is confusing, e. g. in the case of orthographic "w" which is pronounced in Polish always as IPA [v]. Notice that the Polish orthographic "y" corresponds to IPA [ɨ].

ABBREVIATIONS

adj.	adjective
dat.	dative case
dim.	dimunitive
fem.	feminine
inf.	infinitive verb
loc.	locative case
nom.	nominative case
pl.	plural
pres.	present tense
ptc.	participle
sg.	singular

CONTENTS

Chapter 1

THE POINT OF DEPARTURE

1.1 Introduction

Phonological theory of the eighties and nineties was dominated by an approach which was seriously articulatory biased, in the sense that explanations for linguistic phenomena were reduced to articulatory-driven aspects, whereas the role or influence of the listener on the structure of a language as well as perceptual factors in generall were disregarded. As Parker-Rhodes (1978) notes, our civilization is a civilization of speakers, i. e. it is important to produce, express and articulate.

> The skillful speaker wins praise; the skillful listener, despite the mystery of his achievement, is ignored.
> (Parker-Rhodes, 1978, xiii).

This global approach in society might be reflected in the way topics of interest are selected in research. Another factor might be based on the obvious difficulty of conducting research which focuses on perception. Whereas we may directly observe what happens with the articulators, and we have ways to describe our findings without referring to meta-language, what we hear remains unavailable to direct scrutiny. Whereas articulation may be – literally – touched, audition can be approached only with instruments, via introspection or with complex experimental settings, which makes both the description and the understanding of perception much more difficult. Only in recent years have the necessary techniques and instruments been developed which allow some insights into speech from the listener's perspective. A new approach to phonology, one which employs the findings of the research on acoustics of speech and speech perception, seems to be necessary, cf. research by Steriade, e. g. (1995a) and (2001), Flemming (1995) and (2002), Ohala, e. g. (1981) and (1992), Jun (1995), Boersma (1998), Guion (1998), Padgett (2001a) and (2001b), and many others.

1.2 Goals and Organization

The aim of the present study is to identify various articulatory and perceptual factors in phonology and to show their interaction on the example of a common phonological phenomenon within the system of one language. The phenomenon discussed in this dissertation is palatalization and the term is used here to refer to any alternation in a consonant triggered by the vicinity of the front vowel.

It seems plausible that if language is spoken in order to be perceived and understood, then the shape of a language depends on both the articulatory mechanisms as well as on the mechanisms responsible for the reception of the acoustic signal. Thus, the study of any phonological phenomenon should involve articulatory and perceptual factors.

The thesis of this study is that palatalization is an effect of the interaction of four tendencies:

1. The tendency to prolong the duration of the perceptual feature to make it (more) perceptible.

2. The tendency to assimilate the articulation of a consonant to the vowel, thereby reducing the articulatory effort.

3. The tendency to keep the surface realizations perceptually faithful enough to the underlying perceptual representation, which constraints the possible assimilation of both articulatory and auditory type (i. e. 1-2).

4. The tendency to optimize the contrasts between segments, that is, to achieve maximal distinctions between contrasting segments.

It is important that the study is focused on one particular language, taking into account the details of phonetics (articulation and acoustics) and morpho-phonology (e. g. classification of sounds of a language based on their phonological behavior in the particular language, the richness of the inventory of contrasts, and the resulting distribution of segments in the perceptual space). The attempt is to offer an account of palatalization which is in accordance with, and is a logical consequence of the whole system of the language.

It seems that many earlier approaches aiming to provide a general cross-linguistic theory of palatalization necessarily had to disregard the fine interaction of palatalization with other factors responsible for the ultimate shape of the language. While working on these issues it became clear that the phonological accounts of palatalization processes discussed earlier in the literature are in many cases difficult to verify for the lack of proper phonetic (articulatory and acoustic) description. In this study, the attempt is to offer an account of palatalization based on the proper phonetic description. It is possible that some conclusions from this investigation of palatalization in Polish may be generalized to other languages, though it is not the goal of this study to provide a general theory of palatalization.

This dissertation is organized as follows. Chapter 1 concludes with background information about Polish. Section 1.3 provides a short overview of palatalization processes in Polish. The reader familiar with the data is encouraged to proceed directly to section 1.4. where earlier approaches are summarized. The basic conclusion of this part is that previous accounts leave a number of questions unanswered and that existing phonological frameworks do not provide the necessary tools to solve these problems. The claim is that we cannot answer the remaining questions if we do not take into account the effects connected with the perception of palatalization. In section 1.5, I review the results of research pointing to the parallels between the phonological generalizations regarding palatalization and some acoustic regularities. This leads us to the conclusion that we need to incorporate mechanisms referring to perception into our theory, which will allow us to provide a better account of palatalization processes discussed earlier. Chapter 2 offers a framework with integrated perceptually (auditory) grounded features, where Optimality Theory - type of constraints may refer to both articulatory and auditory representations (Optimality Theory: henceforth OT; [Prince and Smolensky, 1993]). Apart from definitions of auditory features, and the resulting new typology of perceptually and articulatory based constraints, chapter 2 contains a new solution to the derived-environment problem. In chapter 3 the phonetic properties of Polish sounds involved in palatalization processes are discussed to prepare the ground for claims about the particular featural specifications of sound strings. In chapter 4 an analysis of major palatalization processes will be offered, in terms of the interaction of tendencies 1, 3 and 4, as mentioned earlier. Chapter 5 is devoted to the effects of articulatory type: it is argued that the articulatory feature that is active in palatalization processes in Polish is [+ATR]. Chapter 6 summarizes the results of the discussion.

1.3 Basic Information about Polish

Polish contrasts following surface vowels (Rubach, 1984):[1]

(1) Surface inventory of vowels in Polish

High:	i	ɨ	u
Mid:	e		o
Low:		a	

Additionally, two underlying phonemes are assumed in Rubach (1984), a front yer, and a back yer, which both surface as a front mid vowel. Earlier analyses of palatalization presented in the following section assume the inventory of vowels in (1) above, and it is also adopted in this dissertation (though I make different claims about the featural make-up of Polish phonemes). The topic is discussed in more detail in chapter 3.

As to the consonantal inventory of Polish, it is clear that Polish contrasts plain and palatalized series of sounds, where palatalized does not always mean secondarily phonetically palatalized but rather contrasting with the plain counterpart:

(2) Surface inventory of consonantal phonemes in Polish

Place	Labial	Anterior	Post-alveolar	Prepalatal	Palatal	Velar
Plosive	p b	t d				k g
Fricative	f v	s z	š ž	ɕ ʑ		x
Affricate		ts dz	tš dž	tɕ dʑ		
Nasal	m	n		ɲ		
Lateral		l				
Rhotic		r				
Glides	w				j	

In general, the inventory in (2) corresponds to underlying contrasts and the set of phonemes has been adopted in this dissertation (though the featural make-up of the segments might be different from the classical views, given the perceptual features proposed in this dissertation).

In the literature on Polish, a number of palatalization processes are described. They will be reviewed below (the division and names of processes is based on Rubach (1984)), and summarized in table (3). The names of palatalization processes come from the target groups of sounds. The outputs of palatalization differ depending on the input. Basically, anterior coronals

[1] Additionally, there is some discussion about the status of the high central vowel and nasalized vowels.

are palatalized to prepalatals [ɕ, ʑ, tɕ, dʑ, ɲ], velars – to post-alveolars [š, ž, tš, dž], and labials – to secondary palatalized labials [p^j, b^j, f^j, v^j, m^j], respectively. Liquids ([l] and [r]), usually assumed to be coronal [+anterior] and to be a part of Coronal Palatalization, alternate with [w] and [ž] respectively.

(3) Palatalization in Polish

a. First Velar Palatalization

krok 'step'	kro[tš] + ek dimun.
	wy+ kro[tš]+ y + ć 'to step out of limits'
mózg 'brain'	móž[dž] + ek dimun.
	wy + móž[dž]+ y + ć 'to stupify'
mu[x]+a 'fly'	mu[š] + ek gen. pl.
	od + mu[š] + y + ć 'to eliminate flies'

b. Coronal Palatalization

rat + a 'instalment'	ra[tɕ] + e dat.
rad + a 'advice'	ra[dʑ] + e dat.
ras + a 'rase'	ra[ɕ] + e dat.
zaraz + a 'plague'	zara[ʑ] + e dat.
ran + a 'wound'	ra[ɲ] + e dat.
bu[w] + a 'bread roll', augm.	bu[l] + e dat.
kur + a 'hen'	ku[ž] + e dat.

c. Labial Palatalization

grup + a 'group'	gru[p^j(j)] + e dat
ryb + a 'fish'	ry[b^j(j)] + e dat
raf + a 'riff'	ra[f^j(j)] + e dat
mo[v] + a 'speech'	mo[v^j(j)] + e dat
mam + a 'mom'	ma[m^j(j)] + e dat

d. Surface Velar Palatalization

krok 'step'	kro[c] + em instr.
wróg 'enemy'	wro[ɟ] + em instr.

e. Surface Palatalization

[t^j]inktura 'potion'
[d^j]iva 'diva'
[s^j]inus 'sinus'
[z^j]imbabwe 'Zimbabwe'
[$tš^j$]ile 'Chile'

The alternations in (3) may be summarized as below:

(4) Palatalization processes in Polish

Alternation	Input in surface terms	Output	Phonological trigger	Morphological condition
Coronal Palatalization	s z t d n w [ł] r	ɕ ʑ tɕ dʑ ɲ l ž	i (exceptionless in surface terms), front mid vowel (surface-terms exceptions); sometimes surface ɨ is a trigger of palatalization to [ž], but never – to prepalatals. Earlier analysis: underlying front vowel.	Across morpheme boundary
1st Velar Palatalization	k g x	tš dž/ž š	Surface terms: before some [ɨ], and some mid front vowels. Earlier analysis: underlying front vowels of vowel-initial suffixes which usu. trigger also palatalization on dentals and labials	Across morpheme boundary
Labial Palatalization	p b f v m	p^j(j) b^j(j) f^j(j) v^j(j) m^j(j)	i (to secondary palatalized sounds), front mid vowel irregularly (surface-terms exceptions), never before ɨ, ɛ. Earlier analysis: underlyin front vowels	Across morpheme boundary
Surface Palatalization	All consonants	Secondarily palatalized segments (n becomes a prepalatal)	i, j	Everywhere, also across word boundary
Surface Velar Palatalization	k g	c ɟ	Surface i, e (underlying: ɨ and non-palatalizing –e); For the fricative – only high front vowel environment	Across morpheme boundary

Some other alternations, i.e. Affricate Palatalization (Rubach, 1984), 2nd Velar Palatalization (Rubach, 1984) and (Szpyra, 1995), and Iotation (Rubach, 2001) are not discussed in this dissertation.

In the following sections earlier accounts of palatalization processes in Polish will be summarized.

1.4 Earlier Approaches to Palatalization: Comparison

The following section presents earlier analyses of Polish palatalization. While rule-based approaches tried to encompass the whole spectrum of alternations, later approaches, especially OT, usually focused on a smaller selection of processes.

Perhaps it goes without saying that all of the presented analyses have their pluses, and that they were answers to problems proposed at a particular time and given a particular progress of the theory. The goal here is, however, not to evaluate any of them but to identify the questions that we can ask given our perspective. Thus, I focus deliberately and exclusively on the aspects of the analyses which, from the perspective of the current developments in the theory, might be seen as not sufficiently explanatory.

1.4.1 Approach within the Framework of Lexical Phonology

Within the framework of Lexical Phonology, a complete analysis of the Polish data concerning palatalization was offered by Rubach (1984).[2]

Let us turn first to the alternations of anterior coronal sounds, as repeated below:

(5) Coronal Palatalization

rat + a 'instalment'	ra[tɕ] + e dat.
rad + a 'advice'	ra[dʑ] + e dat.
ras + a 'rase'	ra[ɕ] + e dat.
zaraz + a 'plague'	zara[ʑ]+ e dat.
ran + a 'wound'	ra[ɲ] + e dat.
bu[w] + a 'bread roll', augm.	bu[l] + e dat.
kur + a 'hen'	ku[ž] + e dat.

Rubach (1984) assumes that the surface [w] is underlyingly a velarized coronal lateral and accounts for the data in (5) by the rule of Coronal Palatalization as below:

(6) Coronal Palatalization (Rubach, 1984, 243)
[+anterior, +coronal, −del release, α obstr] →
[−back, +distr, +high, −anter, α strid] / ___ [−cons, −back]

The rule in (6) takes anterior coronals (to the exclusion of affricates), that is, [t, d, s, z, n, r, underlying $l^{ɣ}$] to non-anterior, palatalized laminals, i.e. [t^j, d^j, s^j, z^j, n^j, r^j], in the context of a front vowel. By α-convention, obstruents become strident; that is, underlying dental stops surface as affricates, and sonorants remain non-strident.

Coronal Palatalization in (6) is clearly an assimilation process in terms of feature [−back]: the consonant assumes [−back] in the context of [−back] vowel. However, the way the rule is formulated does not provide an explanation as to:

1. why only anterior sounds may palatalize,
2. why affricate dentals are excluded from palatalization,
3. why there is a shift to the non-anterior place of articulation in the context of a vowel which is simply [−back],

[2] Earlier approaches in early generative and cyclic phonology framework, e.g.: Steele (1973), Gussmann (1978).

4. why the output has to be distributed.

Further, another question is related to the connection between the value for [obstruent] of the input with the value of [strident] of the output. The linking of the value of the feature obstruent in the input with the value strident in the output, though phonetically justified and logical, theoretically is arbitrary. Thus, the problem is not particular to the analysis, but addresses the assumptions about features generally assumed at the time the analysis was offered. This problem can be solved within the framework of feature geometry (see next section), which sought to design a geometry describing all and only the possible groupings of features. From the phonetic point of view, it is clear that if a sound is an obstruent, it may be affricated, and if a sound is not an obstruent, then affrication is impossible. Yet, why should there be affrication of the obstruents at all in the context of a front vowel?[3]

Further, the rule in (6) aims to target liquids as well as obstruents: the postulated underlying /$l^{ɣ}$/ (surface [w]) and the rhotic. However, as formulated in (6), it does not generate surface realizations of liquids: liquids after the application of (6) are secondarily palatalized and non-anterior (e. g. l^j and r^j), whereas the surface realizations are dental [l] for the lateral (and only before surface [i]–[l^j], where the secondary palatalization may be attributed to Surface Palatalization), and a fricative voiced [ž] for the rhotic. Thus, further spell-outs (7)–(8) have to be postulated to derive surface liquids:

(7) Liquid spell-out (Rubach, 1984)
[−anterior, +sonorant, +cons, −nas, α continuant] →
[−high, −α anterior]

Liquid spell-out (7) interprets liquid outputs of Coronal Palatalization as non-palatalized ([−high]) on the surface and adjusts the place of articulation of the lateral ([−continuant]) to [+anterior], and – of the rhotic ([+continuant]) – to non-anterior. Thus, the lateral output of (6), that is [l] ([−anter, −back, +high, +distr, −strident]), becomes by the rule in (7) surface non-palatalized anterior [l]. The rhotic output of Coronal Palatalization in (6), that is r[−anter,−back, +high, +distr, −strident], loses secondary palatalization and becomes r[−anterior].

Further, an additional r-spell-out (8) applies after the liquid spell-out, changing the depalatalized rhotic to the anterior place of articulation before a consonant or otherwise turning it into a fricative.

[3] For the feature geometric answer, see e. g. Padgett (1995).

(8) r-spell-out
$[+\text{son}, +\text{cons}, -\text{anter}, -\text{high}] \rightarrow [+\text{anter}] \;/\; \underline{\quad}\ \text{C}$
or
$[+\text{obstr}]$

The rule in (8) renders the resulting from (7) non-palatalized non-anterior rhotics as voiced fricatives. If the rhotic should be followed by another consonant, it should not be changed to a fricative, but fronted to [+anterior] place of articulation.[4] The liquid spell-outs undo the articulatory assimilatory effect of (6) for liquids. Whereas the series of rules (6)–(8) derives the surface facts, it does not provide a full explanation. When seen in surface terms, the whole alternation for liquids is arbitrary.

1st Velar Palatalization is formalized in Rubach (1984), as in (9):

(9) 1st Velar Palatalization
$[+\text{obstruent}, -\text{coronal}, +\text{high}] \rightarrow$
$[-\text{high}, +\text{coronal}, +\text{strident}] \;/\; \underline{\quad}\ [-\text{cons}, -\text{back}]$

The rule in (9) targets velars (velars are assumed to be all [+high]) and changes them to non-palatalized post-alveolar affricates and fricatives (stops alternate with affricates, fricatives retain their manner of articulation). As stated in (9), the rule delivers the correct surface output form without any further spell-outs and modifications. However, as it stands, unlike the rule of Coronal Palatalization in (6), it is not an assimilation but rather an arbitrary change. It states that velar stops in the context of front vowels become coronal affricates. We could ask these questions now: why do only velars change, why only in the context of front vowels, and why are they not secondarily palatalized?

For labials, Rubach (1984) distinguishes between the environment before [i] and the environment before [e]. Before [i], the secondary palatalization of labials is derived by a late allophonic-type rule of Surface Palatalization (10):

(10) Surface Palatalization (Rubach, 1984, 246)
$[+\text{cons}] \rightarrow [+\text{high}, -\text{back}] \;/\; \underline{\quad}\ ([-\text{seg}])\ [-\text{cons}, +\text{high}, -\text{back}]$

By rule (10), any consonant before [i] or [j] will be secondarily palatalized,

[4] The data for which the second part of the spell-out have been proposed are forms like:
i. star+y 'old' sta[ž]+ɛts 'old man' sta[r+ts]a 'old man', gen. sg.
In sta[r+ts]a the palatalization is blocked. I do not discuss these data because I could not find a synchronic rationale for the blocking of palatalization to [ž] before a consonant, analogue to the mechanism proposed for blocking of palatalization in labials, see chapter 4. These data are, however, discussed by Rochoń (2000).

irrespective of the morpheme- or word boundary ([−seg] notation in the rule). It is an example of an assimilation in terms of features [+high, −back].

Further, for [e]-context, Rubach assumes that the front vowel [e] triggers j-insertion, which in turn causes surface palatalization of the preceding consonant, see (11).

(11) Labial j insertion (Rubach, 1984, 169)
$\emptyset \rightarrow$ j / [+lab] ___ [+syll, −high, −back]

The rule in (11) produces the insertion of a [+high, −back] consonant before a [−high] vowel. These questions arise:

1. why j-insertion applies only after labials,
2. why there should be segment insertion instead of assimilation of the preceding consonant,
3. why high vowels have to be excluded as a trigger when the inserted segment is [+high].

The derivation would proceed as in (12):

(12) The derivation of *chłopi* 'peasants' Nom.Pl. and *chłopie* 'peasant', Loc. Sg.

p+i	p+e	UR
–	pj+e	j-lab insertion
p^j+i	p^jj+e	Surface Palatalization

The alternative would be to assume (secondary) palatalization of the consonant with the subsequent j-insertion. The latter solution is dismissed by Rubach, because in the lexical approach the necessary cost would be to postulate a depalatalization rule for the cases like the ones in (13a):

(13) Derivation of *chłopski* 'peasant, adj.' versus *chłopie* 'peasant' Loc. Sg.

a. Analysis with palatalization and depalatalization

chłopski	*chłopie*	
p+ĭsk	p+e	UR
p^j+ĭsk	p^j+e	Pal.
p^j+sk	p^j+e	Yer deletion
p+sk	p^j+e	Depalatalization
–	p^jj+e	j-lab. insertion

b. Analysis with j-lab insertion (adopted by Rubach)

p+ĭsk	p+e	UR
–	pj+e	j-lab insertion
p+sk	pj+e	Yer deletion
p+sk	p^jj+e	Surface Palatalization

As we see, the derivation in (13a) would require a rule "undoing" the effects of the earlier ordered rule, and the derivation in (13b) is simply less complex. However, this is only true, if the statement of j-insertion excludes /i/ and front yer as a possible trigger, as stated in (14):

(14) j-lab insertion (Rubach, 1984, 169)
$\emptyset \rightarrow$ j / [+lab] ___ [+syll, −high, −back]

The high front vowel has to be excluded as a potential trigger because otherwise, in cases like *chłopski* above, we would have to postulate a rule of j-deletion, e. g.:

(15) *chłopski* derivation (high front vowel not excluded from j-lab insertion)

p+ĭsk	p+e	UR
pj+sk	pj+e	j-lab insertion
pj+sk	pj+e	Yer deletion
p+sk	pj+e	j-deletion
pj+sk	p^jj+e	Surface Palatalization

Whereas j-deletion of [j] flanked by obstruents seems reasonable (for the sake of Sonority Sequencing Generalization), the argument that the analysis is simpler is no longer valid. Additionally, Rubach (1984) did not take into account the surface realizations of the discussed sequences without [j], which according to the pronunciation dictionary by Karaś and Madejowa (1977) are also correct in some versions of Polish. For these realizations, one would need j-deletion even if we accepted that the only trigger of palatalization on labials is /e/ to the exclusion of high front vowels. Thus, we are left without any argument for the j-lab insertion and against direct palatalization of labials.

Summary of the analysis in Rubach (1984)

Both Coronal Palatalization (with respect to obstruents) and Surface Palatalization are, in Rubach's approach (1984), assimilations of consonants to the fronted and raised position of the tongue, as in the articulation of the subsequent vowel. 1st Velar Palatalization is, however, an arbitrary change, and j-insertion after labials is also only partly motivated (because of excluding the high vowel [i] as a trigger). The surface alternation between [w] and [l] is arbitrary, and the necessary spell-outs for liquids have to undo the effects of Coronal Palatalization. The change of stops to affricates in the approach discussed above is not externally motivated, either.

In the Lexical Phonology approach presented above, it is not clear why the effect of a front segment onto consonants varies depending on the place of articulation of the segment. If it were simply an articulatory assimilation, the obvious effect should be in all cases a secondarily palatalized consonant; that is, assuming the specification of a front vowel as [−back], all consonants should turn [−back]. This scenario does not correspond to the facts. An alternative answer will be provided in chapter 4.

On the other hand, Lexical Phonology deals successfully with the fact that most of the Polish palatalization processes apply in the derived environment only by offering a theory internal rationale.

1.4.2 Feature Geometric Approaches

Within the framework of Feature Geometry (Sagey (1986), McCarthy (1988), Clements (1985)), it has been acknowledged that palatalization is an articulatory assimilation and the formalism should express this insight. Four major types of analyses of palatalization were proposed, depending on the theories of the featural make-up of front vowels. Palatalization was treated as the spreading of vocalic specification of

1. Dorsal [−back],
2. Coronal [−anterior],
3. spreading of [+high], or
4. spreading of the Place node including its dependents.

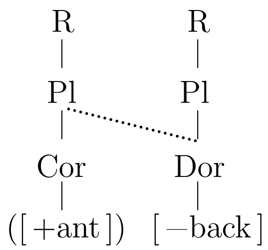
Each of these approaches is problematic from our current perspective. The approaches (1) and (2) necessarily have to posit intermediary stages (are not output-oriented), and further spell-outs different for each input place of articulation, as will be shown in detail below. Further, approach (1), assuming that front vowels are Dorsal, predicts rather the changes of consonants to velar articulation in the context of front vowels, instead to coronal, contrary to facts, cf. Clements (1985), Hume (1992), Clements and Hume (1995)), as discussed in more detail below. Proposal (3) makes wrong predictions about the possible palatalization processes. Finally, approaches treating palatalization as an articulatory assimilation to front vowels which contain more complex specification may account for the data. However, they still leave a number of questions unanswered, which are problematic for all purely articulatory approaches to features in general: the distinction between the possible and impossible articulatory assimilations, the emergence of affrication, and the different outputs of palatalization when the trigger is always the same.

Spreading of Dorsal [−back]

Sagey (1986) assumed that all vowels are Dorsal, and proposed a feature geometry where front vowels were [−back], and the feature [−back] – realized by the tongue back – is a dependent of the Dorsal node. She analyzed palatalization in Kinyarwanda, Zoque and Pame, where plain consonants are alternating with secondarily palatalized counterparts or change their articulation to palatalized velars.

When we apply the solution proposed in Sagey (1986) to the Polish data, we would arrive only at some intermediary stage, similar to the analysis of Coronal Palatalization proposed by Rubach (1984). Spreading of the feature [−back] from the front vowel to the Place node of the coronal consonant would result in secondary palatalized dentals (Ćavar, 1997) as in (16):

(16) Coronal palatalization: spreading of [−back]



R=Root, Pl=Place

The result of spreading in (16) is an anterior (dental or alveolar), secondary palatalized consonant, whereas the surface output is prepalatal ([−anterior]). The surface output (prepalatals, liquids) is crucially created by the further spell-out rules, similar to the analysis by Rubach. First, the spell-out for coronals must change [+anterior] to [−anterior] in the consonant with the vocalic feature [−back]. Additionally, [strident] or any feature effecting affrication needs to be added. The spell-outs would be summarized as follows:

(17) t^{j}, d^{j}, s^{j}, z^{j}, n^{j}, l^{j}, r^{j} → tɕ, dʑ, ɕ, ʑ, ɲ, l, ž

Spell-outs in general might be reasonable from the phonetic (articulatory and motoric) perspective (e. g. addition of stridency in non-anterior area), yet they illustrate a theoretical problem: if, for example, [strident] is not spread but inserted, how does phonology know what can and what cannot be inserted? Spell-outs are not limited by the universal feature tree. Theory of feature geometry does not possess means to make a distinction between possible and impossible spell-outs. In other words, if we accept spell-outs in general, there is nothing in the theory to stop anybody from postulating a spell-out like, for example, in (18):

(18) $[+\text{strident}] \rightarrow [+\text{round}]$ / ___ $[+\text{nasal}]$

Notice that the major reason to propose the geometry of features was originally to constrain the set of possible and impossible feature groupings. Accepting spell-out is a weakening of the explanatory power of the theory.[5] In contrast, the model proposed in chapter 2 assumes that violations of faithfulness with respect to underlying representations are motivated externally.

Another problematic issue will be clear when we consider the data of 1st Velar Palatalization, cf. Clements (1985), Hume (1992), Clements and Hume (1995) and many others for the argumentation on the basis of non-Polish data. In Polish, velars alternate with post-alveolars [tš, dž, š]. If we assume that front vowels are Dorsal [−back], then the change of dorsal sounds in the context of a dorsal vowel to coronal sounds is unmotivated. Even if we say that Dorsal [−back] denotes only a secondary articulation, then the resulting set of sounds should be something like palatalized velars [c ɟ ç], but the facts are different.

If we assume that palatalization is a spreading of Dorsal [−back], we cannot explain the change of the major place of articulation to coronal. The burden of the explanation of the facts lies on the spell-outs, whereas the spreading of Dorsal [−back] derives abstract intermediary stages.

Other problems concerning all earlier approaches will be discussed at the end of the chapter (section 1.4.3).

Palatalization as Spreading of Coronal

Hume's approach (1992) differs from that of Sagey in that Hume assumes, following Clements (1985), that front vowels are coronal. This assumption is motivated by two factors. First the articulatory facts: front vowels are pronounced with the raising of the front of the tongue towards the hard palate; the relevant constriction is produced by the tongue front and not by the tongue back (Hume (1992), Clements and Hume (1995)). In the case

[5] In this case, we cannot argue that the spell-out is phonetic in nature because not all secondarily palatalized coronals are banned in Polish, e. g. *sinus*. Compare chapter 5.

of secondary palatalization on consonants (19b), it is also the tongue front which is raised towards the hard palate, in addition to the major articulation. Second, it is clear under this assumption why in many cases palatalization amounts to the change in the primary place of articulation (as opposed to the addition of the secondary articulation) to the coronal area – ranging from alveolar to palatal, see (19a):

(19) Palatalization

a. Change of the major place of articulation
k →ʧ / ___ i

b. Secondary palatalization
k → kʲ / ___ i

To say that vowels are coronal seems to be a contradiction of the assumption of Sagey (1986) and Halle (1995), who have claimed that all vowels are dorsal. All these authors refer, after all, to articulatory definitions. Who is then wrong? The seeming contradiction derives from the different definitions of articulatory correlates. Sagey and Halle refer to the active articulators, thus, front vowels are claimed to be dorsal because it is the dorsum that is producing the movement. The forward movement of the back of the tongue produces a maximal constriction in the back of the coronal area, and this place of maximal constriction is claimed to be relevant by Hume (1992) and by Clements and Hume (1995).

The Clements/Hume model distinguishes between the two levels where place features may be located. C-Place (Consonantal Place) is a node at which consonantal place features are specified, and V-Place (Vocalic Place) hosts vocalic place (quality) features. In vowels, C-Pl is always empty, whereas V-Pl in consonants is the place of location for the secondary articulation features, compare (20) below. Such a structure seeks to reconcile two contradictory observations – that vowels and consonants have to be separated as far as place specification is concerned because consonants usually do not block vowel harmony, and, on the other hand, the observation that vowels and consonants do share place features in certain processes, of which palatalization is one example.

Hume (1992) briefly discusses Polish non-anterior sounds. She assumes, following Halle and Stevens (1989), that prepalatals are palatalized versions of post-alveolars. Thus, post-alveolars and prepalatals are distinguished in Hume's (1992) approach by the presence or absence of the vocalic place node, see (20).[6] The prepalatals are [coronal, −anterior] and contain additionally a vocalic place node containing additional [coronal, −anterior] specification, as in (20b). Third, the palatalization processes with the change of the major place of articulation to [coronal, −anterior] are analyzed as a spreading of [coronal, −anterior] of the vowel with the change of the status of constriction (from the dependent of the vocalic place node to the dependent of the consonantal place node), as in (20c), and secondary palatalization – the same without the change of the status of constriction (20d). Under these assumptions, Polish processes may be represented as in (20c-d):

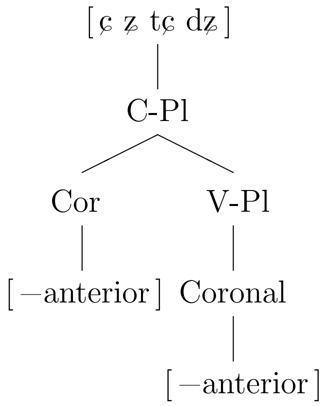
(20) The analysis of palatalization processes as spreading of Coronal
C=consonant, V=vowel, C-Pl=consonantal place, V-Pl=vocalic place

a. The representation of Polish sounds [š ž tš dž]

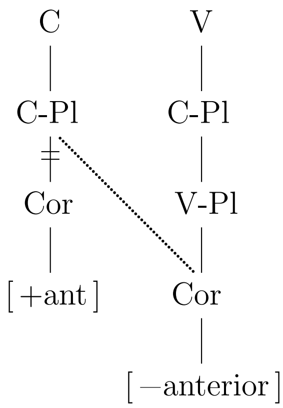
```
[ š ž tš dž ]
      |
    C-Pl
      |
     Cor
      |
 [ −anterior ]
```

[6] Hume (Hume, 1992, 93) assumes further, following Halle and Stevens (1989), that Polish sounds (which in this study are referred to by symbols [š ž tš dž]) are palato-alveolars; that is they are [+coronal, −anterior, +distributed]. However, post-alveolars are in fact [-distributed], compare chapter 3. Hume (1992) discusses also allophonic secondarily palatalized post-alveolars [$š^j$ $ž^j$ $tš^j$ $dž^j$]. To distinguish them from prepalatals (because both series would be [+distributed], and both would contain Vocalic Place, feature [+round] specifies additionally post-alveolars in this account. Whereas I agree with the claim that plain post-alveolars are articulated with lip roounding, I cannot confirm that this is also true for secondarily palatalized post-alveolars. Palatalization processes are not discussed directly in Hume (1992). Since features [distributed] and [round] in the specification of post-alveolars do not play a role in the two major processes discussed here (Coronal Palatalization and Velar Palatalization), they are omitted in the representations in (i).

b. The representation of Polish prepalatals

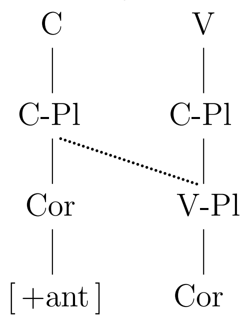


c. Palatalization with the change of the major place of articulation



Change of the constriction status: yes

d. Secondary palatalization



Change of the constriction status: no

If we apply the proposal of Hume to the Polish data, Labial Palatalization will be basically interpreted (leaving aside the question of j-insertion) as an instance of (20d), and 1st Velar Palatalization – as a spreading with the change of the status of the constriction, (20c). However, if we assume the feature specification of prepalatals in (20b) then we have no way to derive them from dentals by application of either (20c) or (20d) within one step.

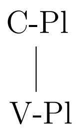
If we adopt a feature promotion analysis deriving an intermediary stage of secondarily palatalized consonants with the original ([+anterior]) place specification, Hume's model faces the same problem as Sagey's proposal, and the motivations for the place shift remain unclear within this theoretical framework.

Palatalization as a spreading of [+high]

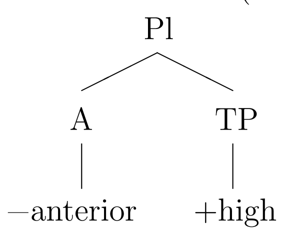
Lahiri and Evers (1991) adopt a representation where the only possible relation between place features in one segment is that of sisterhood, as in the Halle/Sagey approach (and unlike in Clements and Hume (1995)), and assume that front vowels are coronal [−anterior], following Clements (1985).

(21) The relation between multiple place specifications
C-Pl = Consonantal Place, V-Pl = Vocalic Place, Pl = Place, A = Articulators, TP = Tongue Position

a. Clements and Hume (1995)



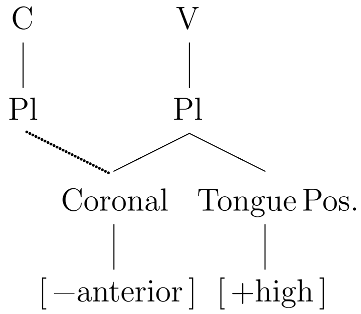
b. Lahiri and Evers (1991)



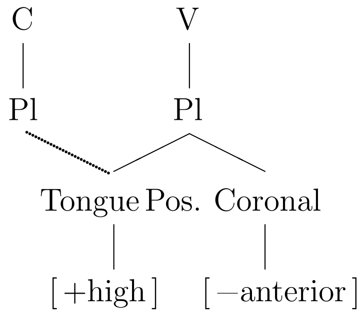
The possible variation in the output of spreading of front vowel features (post-alveolar or prepalatal) is in their approach a consequence of the claim that the palatalizing vowel is Coronal [−anterior] and [+high], where [+high] is a dependent of the Tongue Position node. When Coronal node spreads onto the consonant, the result is the coronalization of the consonant, i. e. shift of the major articulation place to coronal [−anterior], as in (22a). The spreading of [+high] onto the consonant is responsible in Lahiri and Evers proposal for secondary palatalization as in (22b).

(22) Palatalization adopting Lahiri and Evers (1991)

a. Consonants become cor[−anterior]:
C → tš / ___ i

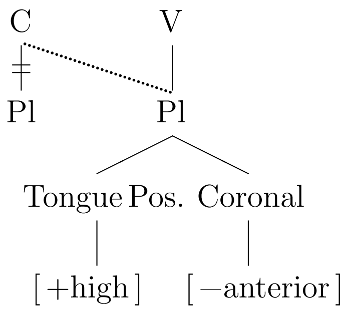


b. Secondary Palatalization as spreading of [+high]:
C → C^j / ___ i



Although Lahiri and Evers do not discuss Polish data, let us try to adopt their ideas to Polish. 1st Velar Palatalization may be accounted for as a spreading of [−anterior], as in (22a), and Labial Palatalization can be accounted for by (22b) (with some phonetic spell-out inserting j). Coronal Palatalization in Polish might be analyzed in this approach as a spreading of the whole Place, as in (23).

(23) Coronal Palatalization



The result of the spreading of the whole Place node, with all the features arrayed underneath, is a [−anterior] coronal sound, phonetically soft, that is, secondarily palatalized.

This way, we avoid the intermediary stage of secondarily palatalized alveolars, and the analysis is substantially less complex than that in the approach à la Sagey or Hume, as illustrated in previous sections, where the vowels are equipped with just one place specification feature. However, the output of the palatalization of liquids still needs extra spell-outs.

The model by Lahiri and Evers predicts the three types of palatalization as observed in Polish. However, it predicts also that only high vowels may trigger secondary palatalization. It is difficult to defend the claim that, in languages where /e/s trigger secondary palatalization, the relevant /e/-s are all [+high]. It is probably not the case in Polish, where a mid vowel triggers palatalization of labials. In Russian, a mid front vowel triggers regular secondary palatalization of all consonants. Also, there are languages where a front low vowel triggers secondary palatalization, cf. Bhat (1978).

On the other hand, high back vowels should also be able to produce secondary palatalization but never coronalization, unless, again, we argue that back vowels in these languages are underlyingly front, that is, in this formalism Coronal, and for this reason may trigger coronalization. To support the claim that high back vowels may trigger palatalization, Lahiri and Evers cite the phenomenon from Japanese where there is an affrication of consonants in the adjacency of high back vowels and no change in the major place of articulation. As pointed out by Hume (1992), change to a dental affricate is, strictly speaking, not secondary palatalization. For Polish (Labial Palatalization), and other languages where only front high vowels trigger palatalization, we would have to explain why the high back vowels do not cause palatalization, in other words, we would have to distinguish between [+high] of [i] and [+high] of [u].

Finally, let us consider some other languages where a high back vowel triggers palatalization that are cited in Bhat (1978). As examples of palatalization in the context of back high vowel/glide, Bhat cites processes in Tepehuan, Basque, Proto-Iranian, and Tswana. I tried to verify the examples quoted in Bhat's study. In the study of (Southern) Tepehuan by Willett (1991), there was no mention of palatalization in the context of [u] whatsoever, and neither are there any phonemic secondarily palatalized alveolars. In Basque, as described in the monograph by Hualde (1991), the Ondarroa dialect has an alternation between dental and alveolopalatal affricates (for younger speakers) or prepalatal stop (for older speakers). In other dialects the output of palatalization is prepalatal stop for dentals. However, Hualde describes palatalization only before high front vowel [i]: palatalization effects before high back vowels or glides are not mentioned at all. It is difficult to say why the phenomena referred to by Bhat are not treated in the newer available sources. In Tswana, contrary to the predictions of Lahiri and Evers, the environment of front high vowel produces an alveolar affricate/fricative, and prepalatal affricates/fricatives, that is – coronalization with the shift to [−anterior] – in the environment of secondary labialization [^{w}]. Proto-Iranian data cannot be falsified for obvious reasons, thus, it does not constitute a convincing argument in support; we will never know for sure what quality the segments in the context of high front and back vocoids had.

In general, the cases of palatalization in the context of high back vowels/glides are either altogether difficult to verify, or might be interpreted as involving other features from [+high], or might be separate processes from those triggered by high front vowels. Thus, there is no clear evidence that we need a theoretical device to express palatalization as the spreading of [+high].

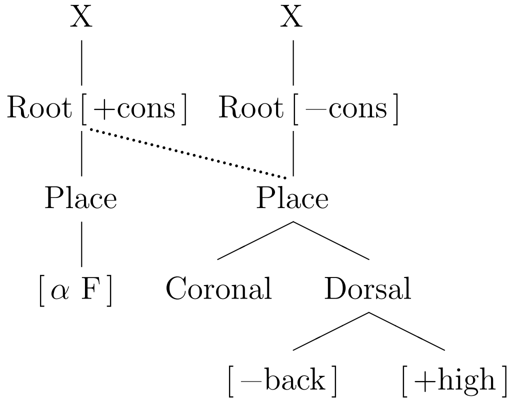
The model proposed by Lahiri and Evers (1991) would predict also that front low vowels should only be able to trigger palatalization with the change of the primary place of articulation (k → ʧ) because they do not contain [+high]. This is not always born out by the facts, cf. Bhat (1978). An example from Slavic area can be offered in addition: in Polish dialects of Masovia low front [æ] triggers secondary palatalization of the preceding consonant, (Furdal, 1955).

In sum, the proposal by Lahiri and Evers accounts for the Polish data, however, makes a number of theoretical predictions about possible types of palatalization which are not borne out cross-linguistically.

Palatalization as a multi-stage process spreading both Coronal and Dorsal [−back]

Within the framework of Feature Geometry, Polish palatalization is directly addressed by Szpyra (1995) and Szpyra-Kozłowska (2001). She analyzes palatalization as a number of multi-stage processes. First, a spreading of the whole place node of the front high vowel [i] occurs: the coronal and the dorsal nodes are spread with [−back] and [+high], see (24) below:

(24) i-Palatalization:
(adopted from Szpyra (1995) and Szpyra-Kozłowska (2001))[7]

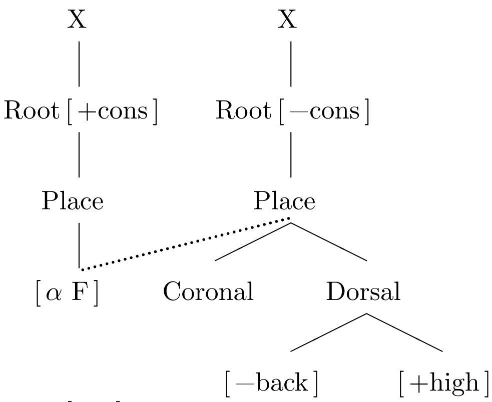


This stage produces palatalized labials [p^j b^j f^j v^j m^j], and secondary palatalized dentals [t^j d^j s^j z^j n^j l^j r^j]. Szpyra does not say it explicitly but i-palatalization must also apply to velars producing secondarily palatalized segments [c ɟ ç].[8] The second stage would be the Coronal Spell-out, introducing the specification of anteriority, of the effect as in (25).

(25) Coronal Spell-out; after Szpyra (1995)
t^j d^j s^j z^j n^j l^j r^j → ʨ ʥ ɕ ʑ ɲ l ž

Further, velars undergo feature inserting rules. 1^{st} Velar Palatalization or 2^{nd} Velar Palatalization, both triggered by the vowel containing the same set of features, produce different effects: 1^{st} Velar is illustrated in (26a) and 2^{nd}

[7] The original feature trees were as in:



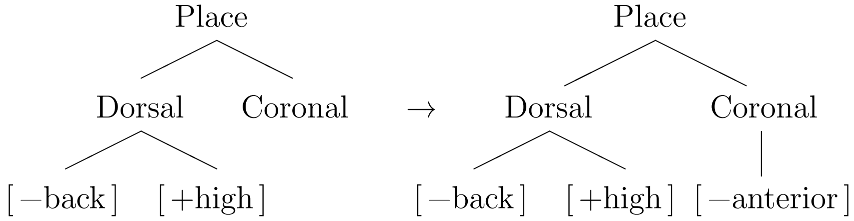
with [αF] adjoined to the Place node of the vowel, however I assume that the intention of the author was to depict assimilation as in (24).

[8] i-palatalization must apply to velars because further Szpyra proceeds by proposing velar palatalization processes described in (ii) and then she assumes already that velars are secondarily palatalized.

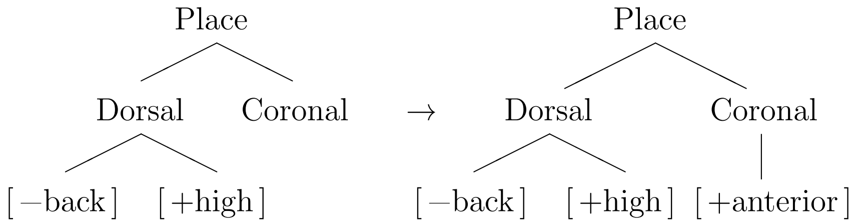
Velar in (26b):

(26) Palatalization of velars (Szpyra-Kozłowska, 2001)

a. 1st Velar Palatalization



b. 2nd Velar Palatalization



In grammatically specified contexts.

Further, the output of palatalization in (26) undergoes Coronal Spell-out for the output of velar palatalization, as in (27):

(27) Coronal Spell-out (for outputs of velar palatalization)
ts^j dz^j tš^j dž^j š^j ž^j → ts dz tš dž š ž

Szpyra discusses only the palatalization of coronals in the environment of [i]. This way her rule of Coronal Palatalization is in surface terms exceptionless. However, alternations appear in a regular fashion also in the context of a great number surface [e]-initial morphemes, to labials, dentals and velars. The suffixes starting with /e/ which trigger palatalization need then to be lexically listed. It is also possible, however, to propose a phonological approach to e-palatalization. One could assume that either the surface palatalizing /e/-s are underlyingly [+high], or that surface non-palatalizing /e/-s are underlyingly [+back].[9] In this dissertation it is argued that two kinds of mid front vowels differ in featural make-up in terms of perceptual features (see chapter 3).

In Szpyra (1995), it is assumed that,

> (. . .) palatalization is not a simple change, but rather a series

[9] For instance, Rubach (1984) assumes that non-palatalizing e-s are underlying back vowels, which, in fact, reflects historical facts.

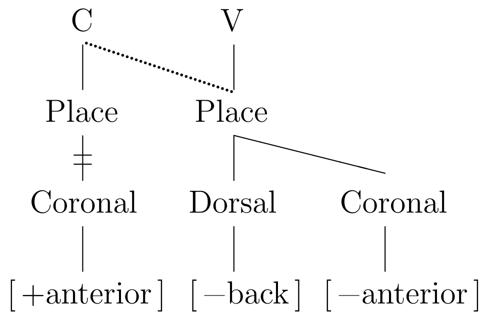
> of modifications whose immediate output has to undergo further adjustments. (Szpyra, 1995, 208)

Whereas the spreading of the features of front vowels has to be regarded as an assimilatory process, the question remains what the justification is for the further adjustments under this approach. Why is secondary palatalization on labials fine but dentals have to be shifted to prepalatals? Why do Coronal Spell-outs (25) and (27) apply to the output of palatalization but not to – in her approach (Szpyra, 1995, 173) – underlying phonemes in words like [idʲota].[10] Similar to other multi-stage approaches (Sagey (1986), Hume (1992)), it is the intermediary stage that is articulatory motivated, but it is the arbitrary (in this approach) spell-outs which deliver the surface form.

One-step Process: Spreading of Coronal[−anterior] and Dorsal[−back]

In the analysis of Polish data in Ćavar (1997), the structure of the front vowel was proposed with both Coronal and Dorsal [−back] specification. Earlier, a similar solution was postulated by Rubach (1993) for the analysis of Slovak, and by Szpyra (1995).[11] In (28), Coronal Palatalization has been accounted for by a spreading of the whole Place specification of the vowel, including Coronal [−anterior] and Dorsal [−back] specifications, and with simultaneous delinking of the original place specification of the coronal consonant. The idea is that the coronal[−anterior] specification comes from the vowel, and thus, we do not need coronal spell-out, see (28):

(28) Coronal Palatalization (Ćavar, 1997)



[10] For the detailed discussion of forms containing surface secondary palatalized coronals, see chapter 4.

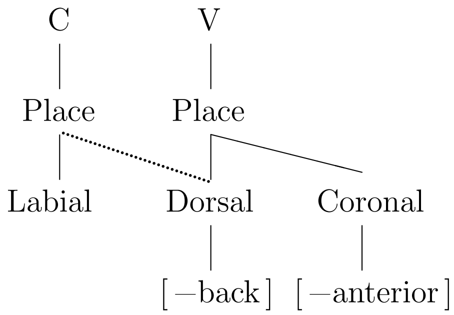
[11] Ćavar (1997) differs from Szpyra (1995) and Szpyra-Kozłowska (2001) in that in Ćavar's account [coronal] in the vowel is further specified as [−anterior].

[+high] on the consonant appears as a phonetic consequence of [−back] and is phonologically irrelevant.[12]

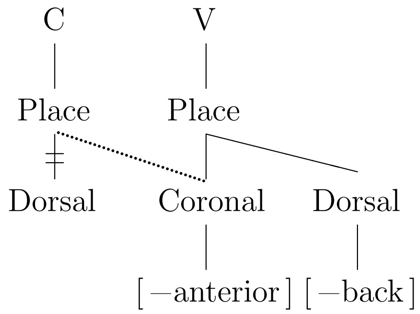
Labial Palatalization will be seen as the spreading of Dorsal [−back] alone, without the delinking of the original Labial specification of the consonant (29a), and 1st Velar Palatalization can be accounted for as the spreading of Coronal [−anterior] alone (29b).

(29) Palatalization in the model with double specification of the vowel as both Coronal and Dorsal

a. Labial palatalization



b. 1st Velar Palatalization



This approach, unlike the account in the model proposed by Sagey, or the solution by Szpyra, disposes of the intermediary stage of secondarily palatalized sounds and derives prepalatal sounds directly. Unlike the model of Lahiri and Evers (1991), it does not make wrong predictions cross-linguistically. Ćavar's approach seems to be descriptively adequate,[13] but still does not face the problems which are common to all accounts disregarding the role of perception, as will be elaborated on in section 1.4.3.

[12] Height phonetic spell-out is necessary, as well as the liquid spell-outs.

[13] It does not account for the 2nd Velar Palatalization, the effects of which have to be assumed to be lexically determined. This position is also adopted in this dissertation.

1.4.3 General Problems of Feature Geometric Accounts

Assimilation to front vowels versus assimilation to back vowels

None of the earlier discussed analyzes raises the following question: Why do only the features of a front vowel have the power to trigger assimilation? We observe in languages of the world mutation of consonants in the vicinity of front vowels, but the question arises why mutation of consonants in the context of back vowels, for instance tu → pu, are not that common.

Feature spreading, theoretically speaking, does not differentiate between the spreading of labiality from [u] onto [t], and the typical palatalization, where features of the front vowel spread onto any consonant. As will be demonstrated further, an answer to this problem can be provided if we accept the role of perception in phonology. Steriade (2001), following Lindblom et al. (1995), Kohler (1990), and Hura et al. (1992), argues that consonantal assimilation is a "perceptually tolerated articulatory simplification". In other words, possible consonantal assimilations are the ones which are acceptable from the point of view of the listener. This view may be easily extended to the cases of consonant–vowel interaction. The studies of Winitz et al. (1972), Guion (1998), e. g. Ohala (2001) show that coronal consonants are perceptually similar to consonants articulated in other places of articulation in the context of a front vowel. We will elaborate on this point in section 1.5.

Predicting the emergence of prepalatals in palatalization

In fact, it is only the models proposed by Lahiri and Evers (1991) and Ćavar (1997) that predict the possibility of the emergence of prepalatal sounds in the palatalization processes. Admittedly, prepalatals are not very common sounds cross-linguistically, but it is no coincidence that they are an effect of palatalization, as would be concluded if we accept that they are a result of a spell-out rule and not palatalization directly. It is probably also no coincidence that [ɕ] occurs in a language that also has [š] in its inventory.

In fact, palatalization to prepalatals does occur in languages other than Polish. For instance, in Swedish, a voiceless velar stop is never followed by front vowels; instead a prepalatal [ɕ] surfaces on such occasions. Interestingly, Swedish has also a very 'crowded' perceptual space for fricatives. With respect to voiceless fricatives, Swedish distinguishes between surface [f], [s], [ɕ], [ʂ], and [ɧ] (palato-velar labialized fricative) (cf. e. g. Lindblad, 1980; Ladefoged and Maddieson, 1996). In contrast, Swedish does not have sounds which are more common cross-linguistically, e. g. palato-alveolar [ʃ] and velar [x]. According to Ladefoged and Maddieson (1996), yet another language which has [ɕ] in its inventory, Standard Chinese, has an inventory similar to Polish; that is, it contrasts [f, s, š, ɕ, x] fricatives. One explanation for these facts would be in terms of optimal contrast: simple cross-linguistically common sounds are disfavored, and instead more complex articulations are preferred if there are more contrasts to be expressed.

Distinction between palatalization of different groups of consonants

If we assume that palatalization is simply an articulatory assimilation to the front vowel, we would expect that the result of such an operation would always be the same, that is, the consonant which most closely assumes the tongue position of the front vowel. A difference in the effects of palatalization on labials, coronals, and velars remains a puzzle within the Feature Geometry approach, cf. Ćavar & Hamann (2001).

Affrication

If we consider palatalization as an assimilation to the place of articulation of the front vowel, a question arises why the effects of palatalization most often surface as fricatives or affricates. This is the case in the analysis of Coronal Palatalization, also in the case for 1st Velar Palatalization, but also this generalization holds cross-linguistically, see Bhat (1978). The problem with affrication is that the emergence of affrication does not directly result from extending the vowel 'stridency feature' onto the consonant, and cannot be accounted for as spreading, but rather as a feature insertion in certain environments. Hall (p. c.) points out that there is nothing wrong about feature insertion as long as it is phonetically motivated. The question is then, providing affrication is a phonological effect, how does phonology know which feature insertion is phonetically motivated and which is not. The problem of distinguishing between possible and impossible sound changes is supposed to be the core of phonological theory, and should be formalized.

Lahiri and Evers (1991) (compare also Kim (2001)), motivated the appearance of affricates instead of stops as a side-effect of the characteristic articulation of the palatalized consonant with an off-glide [j] release:

> Coronal consonants have relatively more energy in the higher frequencies than in the lower frequencies (Lahiri *et al.* , 1984, 402). If, in addition, there is an off-glide [j] release for the [+high] palatalised coronal consonants, then there will be a greater increase in the higher frequencies, causing a concentration of energy in the high frequency range – a characteristic of strident segments. (Lahiri & Evers, 1991, 95)

This passage aptly explains the mechanics of the rise of stridency; however, it is unclear how this account should be formalized within Feature Geometry, and how acoustic properties of the sound should influence the structure of a sound without prior assuming the existence of perceptual features.

Another explanation was hinted in Lahiri and Evers (1991), this time referring to articulation. The solution would be to claim that stridency emerges because of the change to the palato-alveolar region, where the unmarked articulation of all obstruents is with stridency, cf. Lahiri and Blumstein (1984, 142). It is true that in languages of the world non-anterior obstruents tend to be affricates or fricatives. Yet, there are languages which have post-alveolar stops in their inventory (Ladefoged & Maddieson, 1996), and even Bhat (1978) quotes one example of a language where palatalization produces a prepalatal stop i. e. Acoma ((Bhat, 1978), after (Miller & Davis, 1963)). It remains unclear, then, why in some cases affrication occurs and in some others it does not.

As has been pointed out to me by Hall (p. c.), the problem may find a formal solution if we assume, following Lombardi (1990), and Sagey (1986), that affricates contain double specification for the feature [continuant]: they are both [−continuant] and [+continuant]. Affrication may be in this case considered to be a spreading of [+continuant] from the vowel.

(30) Affrication

C V

Place [−continuant] [+continuant]

However, a structural description of the rule is met also in a back vowel, yet the spreading does not occur. Low or back vowels do not seem to have the tendency to affricate adjacent stops, and it is not clear why a spreading of continuancy should be limited only to situations when the trigger is a front vowel. One cannot say, for instance, that front vowels are more continuant than back vowels. The relation between palatalization and affrication is not clear in this approach either.

This problem reappears in all feature geometric and all purely articulatory approaches to palatalization processes.

Summary of the problems of feature geometric analysis

Summing up, Feature Geometry approaches are complex multi-step solutions, where only the intermediary stage may be seen as an articulatory assimilation, and the surface realizations are derived by the application of spell-outs. Only Lahiri and Evers (1991) and Ćavar (1997) may provide an analysis of Polish data as a direct change. The two models predict that prepalatals may be the output of palatalization, whereas in other approaches they have to be derived by spell-outs. Still, the model proposed in Lahiri and Evers (1991) makes wrong predictions about possible palatalization processes cross-linguistically.

In general, Feature Geometry does not explain why there is an assimilation of the consonant to a front vowel, but other types of assimilations, for instance, to low vowels, are not to be expected, or at least are not that common. Further, Feature Geometry accounts have to treat affrication as a separate process, without explaining the regular cooccurrence of palatalization and affrication. The relation between affrication and front vowels, though convincingly motivated in terms of phonetics, is not formalized in Feature Geometry, under any approach, since we have here to do with either the rise of a certain property on the consonant as a side-effect of a spreading, and not with a spreading itself, or with a spreading of [+continuant], where some continuant sounds trigger affrication and some others do not. In Feature Geometry, adding stridency is theoretically unmotivated. The same holds for spreading of feature [continuant], where its particular relation to front vowels remains unclear. Finally, Feature Geometry analyzes do not raise the problem of the morphological environment at all.

1.4.4 Earlier Approaches in the OT Framework

The palatalization of labials and coronals

Coronal Palatalization within the framework of Optimality Theory has been analyzed by Rochoń (2000). The author argues that palatalization is triggered by a floating feature [PAL],[14] which is a lexical feature of palatalizing suffixes. This way she explains, first, why only certain suffixes trigger palatalization, second, why Coronal Palatalization does not apply morpheme-internally.

Palatalization itself is an effect of the interaction of the faithfulness constraint requiring [PAL] on the surface (31), an alignment constraint which is supposed to link the application of the alternation with the environment of the morphological boundary (32)–(33), and the constraint against secondarily palatalized dentals (34).

[14] Earlier, the floating feature analysis for Polish yers was proposed, among others by Rubach (1986), and Gussmann (1992).

(31) Max[PAL]
Every [PAL] in the input has a correspondent in the output. (Rochoń, 2000, 235)

(32) No-Intervening (ρ; E; D)
There is no material intervening between ρ (any element, e. g. a floating feature) and an edge E in domain D. (Rochoń (2000, 235), after Ellison (1995, 2) and Zoll (1996, 108))

(33) No-Intervening([PAL]; Right; Stem)
The final segment of a stem is a target of the floating feature [PAL]. (Rochoń, 2000, 235)

No-Intervening (33) is violated if some segment should intervene between the docking place of [PAL] and the edge of the stem; this way [PAL] may not dock morpheme internally. The candidate which does not realize [PAL] on the surface, thus, satisfying No-Intervening (33) vacuously, is excluded by MAX[PAL] (31).

(34) Coronal Palatalization in the account of Rochoń (2000, 236)

sus+[PAL]e	No-I([PAL]; R)	MAX[PAL]
☞ suɕe		
suse		∗!
ɕuse	∗!∗	
ɕuɕe	∗!∗	

In (34) the form [suse] is eliminated by MAX[PAL] because it does not realize the underlying [PAL] on the surface. [ɕuse] and [ɕuɕe] both realize [PAL] on the first segment, that is, there are in each case two intervening segments between the docking place of [PAL] and the right edge of the stem. The optimal [suɕe] realizes the underlying [PAL] on the consonant at the edge of the stem, thus, it does not violate either (31) or (33). Rochoń (2000) discusses the emergence of prepalatals instead of palatalized dentals only in the diachronic perspective. We could assume that the constraint which she proposed (35) holds in Polish synchronically:

(35) ∗[Cor,Pal]:
Do not have secondarily palatalized coronal.

Thus, in the example (34), a hypothetical form [sus^{j}e] would be still non-optimal.

Palatalization of rhotics

Rochoń (2000) discusses also the output of palatalization of rhotics. The surface realization of rhotics is accounted for by the interaction of articulatory constraints, as in (36), with No-Intervening (32), and faithfulness MAX[PAL] (31):

(36) Articulatory constraints on the articulation of rhotics in Polish (Rochoń, 2000, 245)

a. ∗[ř]: [ř] is prohibited.
b. ∗[ř^{j}]: [ř^{j}] is prohibited.
c. ∗[r̠^{j}]: [r̠^{j}] is prohibited.
d. ∗[r^{j}]: [r^{j}] is prohibited.
e. ∗[ž^{j}]: [ž^{j}] is prohibited.
f. ∗[ž]: [ž] is prohibited.

According to (36), surface fricative rhotic, fricative palatalized rhotics, post-alveolar palatalized rhotics, dental palatalized rhotics, as well as palatalized post-alveolar voiced fricative and non-palatalized voiced fricative are banned. Whereas (36a-e) are high-ranked, ∗[ž] is ranked below No-Intervene (33) and MAX[PAL] (31). Thus, [PAL] is realized as a change of /r/ to [ž]: MAX[PAL] is not violated, and No-Intervene is not violated, the higher ranked articulatory constraints are not violated either. In contrast, a form faithful to the input with surface [r] is eliminated by MAX[PAL].

In the present dissertation, it is also assumed that articulatory constraints ban certain possible types of articulation. However, an additional claim is made to explain why in Polish constraints against [ř], [ř^{j}], [r̠^{j}] hold absolutely, and in some other languages not: the explanation offered in chapter 4 (section 4.8.2) refers to the interaction of articulatory constraints and constraints yielding contrast preservation.

Depalatalization of labials

Rochoń (2000) accounts for the depalatalization of the underlyingly palatalized labials word-finally, cf. forms in (37):

(37) Depalatalization word-finally

pa[v] 'peacock' pa[v^{j}j]+om 'peacocks', dat.
versus
chło[p] 'peasant' chło[p]+om 'peasants', dat.

In the word pa[v^jj]+om in (37), we have to assume that the palatalization is underlying, because the regular ending of dat. pl. is -om (and not -jom). Also, the stem pa[v] behaves like a soft stem, i. e. like a stem ending with a palatalized consonant, for the sake of the choice of declentional suffixes.[15] There is a limited number of stems that behave in a similar way. Rochoń proposes an analysis of word-final depalatalization in terms of syllable: secondary palatalized labials are forbidden in the coda by constraint [∗[Lab, Pal]] & NoCoda]SEGMENT as defined in (38).

(38) Constraints in the analysis by Rochoń (2000, 187-193)

a. ∗[Lab, Pal]
Do not have palatalized labials.

b. [∗[Lab, Pal]] & NoCoda]SEGMENT
No palatalized segment in coda position.

c. IDENT[Lab,Pal]
The secondary articulation of underlying labials must be retained on the surface.

A ban on secondary palatalized labials in the coda is higher-ranked than a faithfulness constraint, and higher-ranked than a general constraint against secondary palatalized labials as in (39):

(39) Depalatalization of underlying palatalized labials

gołą/b^j/	[∗[Lab, Pal]] & NoCoda]	IDENT[Lab,Pal]	∗[Lab, Pal]
☞ gołą[p]		∗	
gołą[p^j]	∗!		∗

Forms like 'gołą[p^j]' violate the ban on secondarily palatalized labials in the coda, and a non-palatalized labial will surface. If the local conjunction[16] is not violated (because a segment is not in a coda position) secondary palatalization will surface, because faithfulness is ranked higher than the general markedness banning palatalized segments, as in (40).

(40) Surfacing of palatalized labials

/p^jasek/	[∗[Lab, Pal]] & NoCoda]	IDENT[Lab,Pal]	∗[Lab, Pal]
[p]asek		∗!	
☞ [p^j]asek			∗

[15] Soft stems select a different set of endins, e. g. soft endings take -e in nom. pl., and hard stems -i or -ɨ.

[16] Local conjunction here as defined in Smolensky (1995) and (1997).

A candidate like '[p^j]asek' in (40) does not violate the specific constraint against palatalized labials in the coda. The form without palatalization is excluded by faithfulness constraint referring to palatalization on labials.[17]

While this analysis describes the facts, it does not explain why there is a ban on a complex articulation of labials but a complex articulation of coronals is permitted, even before segments which do not agree in either voice or place, or palatality, see (41):

(41) Complex articulation on coronal sounds

prza[ɕn]y	'(of bread) unleavened'
gu[ɕ]le	'witchery', 'witch trick', dat./loc. sg.
wie[dʑ]ma	'witch'
[ʑdʑ]bło	'stalk'
Ma[tɕ]ka	'Maciek', name, gen. sg.
[dʑ]gać	'to stab'

Rochoń's account has another problematic aspect. There is a set of data in Polish where depalatalization appears although the relevant segments are in the onset. Consider the examples in (42):[18]

(42) Depalatalization in onset:

[p^jj]eń	but	[p]nia	'trunk', nom. sg./gen. sg.
[v^jj]eś	but	[f]si	'village', nom. sg./gen. sg.

Rochoń analyzes the words like in (42), as containing secondarily palatalized labials in the underlying representation. (Palatalization cannot be an effect of the process of palatalization, because it is triggered only by lexically specified set of suffixes.) To account for the surface lack of palatalization when the labial is followed by the consonant, she has to propose yet another constraint:

(43) Constraint referred to in the analysis of depalatalization in onset (Rochoń, 2000, 210)
∗[Lab,Pal]C
No palatalized labials are followed by another consonant.

∗[Lab,Pal]C is not violable in Polish. A word like [pɲa] (UR: p^jPALɲ+a, cf. another surface form [p^jjeɲ]) has to surface without palatalization because, after the yer is deleted, it is followed by a consonant. Thus, in the end, Rochoń postulates a constraint forbidding secondary palatalized in codas, and another one prohibiting them in onsets. We will come back to this

[17] j-insertion is not discussed by Rochoń (2000).
[18] [v]–[f] alternation is due to voice assimilation.

data in chapter 4, proposing one explanation for both sets of data: word-final and preconsonantal depalatalization.

Rochoń's analysis does not raise questions posed in the context of feature geometric accounts.[19] It does not touch upon the issue of affrication. It does not raise the question why front vowels trigger assimilation in the place feature in contrast to other types of possible articulatory reasonable simplifications of CV sequences, e. g. /ki/ to [ka]. Lexical [PAL] is not clearly defined and there is no external correlate of an abstract [PAL].

Palatalization of velar sounds is not discussed in Rochoń (2000), thus, we will turn to another study where the data of palatalization of velar sounds is discussed.

1st Velar Palatalization in Łubowicz (1998)

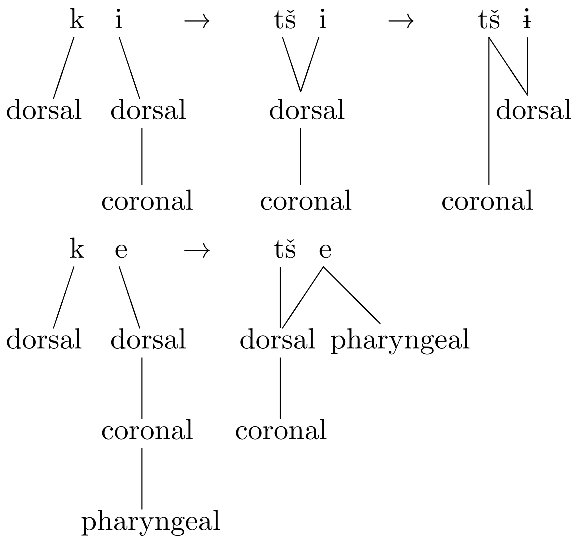
Łubowicz (1998) offers an original solution to the problems of the derived environment. Her proposal will be discussed in detail in chapter 2. On this occasion, Łubowicz discusses the data of the palatalization of velars. She analyzes 1st Velar Palatalization as a spreading of the corono-dorsal specification of the front vowel onto the neighboring consonant. In her account, [i] is dorsal and coronal, [ɨ] is dorsal, coronal and pharyngeal, as represented in (44):

(44) Feature representations of Polish segments in Łubowicz (1998, 21)
Vowel [i]: [Coronal, Dorsal]
Vowel [ɨ]: [Dorsal]
Vowel [e]: [Coronal, Dorsal, Pharyngeal]
Velar consonants: [Dorsal]
Post-alveolar consonants: [Dorsal, Coronal]

However, the spreading alone is not sufficient and the candidate satisfies constraints in an optimal way if the consonants take over the features of the vowel, i. e. if the original specification of the vowel may completely be deleted. Thus, the mapping of the underlying /ki/ to the surface [tšɨ] might be interpreted under these assumptions as shifting the coronal specification from the vowel onto the consonant, as in (45).

[19] Rochoń's study was concentrating on other aspects of Polish phonology than palatalization.

(45) Mappings in 1st Velar Palatalization (Łubowicz, 1998, 21)



The aim of the operation (45) is to delink the coronal specification from the vowel altogether, the result of which is the retraction of the corono-dorsal [i] to dorsal [ɨ]. In the case of mid vowels, there is no surface retraction of the vowel, because Polish prohibits mid central vowels altogether, see constraints (46)–(47) postulated by Łubowicz (1998).

(46) Constraints referred to in the analysis:

a. NO MULTIPLE (coronal)
Constraint against multiple linkage of coronal (Łubowicz, 1998, 22)

b. ∗MidCentral
No mid central vowel [ə]

c. ∗Highcentral
No high central vowel [ɨ]

(47) Palatalization as a coronal transfer

a. palatalization before [i]

/k i/ dorsal dorsal coronal	NoMultiple (coronal)	∗HighCentral
a. tš i dorsal coronal	∗!	
☞ b. tš ɨ coronal dorsal		∗

b. palatalization before [e]

/k e/ dorsal dorsal coronal pharyngeal	MidCentral	*NoMultiple (coronal)
☞ a. tš e dorsal pharyngeal coronal		*
b. tš ə coronal dorsal pharyngeal	*!	*

In (47a), candidate (a) violates NoMultiple because the vowel is multiply specified as dorsal and coronal. In candidate (b), in contrast, the vowel is only dorsal, that is, NoMultiple is not violated. Candidate (b) is selected as optimal.

In (47b), candidate (a) crucially does not violate constraint against mid central vowel [ə] (which is dorsal and pharyngeal). Candidate (b) violates constraint against [ə], and is excluded from further evaluation. A candidate with vowel [e] is optimal.

Łubowicz's account is difficult to evaluate because it is not clear how other palatalization data (palatalization of coronals) should be analyzed. If we assume that post-alveolars are coronal and dorsal, it is not clear how we should analyze prepalatals, and, consequently, how Coronal Palatalization should differ from 1st Velar Palatalization. Then the question about the phonetic grounding of the proposed featural make-up of sounds might be raised. For example, post-alveolars are in this account Coronal and Dorsal. This assumption wins little support from phonetic studies, cf. chapter 3. Further, the question why central high vowels, but not central mid vowels, are possible surface outputs cannot be answered in a direct way in this framework. If we argued in terms of universality, one could observe that [ə] is, after all, a cross-linguistically more common sound across languages than [ɨ] is.

Instead of seeing palatalization as an assimilation, the goal of the process is, as shown in (47), to shift the contrastive feature from one segment onto another: a sharing of features of the front vowel with the consonant is not satisfactory. One could ask about the motivations for such an operation and possible ways to constrain the application of shifting. The optimal output should contain a depalatalized (retracted) vowel, which is problematic because cross-linguistically palatalization occurs often only in the context of surface front vowels. The motivation for shifting is also unclear: whereas assimilation brings an immediate advantage for the speaker, shifting the feature might lead to some further inventory optimization; however, explanations in terms of inventory optimization often meet with a justified critique. The argument is that speakers do not have an overview of the whole system and do not plan in advance steps to optimize their language; an alternation might serve only immediate purposes and bring only local amendments of the structure, cf. e. g. de Lima (1993).

In general, as with many original approaches, Łubowicz's account does not offer answers to the old questions but instead poses a lot of new ones.

1.4.5 Summary of the Discussion of Earlier Approaches

In the previous sections, we reviewed some existing approaches to palatalization by applying them to Polish data. Generally speaking, whereas attempts were made to provide a comprehensive analysis of palatalization data within framework of Lexical Phonology (Rubach, 1984) or Feature Geometry (Szpyra, 1995), I do not know of any analysis which tries to discuss in a consistent way the Polish data of palatalization of coronals, labials and velars within the OT framework. Rochoń (2000) does not discuss palatalization of velars, Łubowicz (1998) does not discuss palatalization of coronals, and, as noted in the previous section, it is difficult to think of an analysis of Coronal Palatalization which would be consistent with the analysis of 1st Velar proposed by Łubowicz.

Summing up, the following questions are those which are not answered in a formal way in earlier accounts:

1. Why is palatalization cross-linguistically common, in contrast to other types of articulatory assimilation between a vowel and a consonant?
2. Why does palatalization cooccur with affrication?
3. Why are there in Polish three different sets of outputs (for three places of articulation of the consonant) of an assimilation to the same vowel (instead of one most compatible to the vowel)?
4. Why do we have prepalatals ([ʨ, ɕ]) as an output of palatalization in Polish, when cross-linguistically palatoalveolars ([ʧ, ʃ] etc.) are less marked?

1.5 The Role of Perception in Palatalization

The answers to the questions posed above, are probably not available either in the framework of Lexical Phonology, or in Feature Geometry, or in classical OT. It seems that one aspect of palatalization has escaped scrutiny so far. My claim here is that we can find formal answers to our problems if we take into account auditory effects. The results of some phonetic experiments clearly show that perceptual factors play a role in palatalization. In the following sections, some research results will be summarized (sections 1.5.1–5), as well as the proposal of Flemming (1995) viewing palatalization as a result of the prolongation of the duration of a distinctive auditory defined feature (section 1.5.6).

1.5.1 The Directionality of Perceptual Similarity

Winitz et al. (1972) conducted a series of perception tests, where listeners had to categorize bursts in different vowel contexts. In these tests, the listeners misperceived [pi] as a [t] (with any following vowel) in many cases, but a reverse misperception of [t] as [p] did not take place.

Similar findings were obtained for other sounds: [ki] is perceptually similar to [ti] but not the other way round, and [ku] is confused with [pu], but [pu] is not perceived as [ku] (Ohala, 2001).

The directionality of similarity can be accounted for by a reference to general perceptual strategies. If we have two objects which are structurally the same or similar, but one of them has an extra feature, it is likely that the object with an extra feature, when this extra feature cannot be well perceived, is confused with the other object in the pair. On the other hand, the object without extra feature will not be confused with his counterpart, because it will not occur to us to imagine that there is some extra feature when we do not see or hear it. This reasoning holds for the comparison of velar and coronal stops. The formant transitions and stop bursts for /gi/ and /di/ are very similar, however /gi/ has an additional property – a compact mid-frequency spectral peak. For this reason /gi/ can be misperceived as /di/, but /di/ is unlikely to be taken for /gi/, (Ohala, 2001).

These asymmetries in misperception effects coincide with the well-known generalization about the possible sound changes. As to palatalization, coronalization of labials and velars is a common process, the opposite does not occur often – in fact I do not know of any such case (cf. Flemming (1995)).

1.5.2 Perceptual Similarity between Velar Plosives and Alveolo-palatals

The experiments by Guion (1998) show that the auditory scenario of palatalization is very likely, and the author herself argues that palatalization occurs because the alternants are perceptually confusable (and confused).

One experiment described in Guion (1998) examined the acoustic similarity of velars and palatoalveolars of English. In particular, the spectral properties of the consonant and the second formant transitions of the vowels have been investigated. Guion observes that, irrespective of the speech tempo, for [k] and [ʧ] on the one hand, and for [g] and [ʤ] on the other, minimal overlap is observed between the peak spectral frequencies for velars and palatoalveolars before back vowels, but there is an overlap before front vowels. In the environment before the high front vowel, the overlap is even greater. As far as the transitions of the second formant are concerned, velars before front vowels and palatoalveolars are also more acoustically similar to each other than velars before back vowels and palatoalveolars. In another experiment, subjects were confronted with (a) words containing the relevant sequences in fast speech, (b) with shortened, i. e. only 30 ms long tokens (consonant + condition), and they had to say whether they heard [k] or [ʧ]. When all consonant/vowel cues were available, only [ki] sequence was confused sporadically with [ʧi],[20] however, in the experiment with the reduced tokens,

> (...) the [k] before [i] (...) was identified correctly only 53% of the time. This is slightly above the chance. The tokens beginning with [k] and the front vowel [i] were highly confusable with the palatoalveolar affricate. The subjects appear to have been guessing between a response with [k] and [ʧ] for these tokens. (Guion, 1998, 33)

On the basis of these experimental results, Guion concludes that velar palatalization is perceptually conditioned (cf. e. g. Ohala (1981)); in particular, it arises from the misperception of the consonants with a front vowel as an alveolo-palatal affricate.

Whereas it seems important that the alternating sounds are similar, as argued in the next section, it will be argued in this dissertation that the similarity itself is not necessarily a driving force but rather a licensing condition for palatalization (Steriade (2001) and references therein; cf. next section).

1.5.3 Constraining Assimilatory Drive

Steriade (2001) discusses place assimilation processes in general and argues that,

[20] Consonants were compared only in the context of [i], [u] and [ɑ]: [i] was the only front vowel, where the effect was expected to be the greatest.

> (...) the speakers who initiate assimilations as a sound change, select a specific modification of a lexical norm on the basis of two factors: perceived similarity to the original form and optimized articulation (Steriade, 2001, 232). (See also Lindblom et al., 1995; Kohler, 1990; Hura et al., 1992).

One could assume that synchronic alternations may be constrained by the same token, and that assimilatory effects are only possible if they are not blocked by the requirement for the similarity between the underlying auditory representation and the surface realization, cf. Steriade (2001) for the account of phenomena connected with place assimilation in consonantal clusters. This is also a position taken here: it will be argued that palatalization is a conjunction of several factors, two of which are articulatory assimilation (ATR harmony, see chapter 5), and the relative perceptual faithfulness to the underlying representation (see chapter 4).

1.5.4 Perceptual similarity between velar stops and coronal stops

Chang, Plauché and Ohala (2001) studied consonant confusion asymmetries. The aim of the study was to show that the grounding of such effects is of perceptual/acoustic nature and has nothing to do with markedness of coronal sounds.

In particular, the confusion between /k/ and coronals /t/ and /ʧ/ has been investigated. Cheng et al.'s results were that perceptual similarity holds between velars in the front vowel context and alveolar plosives. They studied explicitly the relation between non-aspirated /k/, /t/, and /ʧ/ in American English, and concluded that there is no /ki/ > /ʧ/ confusion asymmetry in laboratory conditions, contrary to Guion's results, but rather /ki/ > /t/. They subscribe the results of Guion to the fact that she offered only a forced choice between /k/ and /ʧ/, without offering /t/. Furthermore, her plosives showed aspiration, unlike the cues used in their experiments. However, /k/ > /t/ is not a common sound change, unlike /k/ > /ʧ/, and this result is explained by Cheng et al. by the fact that their /k/ is unaspirated, whereas normally /k/s might be aspirated and the aspiration of /k/ is interpreted as the friction portion in the affricate. Yet, this account does not explain why, in the real language, the change does not typically result in affricate /ts/. This might support the claim that treating palatalization in terms of perceptual similarity alone is a mistake too. The place of articulation of /ts/ is too far to the front in comparison to the place of articulation of front vowels. If articulation has any influence here, a velar should assimilate to the front vowel, and cannot surface as a dental/alveolar stop. The alternation with a dental/alveolar sound would be only possible if perceptual similarity would be the only important parameter in language change. However, if palatalization is an articulatory assimilation too, then we would rather expect the alternation of a velar with a alveolo-palatal sound.

1.5.5 Experiments on Polish and the Contrast Preservation Hypothesis

Similar results to Guion (1998) have been obtained by Ćavar and Hamann (2001). Polish has an alternation between velars and post-alveolars, and on the other hand between dentals and prepalatals. In the experiment by Ćavar and Hamann, Polish native speakers were asked in an ABX test[21] whether velar and coronal voiceless plosives recorded in the context of a front vowel [i] (i. e. [c]/[tʲ]) are more similar to [ʨ] or to [tš], to test the hypothesis that the velar alternates with [tš], and the dental alternates in palatalization processes in Polish with [ʨ] on the basis of perceptual similarity. In other words, the hypothesis was that the pattern of alternations reflects the closer perceptual affinity of [t] to [ʨ], and of [k] to [tš].

It turned out that both (secondarily) palatalized velars and coronals in the context of a front vowel [i] seem to be more similar perceptually to prepalatals than to postalveolars. In particular, Polish native speakers answered in 65% of cases that /t/ is more similar to /ʨ/ than to /tš/, and in 67% of cases that /k/ is more similar to /ʨ/ than to /tš/.

The experiment did not support the original hypothesis but it also did not refute it: one can argue that the actual synchronic alternations involve dental and velar stops without the context of a front vowel on the one hand, and the affricates in the front vowel contexts, on the other hand. Thus, the choice of the tokens presented to the subjects corresponds to the diachronic changes in Polish, but not to the synchronic alternations. Further, once we eliminate the characteristic formant transitions from the stop to the vowel, the results of the experiment may be completely different (e. g. by presenting the tokens where the tokens are followed by another consonant), because the listeners will focus on other less salient cues than formant transitions, e. g. on the properties of the burst. The frequency of the noise onset actually pairs as more similar velars with post-alveolars, and dentals with prepalatals. The phonetic description of the Polish sounds is provided in chapter 3 and, in

[21] In an ABX test, subjects are presented triads of tokens (A – B – X), and asked to say whether the third token (x) is more like the first token (A), or more like the second token (B).

chapter 4, it is proposed that the frequency of the noise portion may have an influence on the choice of the particular alternants in palatalization.

1.5.6 Perceptual Features in Flemming

Flemming (1995)[22] analyzed examples of palatalization in terms of enhancement of the auditory feature [HighF2] of front vowels by the extension, or prolonging, of this property onto the release of the adjacent consonant. He argues that both secondary palatalization and the change of primary articulation place to palato-alveolar may be accounted for this way.

He addresses the problem of affrication and claims that friction serves to enhance auditory feature [High F2]. To implement friction, a change to strident palato-alveolar is necessary, and this happens if Parse[strident] is ranked lower than constraints inducing enhancement. In fact, as mentioned earlier, friction may be implemented in /ts/ as well, without a change of articulation (for palatalization of coronals). Thus, Flemming's account (1995) does not explain the articulatory shift.

A problem with this analysis can be seen in that Flemming (1995) disregards the articulatory factors altogether. He admits in the introductory chapter of his dissertation that there should be articulatory-driven phenomena (and, consequently) articulatory defined features, but he does not mention any articulatory mechanism in the account of palatalization,and neither does he discuss the relation between the articulatory and auditory processes in general.[23] In contrast, it is proposed in chapter 4 that the perceptually-driven prolongation of a perceptual feature has its role in palatalization; but in order to account for the whole of palatalization data, we need to take into account other factors, also of articulatory nature, as in chapter 5.

1.5.7 Partial Conclusions

Summing up, auditory factors play a role in palatalization, however, it is not a purely auditory-driven phenomenon. It seems that palatalization involves factors such as articulatory assimilation, auditory assimilation, auditory similarity to the input, and the requirements for the contrast preservation. Each

[22] In the revised version of Flemming (2002) there is no reference to the constraint 'spreading preceptual features' in the analysis of palatalization. He analyzes palatalization as an interaction between constraints on optimal contrasts and constraints for articulatory economy. This option is not available in the analysis of Polish. As it will be argued in chapter 4, Polish phonological palatalization, with major assimilation of articulation place, is not triggered by an articulatory feature.

[23] These aspects were revised in Flemming (2002).

of these mechanisms will be theoretically introduced in chapter 2, and illustrated with Polish data in chapters 4 and 5.

1.6 Perceptual Features in Phonological Analysis

Palatalization is clearly not the only phenomenon that would require the incorporation of an auditory perspective into a phonological account. Many researchers throughout the years have pointed to phenomena which have been problematic for the traditional articulatory accounts. Typical cases involve natural classes with primarily non-articulatory definitions (section 1.8.1), and phonological phenomena unclear from the articulatory point of view (1.8.2).

1.6.1 Natural Classes with Primarily Auditory Grounding

One problem of the purist articulatory approach is that some classical features and modern nodes of Feature Geometry are hardly articulatory based.

One such example are the previously mentioned nodes in the Feature Geometry proposed by Sagey (cf. section 1.4.2), which in themselves are not strong arguments for the perceptual/acoustic grounding of features, since the existence of at least the Supralaryngeal Node has been questioned by many researchers. A better example is the broadly accepted feature [continuant], which classically expresses the stop-fricative dimension. There is no unique articulatory correlate of this feature, since it may be implemented by any active articulator. Consequently, researchers have had difficulties in agreeing on the location of this feature in the feature tree, claiming either that it is arrayed directly under the root node (or even a part of the root node), or that it is located under the articulator by which it is in a given case implemented. On the other hand, it is not difficult to identify an acoustic, and what follows, a perceptual correlate of [continuant] for any instant of a fricative. All continuant sounds have characteristic aperiodic noise, whereas stops are characterized by an abrupt amplitude drop and a signal discontinuity.

Another example of a feature ill-fitted into the articulatory framework is feature [strident]. Strident sounds are defined as sounds produced with such a position of articulators so that the produced sounds are louder, cf. Crystal (1991). Thus, their articulatory description refers to the configuration of articulators which is able to produce a particular acoustic effect. Acoustically, they have higher noise intensity.

Many researchers (cf. Lass, 1976; Hyman, 1973; Odden, 1978; Hall, 1997) argued for Peripheral node (or feature [grave], after e. g. Jakobson et al. (1962)), grouping labials and dorsals, which often constitute a natural class in phonological phenomena. Yet, there is obviously no one articulatory correlate for labials and dorsals; these are two distinct articulations. What labials and dorsals have in common is their acoustic (and, consequently, perceptual) properties. Labials and dorsals can be characterized by similar formant transitions: in both cases second and third formants are relatively low.

Another long-standing problem is capturing, in terms of features, the natural class of liquids. Although they are very different articulatorily, there are many cases where liquids of different types pattern together. They are reported to alternate with each other in many languages. Ladefoged and Maddieson (1996) cite Nasioi (Hurd & Hurd, 1966), Barasano (Stolte & Stolte, 1971), Tucano (West & Welch, 1967), where the distribution depends on the vocalic context, and Korean, where the distribution is conditioned by the syllable position. In other languages liquids are in free distribution, as in West African languages discussed in Ladefoged (1968), or Japanese (Ladefoged & Maddieson, 1996) and (Shimizu & Dantsuji, 1987, 16).

Those and similar phenomena would probably be easier to explain if we accepted that liquids have similar acoustic (and thus perceptual) features. Lateral approximants and rhotic flaps have in common a relatively clear formant structure, unlike other consonants, and a clear zero in the spectral envelope, unlike vowels and glides.

The natural class of rhotics raises a similar issue. Rhotics are articulated by different articulators and in many manners, and still seem to constitute a natural class of sounds. For example, they are often subject to substitutions by another rhotic which is sometimes produced with a different articulator. In Polish, the rhotic is apical, yet, in speech distortion it is substituted with a uvular rhotic, and no communication problems arise. A reverse situation holds in High German where the standard pronunciation calls for a uvular sound, which in cases of articulatory problems is rendered as an apical. The changes from the tongue-tip to uvular articulation of rhotics have occurred historically in French, German and Swedish. As reported by Ladefoged and Maddieson (1996), in dialects of Swedish on the boarder between tongue-tip rhotic area and the uvular rhotic speaking area,

> (...) members of the same family may use either front or back r-sound and the other members of the family never notice the difference. (Ohlsson *et al.* , 1977)

This kind of phenomena would be predicted if we adopted the idea of auditory features shared by the two sounds normally articulated by different articulators. Since the apical rhotic and the uvular rhotic have no common articulation, the only way to express their common affinity is to say that they share perceptual features. Ladefoged and Maddieson (1996) argue that apical and uvular trills are similar perceptually, in that they have a similar pulsing pattern with high third formants. The Czech fricative rhotic has the third formant around 3000 Hz, uvular sounds from Swedish, French and German show the third spectral peak over 2500 Hz, sometimes close to the fourth formant. Dental [r] of Spanish also has relatively high third formant though not as high as in uvular rhotics (Fant, 1968). In my measurements, the Polish dental [r] has formants typical for alveolar sounds, that is with formants higher than for labials and velars.

In sum, we can postulate that a tongue tip rhotic (for example, synchronically in Polish and probably historically in, for instance, German), and a uvular flap (for instance in German) are perceptually similar, and for this reason it might come to substitutions when other factors allow or require such a substitution.

1.6.2 Perceptually-driven Phenomena

The catalogue of phenomena that might be accounted for with reference to perceptual factors is long. Some examples of problems which cannot be satisfactorily accounted for under an exclusively articulatory approach, are given in (48) to show what perspectives become open at the moment we acknowledge auditory explanations in phonology. These topics are not going to be further discussed in this dissertation.

(48) Topics referring to perceptual issues

	topic	**Accounts in terms of perceptual factors**
a.	**Sonority Hierarchy** (as defined first in Sievers (1893), Jespersen (1904), Selkirk (1982)) as a reflex of contextual perceptibility of segments and syllable repair strategies (**consonant deletion, vowel epenthesis, metathesis**)	Ohala (1992), Côté (2001)
b.	**Blocking of vowel epenthesis**	Côté (2001)
c.	**Cooccurrence constraints** on sequences of labials + w, apicals + l, and palatals + i; OCP effects	Ohala (1990), Ohala (1992), Kawasaki (1982), Ohala and Kawasaki (1984)
d.	The impact of **nasalization on the vowel quality**	Wright (1986), Beddor et al. (1986)

	topic	Accounts in terms of perceptual factors
e.	**Non-distinctivity of nasalization on vowels** in the context of nasal consonants	Kawasaki (1986)
f.	Diachronic elimination of contrasts	For Polish dialects: e. g. Rudnicki (1927), Koneczna (1965), Rochoń (2001), for Croatian: e. g. Stankiewicz (1986).
g.	**Tendency to undergo assimilation**, as described in Mohanan (1993), Jun (1995, 78-9), **directionality of assimilation**	Place assimilation in German: e. g. Kohler (1990); nasal assimilation: e. g. Ohala (1990), Boersma (1998); Production Hypothesis (Steriade, 1993), (Jun, 1995); P-Map hypothesis (Steriade, 2001); place assimilation in clusters involving retroflex sounds, (Steriade, 2001)
h.	Lenition processes as enhancement of contrasts	Boersma (1998), Hardcastle (1976)
i.	Fortition processes as enhancement of contrasts	Harris (2001)
j.	**Bilateral environment** for the alternation	Flemming (1995), Guion (1998)
k.	**Constraining diachronic sound change or synchronic alternation**	Ohala (1981), Lindblom et al. (1995), Kohler (1990), Hura et al. (1992), Steriade (2001)
l.	**Substitutions in child speech and in adults with deficits in speech organs** as described in Drachman (1969), Lindblom et al. (1979)	e. g. Boersma (2001)
m.	Palatalization	Flemming (1995), Guion (1998)

Chapter 2

THE FRAMEWORK

2.1 Goals

The goal of this chapter is to introduce the theoretical framework applied in this dissertation. In general, the framework adopted in this study is a functional version of Optimality Theory (OT), assuming two types of constraints and representations: auditory- and articulatory-driven. Most similar approaches can be found in Flemming (1995) and Boersma (1998). The basic tenets of OT are recapitulated in section 2.2-3. In section 2.4, the basic notions of the functional approach are presented. Section 2.5 discusses the possible content of the underlying and surface representation, presenting the arguments against the assumptions of Boersma (1998). In section 2.6, the assumptions adopted in this thesis regarding the relation between classically understood phonetics, phonology and morphology are presented. Section 2.7 presents the overview of the model that is developed in further sections. Section 2.8 defines the constraints in the model introduced earlier. In section 2.9, conjunctions and disjunctions of constraints are defined the way these notions will be applied in further chapters. One further issue, discussed in section 2.10, is the problem of defining the derived environment in OT. We will review earlier approaches and propose a new solution more in accordance with the functional approach adopted. Sections 2.11-12 are devoted to feature definitions. Finally, other studies on the role of perception in phonology will be mentioned in section 2.13, and a comparison with the model proposed here, pointing out the the elements I have borrowed for my model follows in section 2.14. Section 2.15 is the summary.

2.2 OT Framework

In this dissertation the basic insights of Optimality Theory (Prince and Smolensky, 1993; McCarthy and Prince, 1986/1996; McCarthy, 2002) are adopted. Grammar consists of two modules: a Generator (Gen), which generates linguistic forms, and an Evaluator (Eval), which evaluates the generated forms (candidates). The candidates are evaluated by means of constraints: in respect to their well-formedness (markedness constraints) and their accordance with the lexical/underlying/input representation (faithfulness constraints). Constraints are ranked according to their importance: a candidate that violates the highest-ranked constraint is less optimal than the candidate that does not violate the highest–ranked constraint but violates the second-highest, etc. The multiple violations of lower-ranked constraints do not matter more than a single violation of a higher-ranked constraint. The best/optimal candidate is the one that violates the hierarchy of constraints in a minimal way: candidates cannot satisfy all possible constraints, because constraints are contradictory, e. g. a faithfulness constraint requires in the surface form a consonant in the coda, the consonant in the coda is, however, forbidden by a markedness constraint against coda consonants, etc. The optimal candidate, violating the hierarchy of constraints in a minimal way, is selected by Eval as the surface representation.

The basic tenets of OT, which are also going to be adopted in this dissertation, are summarized below.

(1) Violability
Constraints are violable, but violation must be minimal.
(Kager, 1999, 12)

Constraints are "soft", therefore they do not hold absolutely. They may be violated by the optimal candidate as long as the violation is minimal and for a good reason, i. e. avoiding the violation of a higher-ranked constraint.

(2) Optimality
An output is 'optimal' when it incurs the least serious violations of a set of constraints, taking into account their hierarchical ranking. (Kager, 1999, 13)

Candidates for the surface output form may be optimal but not perfect, consequently:

(3) Fallacy of perfection
No output form is possible that satisfies all constraints. (Kager, 1999, 16)

Further, constraints hold only at the level of surface representation. There are no constraints on the input:

(4) Richness of the Base (Kager, 1999, 19)
No constraints hold at the level of underlying form.

The notion of Richness of the Base will be important in the critique of the approach to the derived-environment problem proposed by Łubowicz (1998), see section 2.10.

Constraints interact in a single hierarchy, i. e., markedness constraints and faithfulness constraints are interwoven in a single hierarchy:

(5) Parallelism
All constraints pertaining to some type of structure interact in a single hierarchy (Kager, 1999, 25)

The consequence of the statement in (5) is that morphological, phonological and prosodic information is processed at the same time, and also that morphological and phonological properties are mutually dependent, cf. section 2.6. In this study, there is no principle distinction made between different types of constraints, whether they refer to morphological or phonetic information, and they are all arrayed in one hierarchy.

With respect to the choice of the underlying representation, a standard approach is adopted here, going back to the ideas proposed, e. g., by Stampe (1972), and which was defined for OT in Prince and Smolensky (1993):

(6) Lexicon Optimization
Suppose that several different inputs I_1, $I_2 \ldots I_n$ when parsed by a grammar G lead to corresponding outputs O_1, $O_2 \ldots O_n$, all of which are realized as the same phonetic form ϕ – these inputs are phonetically equivalent with respect to G. Now one of these outputs must be most harmonic, by virtue of incurring the least significant violation marks: suppose this optimal one is labeled O_k. The learner should choose, as the underlying form for ϕ, the input I_k. (Prince & Smolensky, 1993, 192)

This means that in the absence of empirical evidence for one input form over another (i. e. lack of surface alternation), the input should be assumed to be identical to the output. This issue is discussed in more detail in the following section.

2.3 What is the Input to Eval?

It is assumed here that input is equal to the underlying/lexical representation. With respect to the underlying/lexical representation, I adopt here the classical assumption that contextual variants of a morpheme derive generally from a single underlying representation (Chomsky & Halle, 1968). The classical correspondence model is reproduced from Kager (1999, 413):

(7) Classical model with underlying representation (Kager, 1999, 413)

			OO-Identity	
	OUTPUT	Base	⇔	Affixed form
IO-Faithfulnes		⇕		⇕
	INPUT	UR		(affixed) UR

In the recent literature on OT, there have been attempts to eliminate the notion of the underlying representation (one lexical representation for semantically related lexical units), cf. Burzio (1996), earlier non-OT proposals in Aronoff (1976) and Bybee (1995).[1] In this study, for the lack of obvious advantages of the latter model over the classical view for our analysis, we adopt the classical view.

2.3.1 Types of Constraints in OT and in this Dissertation

Optimality Theory assumes two kinds of constraints: markedness constraints, evaluating the surface representations, and faithfulness constraints, evaluating the correspondence of the structure to the underlying structure. Further, Output-to-Output Correspondence (Benua (1995), McCarthy (1995), paradigm uniformity and analogy earlier in e. g. Kuryłowicz (1947), Mańczak

[1] Kager (1999, 413) argues that OO-Identity is "a priority of language", and, further, that the model in (7) contains a logical redundancy, because both OO-Identity and the underlying representation have the same function, namely, they both express the one-to-one relation between the lexical items and the atoms of meaning or, in other words, they both maximize uniform exponence. Instead, researchers proposed that there is no separate abstract underlying representation defining the unity of meaning of related forms and that the input to the OT evaluation is a set of forms containing only the morphemes in their surface shape. However, if the set of input representations is equal to surface representations, and these surface representations are limited by a set of markedness constraints, then the set of lexical representations (input) is already evaluated by the constraints. Apart from the fact that this perspective is not in accordance with Richness of the Base, it is also equally redundant as the system in (7) where uniform exponence is maximized by both Base Identity and unity of underlying representation: constraints limit the possible input and the output. A kind of a circular effect arises: surface forms are the way they are because they are faithful to the input, and input is the way it is, because it is a copy of the surface form. In this case, markedness constraints have actually no influence to exert on the surface forms, because the shape of the output is already guaranteed by the faithfulness to the input. Also Kager notices that both models have their advantages and disadvantages, and it is too early to evaluate the results of a theory which seeks to eliminate the notion of the underlying representation.

(1958)), introduces the idea that the faithfulness constraints hold also between surface forms. That is, the choice of the surface form is influenced by other surface forms in that the surface forms should be maximally similar to each other.

2.4 Formalism versus Functionalism

Most of the research in phonology since the seventies has been done with the tacit assumption of the structuralist approach, where it is claimed that phonological processes/facts are the way they are because of the architecture of the phonological part of the grammar in our heads. Since we cannot have insight into our heads and check whether the proposed theory reflects the facts or not, and since the architecture may be only deduced from the surface facts, facts which might be influenced by some external factors and which are subject to accidental gaps, the structuralist theory is not always and fully verifiable. An additional objection is that such a theory is often not really explanatory. To quote Miller (1990):

> (. . .) my own view is that linguists and psychologists subscribe to different theories of explanation. Linguists tend to accept simplifications as explanations. For example, a grammarian who can replace language-specific rewriting rules with x-bar theory and lexicalization feels that he has explained something: the work formerly done by a vast array of specific rules can now be done with a simple scheme. For a psychologist, on the other hand, an explanation is something phrased in terms of cause and effect, antecedent and subsequent, stimulus and response. To an experimental psychologist, x-bar theory is not an explanation: rather, if it is true, it is something to be explained. (Miller, 1990, 321) (quoted after Lindblom (2001))

Functionalism, in contrast, seeks explanation in external factors: phonological paradigms are the way they are because they are produced and – constrained – by human speech organs, received by the human ear, perceived by the human perceptual system, and because human beings have the need to communicate. Functional approaches seem to provide an explanation, as they refer to principles, the working of which can be analyzed in terms of cause and effect. It is also a more general approach, as it refers to principles common to all human motor behavior and perception. To put it in the words of Myers (1997):

> 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. (Myers, 1997)

In fact, most of the works recognizing the influence of perception on phonology are functionalist in approach. The reason for this might be that phonetic functionalism necessarily has to refer to both articulation and perception (unlike structuralism). This approach, going back to Passy (1891) and Martinet (1955), and later developed by, for instance, Lindblom (1986), Flemming (1995), and Boersma (1998), makes certain assumptions which will be also adopted in this work. The underlying assumption is that we speak in order to be understood; that is, our speech is such that it can be easily understood. On the other hand, a speaker does not want to spend any superfluous effort to achieve its goal, and tries to reduce the energy spent on communication. This can be summarized as below:

(8) Functional principles in phonology
  a. Principle of minimization of effort
     The less movement of articulators, the less complex movement, the closer distance of movement, etc. the better.
  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.

Examples of (8a) might be articulatory assimilations, and simplifications of complex articulation. As to (8b), an example might be OCP: adjacent segments that are too similar cannot be distinguished from one another and are avoided. Dissimilation enhances the distinctiveness of adjacent segments. Similarly, a spreading of particular perceptual features has the positive effect of prolonging the time in which a given feature can be perceived, thus making this particular feature more salient.

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

It is important to bear in mind that the current functionalism differs from earlier approaches which were concerned with the social function of language. The "goodness" or "badness" of certain language change was to be assessed in terms of semantic load of a certain structure (in phonology), or discourse motivation (Prague school, and continuation of the stream, e. g. Halliday (1967)). Functionalism, the revival of which we witness nowadays, views language primarily as biological function. Speaking and understanding is not only a social activity – but also biological, rooted and shaped by the biological systems within the human being, namely, motorics and perception. These can be investigated and measured, and statements within this biological functionalist approach are definitely easier to formalize than any "social" approach. However, it is not assumed here that all phonology can be boiled down to biologically-motivated phenomena. It is not excluded that there might be synchronic phonological processes which do not have phonetic grounding in synchronic terms.

In the following sections, the various external factors shaping phonology will be briefly discussed.

2.4.1 Articulatory Grounding

The shape of the vocal tract has inevitable influence on the shape of language and this has been the prevailing topic of the phonological research in the latest decades. Similarly, in sign language, the means of articulation has influence on the language, and the language reflects its possibilities and shortcomings, e. g. Brentari (1995); the use of space in sign language, Keller (1998). Thus, spoken language makes use of only and exclusively such distinctions that can be articulated by our vocal tract. This idea is fundamental to the theory of Feature Geometry, especially in the approach of Halle (1995), where one could see a geometrical tree as

> a model of instructions to the vocal tract to activate some body of muscles and deactivate others to produce this or that segment. (Keyser & Stevens, 1994)

It is also a major problem of Feature Geometry that it recognizes the legitimacy of phonological phenomena based only and exclusively on articulatory grounds.

From the functional perspective, it is of benefit for the speaker to save energy and shape the language in order to use the code with a minimal expenditure of energy. The tendency to minimize effort is not particular to language behavior at all; it is a property of motoric behavior of all animals.

2.4.2 Perceptual Grounding

Our perceptual system has a direct influence on the shape of language. For instance, we are not equally sensitive to all kinds of stimuli. One particular example is that our cognitive system is better prepared to receive acoustic signals at certain frequencies than the others:

> The nonlinearity in the sensation of frequency is related to the fact that the listener's experience of the pitch of periodic sounds and of the timbre complex sounds is largely shaped by the physical structure of the basilar membrane. (...) the basilar membrane is thin at its base and thick at its apex; as a result, the base of the basilar membrane responds to high-frequency sounds, and the apex to low-frequency sounds. (...) a relatively large portion of the basilar membrane responds to sounds below 1000 Hz, whereas only a small portion responds to sounds between 12,000 and 13,000 Hz, for example. Therefore, small changes in frequency below 1000 Hz are more easily detected than are small changes in frequency above 12,000 Hz. (Johnson, 1997, 55-56)

In other words, the important cues in speech perception will be located in lower frequencies and not in higher frequencies. Also, for the perception of vowels, it has been argued that the higher frequency formants integrate into entities perceived as complexes if they are close enough. Bladon (1986) reports that F2, F3, and F4 are perceptually integrated in [i], and in [ɪ, ɛ] – F2 and F3 are integrated.

Another example of the way perception might have influence on phonological regularities is the phenomenon of short-term adaptation. After a certain feature of an acoustic signal is first perceived, the perceptual system gets quickly accustomed to it, and even if the acoustic signal did not change in intensity, the neural response will be weaker after a moment and the signal will be perceived as weaker, if at all. Bladon (1986) discusses English vocalic epenthesis between sibilant-final nominal stems and plural ending as a strategy to avoid effects of short-term adaptation and maintain the –s ending perceptible. In other words, the claim is that [ə] is inserted after sibilants in order to block the short-term adaptation and make the plural ending perceptible. It seems reasonable to me to assume that this mechanism plays a role in the triggering of different kinds of dissimilation processes in human language.

There is also a functional, dynamic aspect to it. The speaker wants to put his or her message across, so it is of benefit to take some additional action and make more effort to result in a more clear articulation, in order to make the task of the listener easier. Thus, the tendency to minimize the effort, discussed in the previous paragraph, is balanced.

In what follows, a functionally-oriented OT model is developed (section 2.7 ff.), involving functionally-driven constraints(section 2.8), and operating on representations of articulatory- and auditory-defined features (sections 2.11-12).

2.5 Underlying and Surface Representations

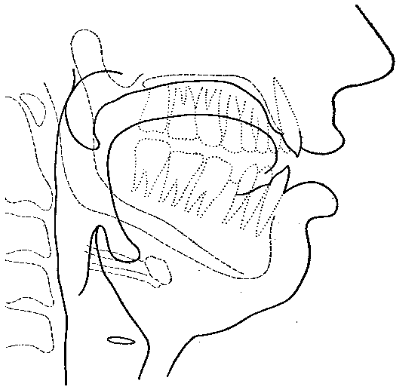
In the following chapters the notions of the underlying and surface representations will often be employed and it is important to make it clear that it is assumed here that both representations contain both articulatory and perceptual specifications.[2]

The input is understood to be the underlying representation/lexical entry stored in the lexicon. This consists, first, of auditory features, second, of articulatory features, third, of timing relationships between them. When somebody learns a language – a child or an adult – he or she first hears a string of words and, it can be assumed that what we hear is stored. This idea that the auditory shape is stored, is supported by psychological experiments on priming; it has been shown that words sounding similar are activated together with a token word, cf. Bybee (2001). Phonetic research has shown also that some features (that I take to be in fact auditory) may be implemented in different ways in different languages (cf. Ladefoged (1980), Ladefoged and Traill (1980)) or by different people, or in different contexts. Anderson (1981) quotes as examples different ways to realize implosive stops or ejective glottalized sounds. Examples discussed in chapter 1, e. g. the pronunciation of rhotics, also may be quoted on this occasion. Another issue that belongs here is the polymorphism of vowels, that is, the phenomenon that one and the same vocalic phoneme may be produced in the same language, in the same context, sometimes by the same speaker, by means of different articulatory mechanisms. It is more or less agreed upon that vowels are easiest defined acoustically. This claim is particularly clear when we consider the fact that some vowel phonemes may be realized by different mechanisms, and the only aspect that such realizations have in common is their acoustic (and, consequently, auditory) properties. For example, consider two realizations of the Russian orthographic ы (high back unrounded vowel):

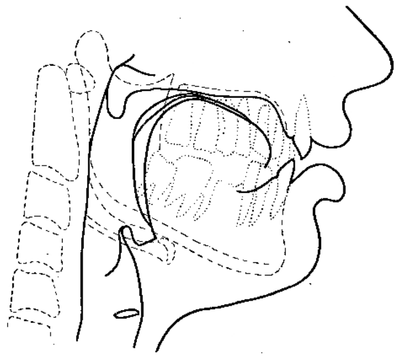
[2] In this respect, the model adopted here is different from e. g. Boersma (1998). Boersma argues that the underlying representation contains only perceptual features, and the articulatory features are derived by a production grammar from the underlying perceptual form.

(9) Russian orthographic ы
(from Koneczna and Zawadowski (1956) pictures 58 and 52)

a.



b.



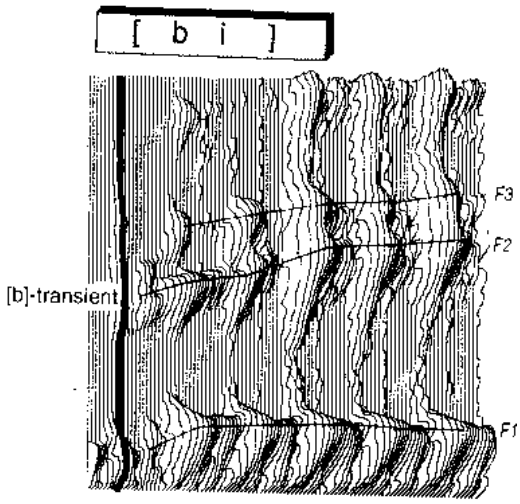
In (9), the Russian back high unrounded vowel is depicted in the articulation of two native speakers. The articulation in (9a) is supposed to be "typical Russian" (Matusewicz (1948); Ščerba (1912/1983)). Koneczna and Zawadowski describe the articulation in (9a) as belonging to the mixed type that is (phonetically) front-central-back at the same time: the tongue lies flat at the bottom of the oral cavity, the oral cavity forming one long resonator. As we can see, the maximal constriction is produced by the front of the tongue approaching the alveolars. In (9b) the same phoneme in the same environment is articulated with the position of the tongue nearly the same as for [u]: ы in (9b) is only a bit more fronted than [u], and the place of constriction is referred to as post-palatal (prevelar?). The place of articulation of ы in (9b) is also the same as for Russian [a], with the difference that in [a] the tongue root is clearly retracted (Koneczna & Zawadowski, 1956). The conclusion is that the place of the strongest constriction for Russian ы may differ, from post-alveolar (9b) to alveolar (9a), within one language irrespective of the context.

A variation of articulation, while retaining some kind of auditory similarity, is to be observed in instances of compensatory articulations in speakers who have undergone some organic problems with articulators (e. g. Drachman (1969)) and normal speakers under unusual conditions (e. g. speaking with a bite block keeping the constant mandibular angle; cf. Lindblom et al. (1979)). All this evidence points to the fact that auditory information is stored.

Further, besides the claim about the auditory underlying representation, it is justified to assume that lexical entries also contain articulatory features. Everybody would probably agree that, for instance, /b/ might be a phoneme of some language, and if stored in the lexicon, forms with /b/ in the context of front vowel and /b/ in the context of the back vowel contain the same representation. However, the acoustics of consonants in the context of various vowels differs. For /b/ in the context of a front vowel, the formant transitions are like that of coronals, that is, in comparable frequency ranges. In the context of back vowels the F2/F3 are remarkably lower, cf. perspectograms[3] in (10):

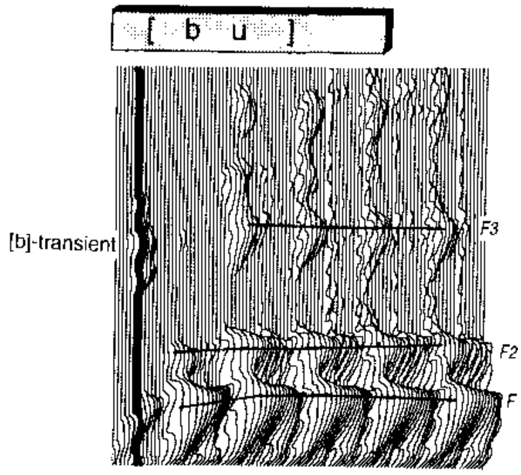
(10) [bi] and [bu] after Pickett (1999, 134, 136)

a.



[3] Perspective spectrograms: the spectra are plotted with a perspective generating slant instead of the normal spectrum scale of vertical frequency versus horizontal amplitude. Thus, the horizontal axis corresponds to time, vertical axis is the frequency, and the "height of the mountains" – the amplitude.

b.



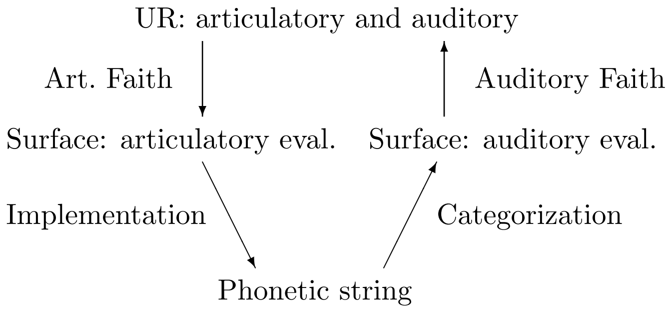
What all /b/-s have in common, and what marks the affiliation of different words with one morpheme containing /b/ in different vocalic environments is its articulation[4] – and this must be stored in the lexicon. Additionally, if the stored lexical underlying representation were devoid of an articulatory component, we would otherwise have to propose, like in Boersma (1998), an extra mechanism deriving articulatory features from the auditory features, so that one could evaluate the articulatory shape of the word in the surface representation. If we argue, following Bybee (2001), for the detailed underlying representation (containing a lot of phonetic detail), which we need anyway (independent arguments by Boersma, 1998; Kirchner, 1997; Flemming, 2001; cf. the discussion against Lexical Minimization in Steriade (1995b)) and also for the simple access to the lexical entry (for the sake of a psychologically plausible model of speech production and processing), but argue against simple representation and complex access, then, it would be logical to claim that we need both articulatory and auditory representations underlyingly. Boersma (1998) has to argue anyway for complex underlying representations containing much phonetic detail and – once we give up the concerns about the economy of the underlying representation – there is no reason not to expand this complexity onto the articulatory features.

If we assume that the articulatory representation is underlyingly present, we can think of production and perception of speech as represented in the model in (11). The surface representation is evaluated with respect to the articulatory faithfulness to the underlying representation, and to the general

[4] It is a fact that details of articulation also differ depending on the context: in the front vowel context labials are articulated with a raising of the tongue towards the hard palate. However, what is crucial, the labial gesture is common for all realizations.

articulatory markedness constraints. The optimal representations would be directly implemented by phonetics, which produces a phonetic form, a string of non-categorical acoustic signal. The other way round, the phonetic string is categorized into auditory features, which then can be recognized (compared via perceptual faithfulness constraints) as a representation stored in the lexicon. Speaker himself hears the produced acoustic signal, categorizes it backwards to derive the surface auditory representation and provide the feedback for the speaker; the surface auditory representation is then evaluated in terms of auditory markedness constraints, and in terms of the faithfulness to the underlying auditory representation. The model, assuming both articulatory and auditory features in the underlying representations, is depicted in (11):

(11) Model of speech production and perception



One could ask whether a speaker possesses the knowledge about how articulatory and perceptual features correspond. One of the optimality theoretic theorems is that anything can be an underlying representation – even those structures that cannot be surface realized. It is the job of the surface representation to satisfy all constraints and requirements, and first of all the requirements of pronounceability. I make the assumption that a universal set of constraints against unpronounceable representations does the first elimination, but the unpronounceable representations are not in principle eliminated as potential inputs. Thus, for example, an underlying representation may contain [LowF2/F3] perceptual specification for Coronal. This pair of features may not be realized together on consonants otherwise as by a retroflex sound, and dental, alveolopalatal and prepalatal candidates are excluded by pronounceability constraints.

2.6 Phonology versus Phonetics versus Morphology

As noted in Bybee (2001), any process in language that takes sounds as its scope, begins as a phonetic process, resulting in small changes that we neither perceive nor care about, then becomes phonological when we start realizing the alternation, and ends up as a morphological process when the phonetic conditioning is no longer clear. However, the borders between stages are fuzzy, and in the synchronic analysis it is, in many cases, difficult to say whether a given phenomenon is only phonetic, or phonological, or already morphological. It seems to me that the divisions between phonetics and phonology or phonology and morphology are artificial ones. As pointed out by many researchers, e. g. see Flemming (2001), the effects of the same external phonetic factors may be interpreted as either phonetic or phonological. Perhaps, whether we want to classify a certain tendency as phonetic or phonological is a function of our cognitive capacities. When the resulting alternation is perceptually clear, when it produces a phoneme, a perceivable distinction, then it belongs to the realm of phonology. When a certain alternation becomes conditioned by lexical information, and not only by phonetic factors, then it starts being morphological, but it does not automatically lead to the violation of phonological constraints. It seems perfectly possible that for a while a process is morphological/lexicalized, though also completely regular (e. g. exceptionless) in terms of phonology. On the other hand, if a form obeys the phonological system of a language, it supports the maintenance of the morphological alternation. In the following, I do not distinguish between constraints of different status: phonological and quasi-morphological processes are discussed on par. Phonetic effects, on the other hand, are for the most part disregarded, since they are not represented in terms of perceptual features. The exception is made with respect to the discussion of articulatory effects in Surface Palatalization (discussed in detail in chapter 5) because they clearly illustrate the same principles as in the analysis of phonological effects in 1st Velar Palatalization and Surface Velar Palatalization.[5]

2.7 The Model of Phonology: An Overview

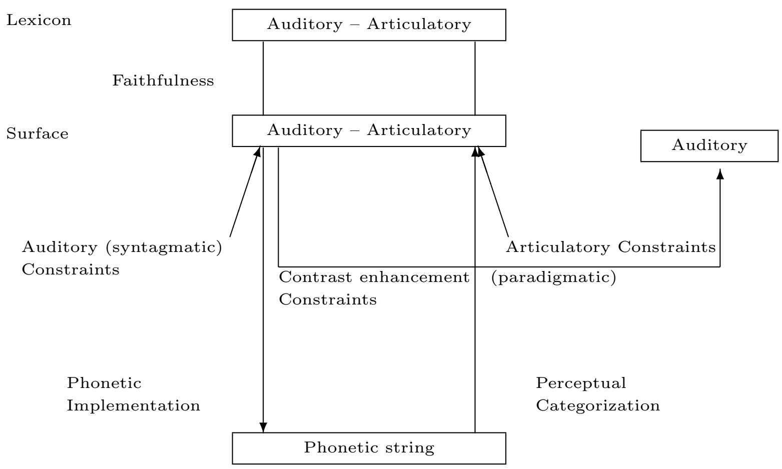
In chapter 1, as well as in previous sections, arguments have been presented for the presence of auditory representations in phonology. It is also clear that things happen in phonology for articulatory reasons, and, thus, we need to assume that both the underlying and surface representations include articulatory and auditory information (features and information about their

[5] This does not mean that the phonetic effects are irrelevant. For instance, the tendency towards strongly accommodative (coarticulatory) articulation in some Slavic languages and not others is responsible for the rise and conservation of phonological palatalization (Sawicka, 1991).

mutual relations). As noted earlier, many researchers, including Boersma (1998), Bybee (2001), Vennemann (1972), Flemming (2001), argued against the standard generative assumption that the underlying representation contains only unpredictable information, and I subscribe to this view. Some arguments to support this view come from the psychological research (see e. g. Bybee (2001)). Similarly, I assume that the information about the speech sound may be encoded in the underlying representation twice – once as an instruction for the articulators, and once as a pattern of perceptual impressions, though for the most of the time the two should describe one and the same physical event.

In (12) the model that is assumed in this dissertation is presented.

(12) Model of phonological representation



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 in terms of auditory features. Whereas **auditory (perceptual) faithfulness** is essential for communication, (guarantees that the speech signal will be categorized into auditory features and recognized, that is compared to the underlying auditory representation and proclaimed to be corresponding), **articulatory faithfulness** is a secondary mechanism to support it. So long as the articulatory faithfulness is not violated, the speaker can be sure to quickly produce the intended string of speech. This mechanism, however, needs a control mechanism, namely, that of perceptual faithfulness for the occasions such as missing teeth, paralyzed muscles, and other motoric deficits.

The surface articulatory representations will be evaluated with respect to **articulatory markedness** constraints, which drive all kinds of articulatory simplifications and assimilations.

The surface auditory representation is evaluated by the auditory markedness constraints, evaluating the syntagmatic and paradigmatic relations between fragments of representations. The requirement of maximal perceptual distinctiveness belongs here. From the syntagmatic perspective, the requirement of maximal perceptual distinctiveness accounts for OCP effects. For instance, many languages do not allow [ji] sequences. A constraint on sequence ∗ji can be motivated by the fact that [j] and [i] are to close perceptually and are not likely to be perceived as two segments. Paradigmatically, maximal perceptual distinctiveness shows up in contrast enhancement phenomena. The idea is that any user of a language also evaluates auditory representations standing in paradigmatic relations to each other, that is, compares surface representations of different words which should be most distinctive, when the contrast enhancement constraints are high-ranked. This way optimal inventories emerge, which in fact are nothing else but derivatives of (systems of) constraints evaluating contrasts between words (and not contrasts between segments).

The constraints will be discussed in more detail in section 2.8 of this chapter, and a comparison with other models is offered in section 2.14.

Additionally, following Hume and Johnson (2001), one needs to include extra-phonetic factors which shape the phonology of a language. For example, one has to observe the tendency towards **generalization**: we tend to simplify cognitive representations based on sensory experience and generalize them by associating them with particular categories. This leads in linguistic terms, for instance, to paradigm uniformity.

2.8 Functional Constraints

One deviation from the classical OT in this dissertation consists in the assumption of the functional approach to language, inspired by the works of Passy (1891), Martinet (1955), later Lindblom (1986), and developed by Flemming (1995) and Boersma (1998). Constraints on the surface form serve the functional purposes, either to decrease the physical effort of the speaker, which proceeds by eliminating and simplifying the speech gestures, or to decrease the effort of the listener, by optimizing the acoustic qualities of the speech. In the following, the constraints relevant for the analysis of Polish palatalization processes will be defined.

2.8.1 Auditory Feature Enhancement

Prolonging the duration of a feature

One way to make a feature more distinct is to prolong it. Thus, a family of constraints MaxDur(fAud) has originally been proposed by Flemming (1995) and adopted here as in (13):

(13) MaxDur(f_{Aud})
Maximize the duration of an auditory feature (Flemming, 1995, 53)

For example, in vowel harmony, the duration of a perceptual feature is prolonged onto the neighboring vocalic segment, thus, the big portions of a word are marked by the perceptual feature and contribute to marking a contrast.

An argument for MaxDur comes from Liberman et al. (1967). They argued that acoustic cues have to overlap in order to make the communication efficient. In case they did not overlap, the tempo of speech would be too slow. Were the cues shorter (to speed up the tempo), speech would turn into unparsable buzz. It is schematically illustrated in (14):

(14) Timing of contrastive units

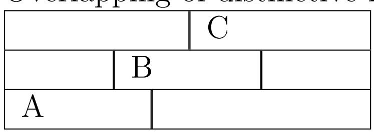
a. No overlapping of distinctive features

		C
	B	
A		

b. Shortening of duration

		C
	B	
A		

c. Overlapping of distinctive features



In (14a) the features have sufficient duration for the perception, however, communicating a string of three features takes a long time. In (14b), the time is shorter, but then, the time for each single feature is not sufficient for perceiving the feature. (14c) illustrates the optimal solution, where the features are sufficiently long, but communicating the string of features takes less time than in the example (14a) due to the overlapping of features.

Thus, it is of benefit to prolong the duration of a perceptual feature onto neighboring segments, because this way we can pack into a period of time more segments without losing the distinctive information. A relevant constraint in the analysis of Polish will be MaxDur([Pal]), PAL for brevity, as in (15):

(15) MaxDur([Pal]) = PAL
Maximize the duration of perceptual palatalization.

The constraint with the opposite effect to MaxDur(f_{Aud}) is auditory faithfulness Ident(f_{Aud}); compare the discussion below.

Feature strengthening

Another way to make a feature more distinct is by adding a perceptual feature. This mechanism is operating both in order to enhance the distinction of a feature within the speech string (syntagmatic enhancement) and to enhance the distinction to other words (or smaller meaningful entities), i. e. a paradigmatic relationship. The former will be a contextual phenomenon, while the latter is context-free adding an extra feature to a phoneme. Flemming (1995, 21) proposed a family of Minimal Distance constraints strengthening the contrast, without distinguishing between the syntagmatic and paradigmatic contrast. Here a constraint referring exclusively to syntagmatic relations is postulated, which we call Enhance:

(16) Enhance(s_1, s_2)(s_1, CueX)
For the string s_1 s_2, the contrast between s_1 and s_2 is enhanced in that the additional cue X has to be realized on segment s_1.

An example comes from Flemming (1995). He describes that in Moroccan Arabic, labials, when followed by a labial glide, are geminated and pharyngealized. The labial in other contexts is realized as plain.

(17) Maroccan Arabic
/bw/ → [bbˤʷ]
/b/ → [b]

2.8.2 Articulatory Markedness

The concept of articulatory requirements in phonology adopted in this dissertation corresponds to that of Boersma's model (1998). It is assumed here that the common property of human behavior, namely, the tendency to save effort, is reflected also in the language behavior in the way that more complex articulations, requiring more time, energy or precision, are avoided.

Constraint against combinations of gestures

It is reasonable to assume that certain gestures and combinations of gestures are more difficult than others. For example, Kirchner (2001) argues that plosives are in general more effort-consuming than non-strident fricatives, because the displacement of the tongue is more radical in plosives (complete closure) than in non-strident-fricatives (only approximation to the roof of the mouth). With respect to gesture combinations, a lateral constriction does not combine well with a fricative manner of articulation. In general, it is easier to produce a ballistic sound (a closure followed by a rapid release) than a (strident) fricative, which requires from the speaker much more articulatory control. Whereas languages usually employ fricatives, a fricative with a lateral constriction is articulatorily more difficult and only seldom appears in the sound inventories of languages. To express this idea formally, a constraint is proposed, as in (18):

(18) *ɮ
No lateral fricatives.

In the same way, several other constraints will be postulated in the further analysis.

Articulatory agreement

From the point of view of articulatory ease, it is advantageous to produce articulation where the beginning and the end of an articulatory gesture do not have to correspond to the edges of the segment but are allowed to spread over the adjacent segments. For example, vowels are often contextually nasalized in the adjacency of nasal consonants. The advantages are following. First, we save effort spent on the control of the gesture timing. Second, if two segments agree in a given gesture completely, it resuls in the elimination of one gesture; therefore, instead of two distinct gestures we end up with just one, which saves us the effort of changing the position of articulators necessary for the two gestures.

(19) Agr (s_1, s_2)(f_{Art})
For adjacent segments s_1 and s_2, and an articulatory feature f_{Art}, f_{Art} has to be adjoined to both s_1 and s_2.

Agr (s_1, s_2)(f_{Art}) is instantiated in Polish by, for example, constraint in (20):

(20) Agr (O_1, O_2)(voice)
Adjacent obstruents O_1, O_2 agree in the position of vocal cords.

Agr (s_1, s_2)(voice) has in Polish the effect of eliminating surface clusters of obstruents which do not agree in voice, e. g.:

(21) Voicing agreement in Polish

a. pro[ɕ]+ić 'ask'
∗pro[ɕ]+ba pro[ʑ]+[b]a 'request, plea'

b. grzy[b]+a 'mushroom'
∗grzy[b]+ki grzy[p]+[k]i 'mushroom', dim.

A constraint relevant for Polish, as argued in chapter 5, is articulatory agreement between vowel and the preceding consonant in terms of the tongue root position:

(22) Agr(C, V)(ATR)
For vowel V, and consonant C, there is agreement in terms of feature ATR.

Agr (C, V)(ATR) is argued in chapter 5 to play an important role in Polish phonology and be responsible for the effects of i-retraction, Velar Fronting, and Surface Velar Palatalization as well as general phonetic Surface Palatalization. For example, when in the context of high front vowel which is always [+ATR], consonants have to be pronounced with the fronting of the tongue root, which produces the effect of surface palatalization. For short, Agr (C, V)(ATR) will be referred to as AgrATR, see (23) below.

(23) Agr (s_1, s_2)(ATR) = AgrATR

2.8.3 OO-Correspondence

The notion of OO-Correspondence in this analysis differs from the standard OT approach. It is argued here that OO-Correspondence must be an auditory-based mechanism. In the speech model presented above in (11), OO-Correspondence is, for example, responsible for the comparison between our own production and the forms articulated by other speakers of a language. Listener/speaker compares his/her production with those of others using the only available tool, namely, the ear.

Another instance of the application of OO-Correspondence is for keeping the members of one category as similar as possible (on the level of morphology, this would lead to paradigm leveling). On the other hand, we would expect that a tendency is to keep members of distinct categories maximally dissimilar. In this study, the latter mechanism is argued to be an important factor shaping the outputs of palatalization in Polish. The constraints, expressing this idea formally, are introduced and defined in the following section.

Enhancing paradigmatic contrast: Minimal Distinction

Whereas previous examples of feature strengthening referred to syntagmatic relation, Minimal Distinction is claimed to affect paradigmatic relations. In this sense, Minimal Distinction is similar to familiar Output-Output correspondence constraints in that it compares forms in a paradigm; however, it compares forms which are not morphologically related, which, in other words, are contrasting. The result of Minimal Distinction is opposite to standard OO-Correspondence constraints: the most dissimilar forms are optimal, promoting the greatest distinctivity. This mechanism will be formally implemented by constraint Minimal Distinction(f_{Aud}), proposed originally by Flemming (1995), as defined in (24):

(24) Minimal Distinction(f_{Aud})=XCues
The minimal distinction between contrasting segments in a given auditory dimension is equal X cues.

MinDist (24) compares the contrasting surface strings of a language, and excludes the forms which contrast elements which are too similar perceptually. An example of its application will be discussed in detail in chapter 4: [ʃ] is not an optimal surface segment in Polish, because it is perceptually too close to other segments of Polish, i. e. [ç] and [š].

Comparison of constraints maximizing contrasts

Flemming (1995) proposed a family of Minimal Distance constraints, which ban contrasts that are not sufficiently distinctive. Referring to Minimal Distance, Flemming analyzes both contextual enhancements, that is, syntagmatic contrasts, as well as contrasts among members of sound inventories of a language, i. e., paradigmatic contrasts.

In the current study, I propose to make a distinction between two types of enhancements. Whereas the syntagmatic enhancement is evaluated by the auditory-oriented markedness constraint Enhance (section 2.8.1), the paradigmatic contrasts can only be evaluated by some sort of anti-faithfulness constraints, that is, evaluating the correspondence between the strings and selecting the most dissimilar candidates.

Special case of paradigmatic auditory enhancement: Preserve Contrast

A special case of auditory feature enhancement occurs when it blocks neutralization of a paradigmatic contrast. For example, vowels are phonetically longer before voiceless sounds. In American English dental stops [t, d] are substituted inter-vocalically with a dental flap [ɾ]. Interestingly, the vowel length is still differentiated before a flap: it is longer before a dental flap in place of voiceless consonant, and shorter when the flap substitutes the voiced [d], though there is actually no voice distinction. This way, a phonetic cue enhancing the voicing distinction is a cue blocking the absolute neutralization.

In our analysis of Polish, it will be argued that the outputs of Coronal and 1st Velar Palatalization have to differ because otherwise the place contrast between palatalized coronals and palatalized velars would be neutralized.

(25) PreserveContrast(Cor-Vel)
The underlying distinction in Place is marked in the surface representation by at least 1 cue.

PreserveContrast is similar to Flemming's MaxContrast. MaxContrast in Flemming's analysis is a positive constraint favoring inventories with bigger number of contrasts. Preserve Contrast acts against the loss of already existing contrasts but does not induce an introduction of new contrasts.

The notion of contrast

In defining PreserveContrast constraints, we refer to the notion of contrast. We can refer to contrast at two levels. First, two distinct surface forms may be significantly different, that is contrasting. Second, the surface distinction is a reflex of a distinction in the mental representation of these forms. According to Kirchner (2001), this surface contrast may only be defined by reference to the distinct underlying representations.

In principle, we should be able to identify any distinction in terms of a single distinctive feature. Thus, for example, the distinction between [t] and [d] can be expressed in terms of feature [voice]. In practice, it is often impossible to identify non-arbitrarily a single distinctive feature marking a contrast. One such case discussed by Kirchner (2001) is when two or more features are mutually predictable. Kirchner's example is a set of voiced sonorants: if all sonorants in a given language are voiced, and all voiced sounds are sonorants, then there is no such output pair that differs only in feature [voice] or only in feature [sonorant]. In the model proposed here, where each lexical item has both articulatory and auditory representation, it is obvious that a distinction between two segments is marked by both articulatory and auditory features. Kirchner proposes to talk about contrastive feature sets, without forcing a choice between [voice] and [sonorant]. In what follows, I will develop this line of reasoning and refer to contrasts between broadly understood feature sets: I will refer to contrasts between categories of a language, i. e. between segments or natural classes of segments. For example, constraint Preserve-Contrast[Dor-Cor] induces a surface contrast between correspondents of an underlying coronal and an underlying velar consonant.

2.8.4 IO-Faithfulness Constraints

Arguing for IO-Perceptual Faithfulness

Some mechanism utilizing IO-perceptual (auditory) faithfulness is necessary for a number of reasons. When we listen to a string of speech that is decomposed into a string of phonological auditory features, in order to recognize a meaningful unit of speech one needs to compare the surface representation (obtained from decoding the acoustic signal) with the underlying representation. This is performed by IO-auditory faithfulness constraints. Also, when the normal articulation is not possible, e. g. because of teeth loss or a surgical operation of the speech organs, we are able to change the production without much trouble, to achieve the effect most similar to that which is socially acceptable. It seems then reasonable to assume that what is stored in our memory is not only the correlates of articulation but also the information about the perceptual features of the signal of speech: an output produced by speakers with some deficits of speech organs will have to be faithful to the auditory – and not articulatory – features stored in the underlying representation.

The role of IO-Perceptual Faithfulness is described in the following section.

IO-Perceptual Faith

It is assumed here that IO-Auditory(Perceptual) Faith constraints compare the perceptual features of the output representation and the perceptual features of the input representation. Their role is that of limiting the extent to which the surface representation may undergo articulatory- and auditory-driven modifications: the output must be similar (i. e. to some extent faithful) to the input, otherwise, the underlying representation is not recoverable from the surface representation. The idea is that the faithfulness does not always have to be treated in absolute terms but rather a requirement of a relative similarity has to be fulfilled; that is, the output may not differ from the input in more than X features. The concept is expressed by the constraint Maximal Distance, as defined in (26):

(26) IO-MaximalDistance(f_{Aud}) = X Cues
An output does not differ from the input with respect to a certain feature dimension by more than X Cues.

For example, underlying [l^j] may be rendered on the surface as [l], because only one auditory cue is different, where [HighestF2/F3] is rendered as [HighF2/F3]. However, a candidate with [f] is not optimal, because it differs from the underlying [l^j] in too many respects: it has [LowF2/F3], friction, etc.

In our analysis we adopt the optimality theoretic families of constraints of Ident and Dep. They are to be understood as particular cases of Maximal Distance. Ident(f) is simply IO-MaxDist(f)=0Cues, where the additional meaning of the "directionality" of comparison is incorporated.[6] The constraints in this study differ from their classical OT counterparts additionally in that they refer to auditory features. For example, in chapter 4, it will be argued that palatalization in the absence of a surface trigger is due to the operation of constraint Ident(Pal), defined as in (27):

(27) Ident([Pal])
An auditory feature [Pal], when present in the UR, has to be realized in the output.

The effect of Ident ([Pal]) is the rendering of perceptual feature palatalization on the surface even if there is no vowel to trigger auditory assimilation.

On the other hand, Dep([Pal]) is a constraint against introducing a perceptual [Pal] feature in the surface representation, when it does not correspond to the feature [Pal] in the underlying representation.

(28) Dep([Pal])
No [Pal] in the surface representation if it does not correspond to [Pal] in the underlying representation.

[6] One might extend the "directionality" distinction onto all Maximal Distance constraints; that is, differentiate between the number of cues in the surface representation which are deleted in comparison to the underlying representation, and the number of cues which are inserted. Polish data, however, did not provide any evidence to necessitate this distinction.

Articulatory Faithfulness

Faithfulness constraints holding between input and output will also operate for articulatorily defined features, which is a necessary condition for the efficient working of the whole system: in order to efficiently produce an output, we need to render faithfully the existing underlying articulatory representation.

2.8.5 Higher-level Functional Factors

In their general model of the interplay of external factors and phonology, Hume and Johnson (2001) point to a somewhat neglected issue; namely, they include in their model factors which they call "higher level effects". The assumption is that – apart from articulatory and perceptual constraints – there are other external factors which influence phonology, that is, our tendency to generalize the system and the tendency to conform to a linguistic and social system, as briefly introduced below.

Generality

A tendency to simplify the cognitive representations reflecting the perceived sensory experience enables the category formation in general. This is a general property of cognitive systems, which is not restricted to language perception. In language, this principle is responsible for paradigm leveling and analogy. Of course, we cannot go too far in eliminating details from the cognitive representation, because otherwise we jeopardize communication, thus, the tendency for generalization is constrained by the tendency to maximize the distinctivity.

Conformity

We have a need to conform to socially accepted patterns of behavior. This is also the case in our language use: speakers will use the linguistic forms which are better identified and accepted. An example here is the choice of socially more well accepted dialects or of pronunciation patterns. This factor is not further discussed in the present study.

Uniformity

A natural tendency of the human cognitive system is to form categories, and to categorize what we perceive according to these categories. In language, the reflexes of underlying representations which are categorized together (for example, according to some semantic criterion) will tend to surface as the same, which is supposed to facilitate categorizing the instantiation into the appropriate category. This tendency is reflected in the phenomenon of paradigm leveling, compare Kuryłowicz (1947), Mańczak (1958), and in OT framework, for example, Benua (1995), McCarthy (1995). With respect to phonology, it will be argued here that the tendency to produce uniform output for the different realizations of semantically related words, referred to as uniformity, will be responsible for the effect of derived environment, see section 2.10 of this chapter. Before we proceed to discuss the effects of derived environment, let us postulate a constraint Uniformity:

(29) Uniform
Semantically related words are surface uniform in terms of auditory features.

Note that Uniform as defined in (29) is different from the OT Uniformity constraint. Uniform (29) is a constraint evaluating the correspondence of the output forms (OO-Correspondence), the OT Uniformity refers to the IO-faithfulness relations.[7]

Because the goal of Uniform is to facilitate the assignment of the surface representation as an instantiation of some underlying representation, or as a member of some category, in order to facilitate recognition, it seems appropriate to limit Uniform to auditory features only. For this reason, there are no surface correspondence relations in terms of articulatory features in the proposed system.

2.9 Macro-constraints

Constraints may act independently, however, their requirements may also be coordinated, as in Smolensky (1995), (1997), Crowhurst and Hewitt (1997).

Crowhurst and Hewitt (1997) provide a formal theory describing possible patterns of coordination of constraints. They observe that patterns of constraints coordination show parallels with classical logical operations of Boolean logic; that is, one can distinguish between conjunction, disjunction, and implication, as in (30).

(30) Complex expressions
a. conjunction $A \wedge B$ ‘A and B’

[7] Uniform: “no element of output has multiple correspondents in the output” – blocking the coalescence of the underlying segments, cf. McCarthy and Prince (1999), Kager (1999).

b. disjunction A $\vee$ B 'A or B'
c. implication A $\Rightarrow$ B 'If A, then B'

The truth value of a conjunction of expressions is defined in Boolean logic in a following way:

(31) Boolean Conjunction (Crowhurst & Hewitt, 1997, 7)
The Conjunction A $\wedge$ B is true, iff proposition A is true and proposition B is true.

In a similar way, a coordination of constraints is to be interpreted as below:

(32) Constraint Conjunction (Crowhurst & Hewitt, 1997, 7)
A candidate Cand passes a conjunction A $\wedge$ B iff Cand passes constraint A and Cand passes constraint B.

This is summarized in tableau (33):

(33) Conjunction

Constraint A	$\wedge$	Constraint B
	*	*
*	*	
*	*	*

Notice that Smolensky's approach (1995) and (1997) to Local Conjunction is different: A candidate only fails if and only if it fails on both members of the conjunct (and not that it passes the conjunct iff it passes both constraints). An approach like that of Smolensky reflects Boolean disjunction:

(34) Disjunction (Crowhurst & Hewitt, 1997, 53)

a. Boolean Disjunction
The disjunction A $\vee$ B is true iff proposition A is true or proposition B is true.

b. Constraint Disjunction
A candidate Cand passes a disjunction A $\vee$ B iff Cand passes a constraint A or Cand passes constraint B.

Unlike in Crowhurst and Hewitt (1997), I assume that the interpretation of the disjunction rests upon the interpretation of the operator OR. If we assume the inclusive reading of OR, the disjunction is satisfied if either proposition A is satisfied, or if proposition B is satisfied, i. e. if both of them are satisfied, the whole expression is also satisfied, as in table (35a). However, it is also plausible to assume the exclusive reading of OR (Logical Inequivalence), and then the whole disjunction would only be satisfied if either A or B is satisfied, that is, if both are satisfied, the expression is not true (35b).

(35) Constraint Disjunction

a. inclusive OR

Constraint A	∨	Constraint B
		*
*		
*	*	*

b. exclusive OR

Constraint A	∨	Constraint B
	*	
		*
*		
*	*	*

The fact that perceptual palatalization occurs only in an alternating environment is expressed formally by a disjunction of constraint PAL (15) and constraint Uniform (29):

(36) PAL ∨ Uniform
Palatalization occurs only when Uniform is violated.

The effect of (36) is such that only forms which contain no palatalization in a uniform environment, and forms which contain palatalization in a non-uniform environment may be optimal in Polish. Thus, it will be argued that we need to refer to the exclusive reading of OR, see the discussion in chapter 4. On the other hand, other examples of the disjunctive constraint interaction will refer rather to the inclusive OR, see chapter 5.

2.10 Morpheme Boundary Phenomena

Palatalization effects in Polish can be divided into two classes: those that apply across-the-board, whenever the environment is met, and those that require the so-called derived environment. In the following sections, we will turn now to the issue of defining the derived environment. Before we propose a way to define derived environment in the spirit of the functional OT, let us have a closer look at the problem and at the previous solutions to it.

2.10.1 Derived Environment, Cyclic and Lexical Phonology

It is often assumed that most palatalization processes in Polish apply across morpheme boundaries only; that is, only if the target is stem-final and the trigger is suffix-initial, and the adjacency is due to morpheme concatenation. This condition on the application of palatalization in Polish has been formally expressed in terms of the so-called derived environment as in Rubach (1984). The notion of derived environment has been defined in Kiparsky (1973)), see (37).

(37) Derived environment
(Kiparsky (1973), cited after Rubach (1984))
   a. Two segments are separated by a morphological boundary.
   b. A segment is created in the course of phonological derivation, i. e. it is not present at the underlying level but rather it is derived by applying a rule.

The Cyclic and Lexical Phonology analysis was that palatalization applies only across morpheme-boundary because it is cyclic, and cyclic rules are subject to Strict Cycle Condition, as below:

(38) Strict Cycle Condition
(Kiparsky, 1982, 4)
   a. Cyclic rules apply only to derived representations.
   b. Definition: A representation ϕ is derived w. r. t. rule R in cycle j iff ϕ meets the structural analysis of R by virtue of a combination of morphemes introduced in cycle j or the application of a phonological rule in cycle j.

Rubach (1984) applied this notion to account for the lack of palatalization in forms such as those in (39):[8]

[8] Notice that any explanation referring to co-phonologies, where palatalization applies in native vocabulary and not in the vocabulary of foreign origin, cannot be a solution, since all the listed words are native Polish.

(39) No palatalization morpheme-internally

[bɛ]z	'without'
[pɛ]st+k+a	'seed/stone inside the fruit'
[tɛ]n	'this'
[dɛ]ntyst+a	'dentist'
[sɛ]r	'cheese'
[zɛ]+rw+a+ć	'to pick up, tear off'
[kɛ]lner	'waiter'
[gɛ]rber+a	'kind of flower'

2.10.2 OT and Derived Environment

In OT, we still have to account for the derived environment effects. In the following, we will present the OT approaches to the derived environment effects discussed in the literature and show why another solution of the derived environment problem needs to be proposed.

One solution, which is not going to be adopted here, is to propose that satisfaction of faithfulness constraints for the roots is more important cross-linguistically than for the non-root morphemes (McCarthy & Prince, 1995). Thus, a constraint ranking as in (40) is claimed to hold universally:

(40) Root-Faithfulness >> Faithfulness

Within this approach, a blocking of a markedness constraint morpheme-internally may be easily accounted for by the ranking of a markedness constraint higher than the general faithfulness constraint, and lower than the root-faithfulness:

(41) Root-faithfulness >> Markedness >> Faithfulness

Kager (1999) illustrates this mechanism on the example of the nasal substitution in Indonesian. In verbs prefixed by /məN−/, the unspecified for place nasal consonant of the prefix is coalesced with the consonant of the stem when it is voiceless consonant, leaving a nasal with the articulation place of the voiceless consonant, e. g.:

(42) Indonesian nasal substitution (Kager, 1999, 59)

məN+pilih	>	məmilih	'to choose, to vote'
məN+tulis	>	mənulis	'to write'
məN+kasih	>	məŋasih	'to give'

The data in (42) is accounted for by a constraint $*N\mathring{C}$ (no nasals followed by voiceless consonants). However, as observed by Pater (1999), the nasal substitution does not occur morpheme–internally. Pater proposes a root-particular version of Linearity-IO, as defined in (43).

(43) RootLinearity-IO
The output reflects the precedence structure of the input segments of the root, and vice versa.

and further, a ranking as in (44):

(44) Blocking of root-internal fusion
RootLin-IO >> $*\mathrm{N}\mathring{\mathrm{C}}$ >> Linearity-IO

A ranking in (44) may correctly predict the surfacing of nasal+voiceless consonants morpheme-internally, see tableau (45):

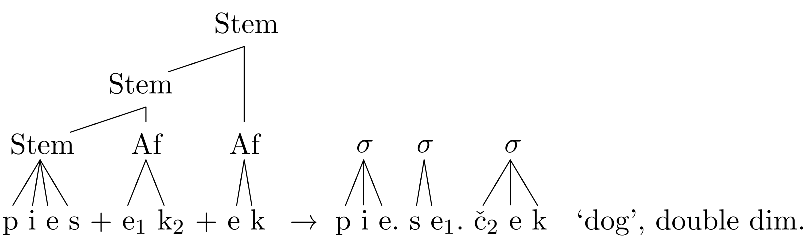
(45) Blocking of root-internal fusion in Indonesian: example

Input: /ə$m_1p_2$at/	RootLin-IO	$*\mathrm{N}\mathring{\mathrm{C}}$	Linearity-IO
a. ☞ ə$m_1p_2$at		*	
b. ə$m_{1,2}$at	*!		*

Unfortunately, this solution is not applicable to Polish palatalization: it would explain why there is no palatalization morpheme-internally, but then we would have to explain why palatalization does happen to the stem-final segments: it is a stem consonant that undergoes palatalization across morpheme boundary.

Another approach has been proposed by Łubowicz (1998). She observes that, since the relevant palatalizing suffixes in Polish are necessarily vowel-initial, and since a preceding consonant will always syllabify as an onset for the suffix-vowel, then the constraint which requires the rightmost edge of the stem to correspond with the rightmost edge of the syllable will always be violated in forms with palatalization. This is illustrated in (46):

(46) Violation of stem: syllable anchoring among suffixes (Łubowicz, 1998, 24)



In (46), the [k_2] of the first affix is treated as stem-final. It will be syllabified as an onset of the final syllable if we add another suffix *–ek*. Thus, the right edge of the stem ([$\check{c}_2$]) does not correspond on the surface to the right edge of the syllable, which is [e_1].

Łubowicz (1998, 24) postulates in her analysis the R-ANCHOR(Stem; δ) constraint, as quoted in (47). Then she procedes to analyze the derived environment problem in terms of local conjunction of R-ANCHOR(Stem; δ)[9] and a constraint inducing palatalization (in her approach understood as articulatory spreading):

(47) R-ANCHOR(Stem; δ)
The rightmost segment of a stem in the input has a correspondent at the right edge of a syllable in the output.

The following constraints were not defined in Łubowicz (1998):

(48) Pal
Denotes adjoining of feature Coronal to the preceding consonant.

(49) R-ANCHOR(Stem; δ) & Pal
Understood as "palatalize when R-ANCHOR(Stem; δ) is violated".

A conjunction (49)[10] is violated when both of its member-constraints are violated. Thus, when only the first one is violated, or only the second one is violated, or none of them is violated, then the conjunct is not violated either, see the table (50) below.

(50) Local conjunction (as adopted in Łubowicz (1998))

	R-ANCHOR(Stem;δ) & Pal	R-ANCHOR(Stem;δ)	Pal
i.	non-violated	violated	non-violated
ii.	non-violated	non-violated	violated
iii.	non-violated	non-violated	non-violated
iv.	violated	violated	violated

A summary is provided in (50) above, of when the conjunction is violated and when it is satisfied. In case i., when the stem edge does not correspond to the syllable edge (derived environment) and when palatalization does take place, there is no violation of a conjunct. In case ii., when the stem edge does correspond to the syllable edge (non-derived environment) and when palatalization does not occur, the correct output is also delivered. In case

[9] ANCHOR is a faithfulness constraint, see McCarthy and Prince (1995), Benua (1995), or McCarthy (2000).

[10] As postulated by Smolensky (1995) and (1997), which corresponds in the terminology adopted in this dissertation to disjunction, compare section 2.9.

iv., when the stem edge does not correspond to the syllable edge (derived environment) but palatalization does not occur, there is a violation of the conjunct. Notice that situation iii., when both members of the conjunct are satisfied, should in principle deliver a correct output, assuming the definition of Local Conjunction as adopted in Łubowicz (1998). Yet, this does not correspond to the surface true facts: the segments which morpheme–internally vacuously satisfy Anchor may not undergo palatalization. The actual table for the Polish data should be rather as below:

(51) Actual surface forms in Polish with respect to the two constraints

	Surface true or not	R-ANCHOR(Stem;δ)	Pal
i.	desired surface result	violated	non-violated
ii.	desired surface result	non-violated	violated
iii.	not expected	non-violated	non-violated
iv.	not expected	violated	violated

That is, the relationship between the two constraints is rather that of a Logical Inequivalence (exclusive OR), where the expression is true only if one of the subexpressions is true, but not if both subexpressions are true. To exclude case iii. of Local Conjunction (cf. tableau (51) above) from the discussion, Łubowicz argues (1998, 24-25):

> Since Palatalization is activated by the violation of anchoring, there is no Palatalization of a segment that vacuously satisfies anchoring, such as tautomorphemically. Only stem final segments can palatalize, precisely because only such segments can incur a violation of anchoring. (...) The locally conjoined constraint is only relevant when the palatalizing segment is stem final (...) Otherwise, the conjoined constraint has no force, and so lower-ranked constraints are decisive.

It seems that this argumentation is equal to saying that some candidate is not evaluated with respect to a particular constraint, because there is no way this candidate can violate the given constraint. I am not aware of other formal applications of the distinction between vacuous and non-vacuous application of a rule/constraint/generalization.

A more serious problem, for the account proposed by Łubowicz comes from Polish data involving yer-initial suffixes; as is illustrated in (52):

(52) drog+a ‘way’
dró[ž]+k+a UR: /dróž+ьk+a/ ‘way, diminit.’
for ь=palatalizing yer

One would have to assume syllabification at the underlying level, because the final segment of the stem would obligatory syllabify as an onset of the following syllable only at the underlying level. If the output surface syllabification is considered, according to the definition given by Łubowicz (1998, 24), the Anchor constraint is not violated, because, in the absence of a surface nucleus, the final segment of the stem syllabifies as a coda to the syllable containing other segments of a given morpheme. (53) illustrates the most likely surface syllabification.

(53) Surface syllabification of forms containing a yer

σ σ

d r u ž . k a

If we wanted to evaluate the syllabification with the vocalic segment, we would have to refer to the underlying representation (input). First, we would have to assume that there is syllabification on the input already, stored in the lexicon. Second, we would have to evaluate the input – which is against the theorem of Richness of the Base, as in (4).

One can also ask about the external grounding of a Pal & ANCHOR conjunct: is it articulatory, acoustic, perceptual or psychological? What is the particular relation between triggering palatalization and the correspondence between the edge of a morpheme and its syllable affiliation on the surface? This relation seems unclear and rather arbitrary, and simply an artifact of the theory.

2.10.3 An Alternative Proposal to the Derived Environment Problem

In what follows, I propose an alternative solution to the derived environment problem. This idea was inspired by Timberlake (1978) (cited after Bybee (2001)), who distinguished between alternating versus non-alternating environments in language change.

What differentiates the morpheme-boundary environment from a stem-internal environment on the surface is the fact that in the across-the-morpheme environment different sequences of neighboring segments may occur: throughout the paradigm and within a word family. Let us, for example, consider the paradigm of '*sinus*':

(54) Paradigm of *sinus* 'service'

Nom.	[sinus], [sinusɨ]
Gen.	[sinusa], [sinusuv]
Dat.	[sinusovi], [sinusom]
Acc.	[sinus], [sinusɨ]
Instr.	[sinusɛm], [sinusami]
Loc/Voc.	[sinuɕe], loc. pl. [sinusax]
Dimunitive	[sinuɕik], etc.

Whereas after s_1 of $s_1$inus$_2$ – throughout all the forms of the paradigm – the sequence of the following segments is *-inu...*, s_2 is followed by a number of various segment sequences. This might account for a different status of the segments: s_1 will not palatalize, s_2 will undergo palatalization.

Let us define formally the alternating versus uniform environment.

(55) Alternating environment: Definition
For A, which is a target, B – a potential trigger, C(C) – an adjacent segment, an environment is alternating when there is more than one surface realization of the underlying sequence of A, B, C within the set of morphologically related surface forms.

An alternating environment refers to morpheme-boundary environments, where A and B belong to a separate morpheme, as in (56).

(56) Environment

Non-alternating	Alternating
AB+C, AB+D	A+B(C), A+(C)

for A = target, B = environment, C, D = adjacent segments

An alternating environment would encompass also the cases of the derived environment without a morpheme boundary, i. e., where it has been created via the application of earlier rules within the framework of cyclic/lexical phonology, or using OT formalism, when the generalization holds for only those surface candidates which are unfaithful to the input anyway:

(57) ABC versus AC
or
ABC versus ADC

The difference in the application of certain constraints in the alternating versus non-alternating environments may be motivated by learning strategies characteristic to the human cognitive system. In a uniform environment, we have no positive evidence for the application of any constraint the representation obeys. An alternating environment, in contrast, makes the generalization more salient; it is more obvious that there is some requirement on the surface form depending on the properties of the environment, since the same word may surface with different environments. In the end, markedness requirements may be blocked by the faithfulness constraints in the uniform environment more likely than in the alternating environment, cf. Anderson (1981), and for the discussion of Alternation Condition of Kiparsky (1973) and (1982). Thus, whereas Łubowicz's solution is more abstract (e. g. it employs the notion of syllabification), the concept of the alternating versus uniform environment refers to surface sequences of segments, and might be psychologically grounded.

Formally, to distinguish between the alternating and uniform environment, a constraint Uniform is postulated:

(58) Uniform$_{ABC}$
A sequence of segments A, B, C is realized on the surface in a uniform way throughout a paradigm and related word forms, where A, B, C are adjacent segments out of which A is a potential target of a generalization, B – a potential trigger, C – an adjacent segment to B.

For example, in the word [sinusax], cf. (54), the sequence [sin−] satisfies Uniform because it is rendered uniform throughout the paradigm. In contrast, [−sax] violates uniform because, first, [s$_5$] may be followed by a different sequence of segments [−ə], [−ami], [−Ø], and, second, [s$_5$] itself may correspond to another segment which differs in the featural make-up, i. e. [ɕ], see (54).

A constraint limited to the alternating environment may be formally expressed as disjoint with Uniform, see (59):

(59) Constraint X$_{ABC}$ ∨ Uniform$_{ABC}$
A disjunction Constraint X$_{ABC}$ ∨ Uniform$_{ABC}$ is satisfied when either Constraint X$_{ABC}$ is satisfied, or Uniform$_{ABC}$ is satisfied.

The effect of the disjunction in (59) is that it is as if any constraint (Constraint X)is activated by the alternating environment.

The two approaches, that of Łubowicz (1998) and the one proposed here, would make different predictions in one respect. Notice that Łubowicz's solution makes a principal distinction between the two kinds of derived environment as in (37). The derived environment of a morpheme boundary will be explained by a conjunction with ANCHOR constraint, and the environment derived resulting from a prior application of a rule will be expressed by a conjunction with faithfulness: a surface effect will only occur when the underlying feature is not faithfully rendered on the surface. In Polish, we have a few examples which might potentially constitute a problem to Łubowicz's proposal, that is, in some cases palatalization processes which occur at a morpheme boundary might also be claimed to apply in the absence of a morpheme boundary where the derived environment is created by yer lowering. Then, accepting Łubowicz's solution with a constraint conjunction, we would have to analyze the same palatalization effects with the help of two different constraints depending on whether the environment is derived by morpheme concatenation or by faithfulness violation. Consider the forms in (60):

(60) a. płótno płó[ʨen]+n+y 'cloth' n. – 'cloth' adj.
b. oɕem ósm+y 'eight' – 'eighth'
c. kroɕen krosn+a 'loom' gen. pl. – nom. pl.

It is evident that palatalization is not underlying, but must come from a process of palatalization triggered by a vowel. It seems also that the correct analysis of these facts requires an assumption that it is the deletion of an underlying vowel rather than vowel epenthesis (compare e. g. Gussmann, 1980; Rubach, 1986), since the same sequences of consonants may appear without vowels as well, see (61):

(61) No need for vowel epenthesis

dr:	cedr 'cedar'	puder 'powder'
zł:	wiózł 'drove', 3rd sg. masc.	węzeł 'node'
sł:	rósł 'grew', 3rd sg. masc.	suseł 'ground-squirrel'

Thus, for words such as *płócienny* in (60), one would like to assume an underlying form like /płutъn+ъn+ɨ/. Notice that the palatalized consonant does not appear at the edge of the stem; it satisfies the conditions of the derived environment, because palatalizing [e] is derived (second case of the derived environment), but local conjunction with ANCHOR constraint does not deliver the correct output here – palatalization cannot apply.

One could try to analyze the data in (60) in a different way. (a) might be analyzed as having an underlying palatalized coronal, which in forms where the coronal is followed by a coronal nasal consonant undergoes depalatalization. In fact, a rule of depalatalization of palatalized coronal stops before coronal continuants were postulated both by Gussmann (1978), and Rubach (1984), as it was claimed that there are no words containing surface strings like [ʨl ʥl, ʨn, ʥn, ʨr, ʥr]. A counterexample to this statement of the rule is the word *ćlamać* [ʨ]lamać – Warsaw coll. 'eat slowly'.[11] It is difficult to say whether the rule is to be stated in a more restrictive way, or the lack of some sequences in the native vocabulary is merely an accidental gap, or the generalization should be viewed in diachronic terms.

(60b) cannot be analyzed with an underlying palatalized sound, as there is no depalatalization of continuants (see (62a)), and there is no depalatalization before labial sonorants, see (62b) :

(62) a. gło[ɕn]y 'loud'
mro[ʑn]y 'frosty'
[ɕl]epy 'blind'
[ʑl]e 'bad, Adv.'
[ɕr]oda 'Wednesday'
[ʑr]ebię 'foal'
b. [ʨm]a 'moth'
wie[ʥm]a 'witch'

Alternatively, we could assume that the form *osiem – ósmy* has to be analyzed as a lexicalized alternation, similarly like the example in (60c). Notice that when forms like *krosien* would have to be analyzed as having two underlying allomorphs, forms like *głos – głośny* (UR głos+ьn+ɨ; where a trigger of palatalization never surfaces) can and will be analyzed as containing an underlying /s/ palatalizing before the front yer, only because the morpheme boundary is there. Forms like *krosien* and *głośny* will have to be analyzed by means of different theoretical mechanisms.

As far as the alternating condition solution proposed here is concerned, it makes different predictions from the Anchor solution. It does not make an à priori distinction between the environment at the morpheme boundary and the cases where the target segment finds itself in an alternating environment due to requirements of other higher-ranked constraints. One has to admit that there is a very limited number of examples of the type listed in (60), containing coronal consonants. A more convincing set of data is morpheme-internal Velar Fronting (Rubach, 1984), which will be discussed in chapter 5.

2.11 Perceptual Features

If we assume there are constraints which refer to perception, we need a set of perceptual features. In this section, a set of perceptually (auditory) defined

[11] The word comes from Warsaw dialect, where other sequences involving coronal affricate and sonorant are also allowed: *cle* [ts]le, tle, Człuchów [tšw]uchów.

features assumed in this dissertation will be reviewed. No claim is made that the presented set should be sufficient and non-redundant for the description of phonological phenomena in general; it should be treated as a working hypothesis.

Following Flemming (1995), I assume features referring to the value of formants. First of all, however, one has to assume a perceptual distinction between sounds with a clear formant structure (sonorants), and those without clear formant structure. This is formalized by the feature [Formant] proposed in (63):

(63) [Formant]
[Formant] are sounds with clear formant structure throughout their whole duration.

This way, obstruent sounds differ from sonorants, see (64):

(64) [Formant]

vowels	glides	laterals	rhotics	nasal consonants	obstruents
+	+	+	+	+	

In Flemming (1995), formants F2 and F3 are two distinct dimensions of contrast, specified by binary features. For instance, F2 dimension might be defined as in (65), and specified by features [Highest F2], [HighF2], [LowF2], and [LowestF2] as, in the example of Polish vowels, in (66).[12]

(65) F2 dimension
The Frequency at which second formant appears in the spectrum.

(66) Example for specification of vowels on the F2 dimension (based on Polish vowels, cf. chapter 3)

F2	i	e	ɨ	ɛ	a	o	u
Highest F2	+	+					
High F2	+	+	+	+			
Low F2					+	+	+
Lowest F2							+

It seems that the value of F3 is not independent. When F2 is extremely high, then it merges with F3 into one broad peak. In these cases, the value of F3 is on its own higher than in cases when there is a greater distance to F2. Bladon (1986) argues that formants – when located close to each other

[12] Feature specification in (66) below differs from the examples given in Flemming (1995, 16) in that a different set of vowels is specified and also a different number of distinctive binary features is utilized.

– are perceived as one perceptual cue. Thus, for example in [i], F2 and F3 would be perceived as one cue with its central value higher than F2 itself. For this reason, I do not assume separate perceptual dimensions [F2] and [F3], but rather [F2/F3], as below. Features in the F2/F3 dimension will be then defined in the following way:

(67) Features in F2/F3 dimension
[Highest F2/F3] sounds have F2 and F3 merged at highest frequencies.
[HighF2/F3] sounds have high F2 values and F3 values, but F2 and F3 can be distinguished in the spectrogram.
[LowF2 and F3] sounds have low F2 and F3 values, and F2 tends to merge with F1.

(68) Specification of vowels on F2/F3 dimension

F2/F3	i	e	ɨ	ɛ	a	o	u
Highest F2/F3	+	+					
High F2/F3	+	+	+	+			
Low F2/F3					+	+	+
Lowest F2/F3							+

In the further discussion we will refer for brevity to the height of F2.

It is not only vowels that are perceived on the basis of the height of formants. The value of formant transitions are the important cues for the perception of the place of consonants (together with the duration of the transition, frequency, intensity, and duration of the noise portion, etc.; compare, for example, Pickett (1999), Machelett and Tillmann (1998)). Coronal consonants have regularly high value of F2 transitions. For labials and velars, the value of F2 depends very much on the following vowel or on the secondary articulation of the consonant: in the context of a high front vowel or secondarily palatalized consonants, they have transitions similar to that of coronals, otherwise the F2 transitions are low. In the context of a front vowel, the level of F2/F3 values for labials and velars corresponds to that of the front vowels. In the case of the secondary palatalization of the consonant itself, the values are very high, corresponding to that of the context of a front high vowel [i], irrespective of the nature of the following vowel.

(69) Surface specification of consonants with respect to F2 transitions

	labial	palatalized labials	coronal	palatalized velars	velar
F2 and F3 transitions	Low F2/F3 (plain or velarized) or High F2/F3 (before front mid vowel), Highest F2/F3 (before front high vowel)	Highest F2/F3	High F2 (not secondarily palatalized) or Highest F2/F3 (secondarily palatalized)	Highest F2/F3	Low F2/F3 (plain) or High F2/F3 (before the front mid vowel), Highest F2/F3 (before the high front vowel)

This situation leads to the higher rate of misperceptions in the case of phonologically plain labials and velars; that is, when in the context of high vowels, labials and velars will be often misperceived for coronals, cf. the discussion in chapter 1.

In addition to formant transitions, important cues for the perception of consonants are the presence versus absence of a distinctively long friction and the properties of the friction that sounds produce. First of all, the listener makes a difference between sounds containing a distinctive friction and those without it. The distinctive friction (in contrast to the normal burst of noise after plosives) is on average longer for a given place of articulation,[13] see for example (70):

[13] The length of transitions as well as the length of the friction period depends on the place of articulation. Dentals (alveolars) have usually much shorter friction because the tongue tip is a very flexible articulator, able to perform quick movements. This is not the case for the back of the tongue, which needs much more time to assume the position required for the production of the consecutive sound. Labial stops usually have very weak (low intensity) and short burst.

(70) Length of the noise portion in stops and affricates[14]

Sound/environment	Friction length (sec.)
MR1/ti	0.058
MR1/ta	0.026
MR1/ki	0.097
MR1/ka	0.028
MR1/ʨi	0.102
MR1/ʨa	0.045
MR1/tšɨ	0.079
MR1/tša	0.038

In speaker MR1, the length of the burst of noise for stops lies between 0.026 sec. and 0.058 sec. Only the velar stop [k] in the context of high front vowel [i] has an extremely long noise period (0.097 sec.), corresponding to the values for affricates. Affricates have the friction portion between 0.045 sec. and 0.102 sec. long. The length of noise in fricatives is, naturally, still longer. Thus, it is postulated here that obstruents may be described by means of features [Friction]:

(71) [Friction]
Presence of a longer period of noise.

Fricatives and affricates will contain the feature [Friction], and further, velar stops in the context of a front vowel may be easily reanalyzed as also containing [Friction].

Additionally, fricatives and affricates may be subdivided into two groups according to their stridency.

(72) [Strident]
Strident sounds are those with noise of relative high frequency and intensity. (cf. Crystal, 1991; A Grand Dictionary, 1991)

The specification of obstruents with respect to features (71) and (72) is summarized in (73):

(73) Noise features for consonants

	p	f	t	ts	s	tš	š	ʨ	ɕ	x
Friction		+		+	+	+	+	+	+	+
Strident				+	+	+	+	+	+	

The qualities of friction are important not only for the fricatives but also for

[14] After the study by Ćavar and Hamann (2001).

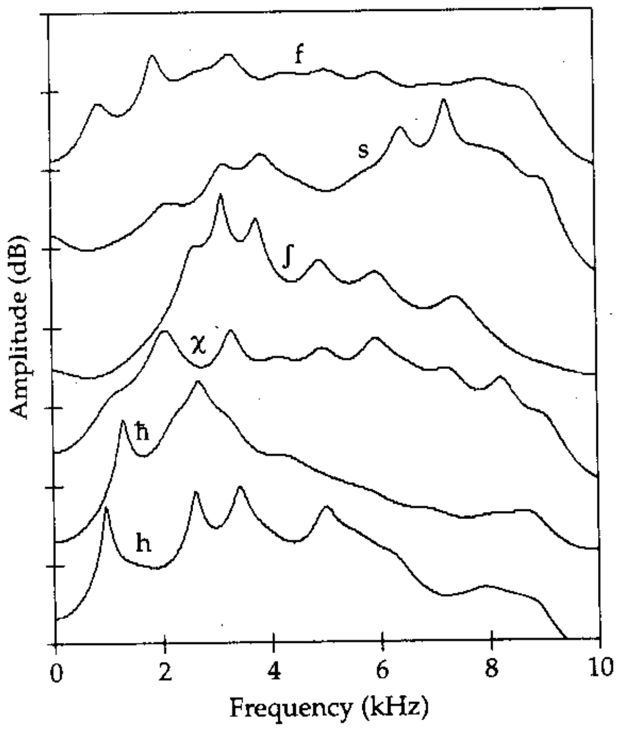
the perception of affricates, which contain a clear noise component, and for plosives, which end in a plosion/burst of noise, and the properties of which correspond to those of fricatives articulated in the same place of articulation. Assuming that affricates contain a perceptual feature [Friction] does not mean to say that they are articulatory [+continuant]. An articulation of fricatives requires a targeted gesture distinct from the closure. In affricates, the friction arises as a side effect of closure, and I assume that affricates are articulatory [−continuant].

Coming back to the properties of friction, Flemming (1995) identifies features such as Noise Frequency, Diffuseness, Noise Intensity, and Intensity. For our purposes, I adopt the dimension Noise Frequency, cf. Flemming (1995, 17).

(74) Noise Frequency
Frequency where energy is concentrated in the spectrum of noise component.

Noise Frequency may be specified in terms of the frequency where the concentration of energy in the spectrum of a fricative is to be observed. In general, for velar and coronal sounds the frequency depends on the size of the cavity in front of the constriction: the larger the cavity, the lower the frequency of the peak amplitude (Flemming, 1995), independent of the language we study. We can observe this relation in figure (75) below, which presents measurements of the fricatives of Egyptian Arabic, but a similar relation between the size of the front cavity and the frequency would hold for any language. Whereas the major peak for [s] (small cavity in front of the constriction) is found between 6-8 kHz, the major peak for [ʃ] (bigger cavity) lies at nearly 4 kHz, for velar [x] slightly lower at 2-3 kHz, and pharyngeal [ħ], and glottal [h] (biggest cavity) between 1 and 3 Hz.

(75) Spectra of fricatives of Egyptian Arabic (followed by long [æ:]) (Johnson, 1997, 121)



For labials,

> (...) there is effectively no front cavity, so the spectrum is relatively flat, but lower frequencies dominate because the amplitude of the noise source is greater at lower frequencies and radiation losses are greater at higher frequencies. (Flemming (1995, 17), cf. Fant (1960))

In the diagram (75), the highest amplitudes for [f] are at 2–3 kHz, similarly like for the velar fricative. Since it is sometimes difficult to identify spectral peaks (though general spectral shapes do support the theory), Flemming (2002) proposes alternatively 'center of mass' as a correlate of Noise Frequency (Jassem (1979), Forrest et al. (1988)), that is, the first moment of the fricative spectrum. This approach, as well as the frequency of the spectral drop (Lindblad, 1980), i. e. the last moment of the spectrum, seems to deliver similar picture for Polish sounds.

For our further analysis, I adopt the following feature specification for fricative consonants with respect to the dimension Noise Frequency (I assume a scalar feature NF, since, in the analysis in chapter 4, I refer to the grade of similarity between the values of particular sounds):

(76) Noise frequency

	x/f	š	ɕ	s
NF	1	2	3	4

These values are based mainly on Ćavar and Hamann (2001), cf. Patryn (1987).

2.11.1 Dimension versus Features: Palatality and [Pal]

Contrasts in nature are not always binary. For example, contrast in the place of articulation is at least ternary, between labial, coronal, and dorsal. One might refer to Place as to a dimension of contrast. In perception, an example of a dimension may be the height of F2 discussed in the previous section: depending on the number of contrasts in a given language, there might be one or more features describing the relations within such dimension, e. g. [HighestF2], [High F2], [LowF2], [LowestF2].

For Polish, I propose that another perceptual dimension is relevant, namely, palatality. It is similar to other perceptual dimensions in that it will be expressed by means of (a set of) features. These features, unlike in other dimensions, will have different acoustic cues, i. e. referring to the height of F2, and the presence/absence of friction.

It is argued here that the distinction in the perceptual dimension of palatality is made by means of feature [Pal] which is to be defined in Polish by means of four different sub-features referring to the value of formants F2/F3 and friction. Perceptual [Pal] is perceived in Polish when the vowel transitions F2 are long and [High F2/F3] or [HighestF2/F3], and, optimally, accompanied by friction. However, the relation is complex. For example, even if a consonant has [Highest F2/F3], it may but does not have to pattern as a [Pal]-bearer if it is not accompanied by friction (e. g. Polish c, ɟ, as argued in chapter 3 are not [Pal]). If a consonant has only [High F2/F3] (but not [HighestF2/F3]) and friction, it may but it does not have to be classified as [Pal]. If a consonant has friction in the signal, but [HighF2] is not there, it will not be analyzed as [Pal].

(77) Cues for [Pal] in Polish

	[Low F2/F3]	[High F2/F3]	[Highest F2/F3]	[High F2/F3] and Friction		Prolonged [Highest F2/F3]	[Highest F2/F3] Friction
[Pal]					+	+	+
Example	p	t	c	s	ts, tš	pj^{j}	tɕ

What is constant for all [Pal] segments is the difference in the sum of the cues. Palatalized segments always have relatively higher formant values than their non-[Pal] alternants in phonological processes, and, either F2 is made more salient by inserting a [j], or friction is added, so the distinction between [Pal] and [−Pal] is sufficient, even if the height of F2/F3 transitions for different [Pal] segments cannot be compared in absolute terms, see (78):

(78) Specification of consonants of Polish with respect to [Pal]

F2 of Pal	***	***	***	***	***	**	**	**	***	***	***	***	***	**	**	**	**
Extra Friction or Length	(*)	(*)	(*)	(*)	(*)	*	*		*	*				*	*		*
Pal	p^j(j)	b^j(j)	f^j(j)	v^j(j)	m^j(j)	ts	dz	l	tɕ	dʑ	ɕ	ʑ	ɲ	tš	dž	š	ž
nonPal	p	b	f	v	m	(k)	(g)	w	t	d	s	z	n	k	g	x	r
F2 of nonPal	*	*	*	*	*	*	*	*	**	**	**	**	**	*	*	*	(*) *

F2: Highest F2/F3: ***, HighF2/F3 **, LowF2/F3 *

The table summarizes the sum of the palatalization cues, the difference represented by the numbers of asterisks: palatalized sounds always have more cues (asterisks) than the non-palatalized counterparts. For the distinction between [r] and [ž], there is a difference between them, as expected, though clear only before high back vowel [u]: in [uru] F2 is at about 1000 Hz, in [užu] – at circa 1500 Hz. (my own measurements). I marked this result as (∗). For labials, [j] is inserted only before a front mid palatalizing vowel, and I marked this as (∗).

The correlation of [Friction] and F2 transition in consonants is not ad hoc. Since the typical high transitions of formants F2 and F3 tend to be crosslinguistically accompanied by friction for the sake of the mechanics of articulation, they might be perceived together with friction as one entity, a complex feature, or a feature aggregate (cf. Boersma (1998) for the notion of feature aggregate). The characteristic articulatory gestures producing the F2/F3 complex effect, that is, holding the tongue body in an extreme high position, may produce friction as a side-effect when the transition from the palatalized consonant to the vowel is not rapid enough. Thus, the high values of F2/F3 are often accompanied by friction noise, which might be in the end interpreted as a cue of palatalization. For example, a listener will not perceive palatalization if it is without friction. This additional cue might turn out generally advantageous for the communication since friction on its own is a very robust and salient cue.

It might seem, at the first sight, that the acoustic correlates of the feature [Pal] are not consistent. For example, dental fricatives [s, z] have High F2 and friction and are not [Pal], whereas [ts, dz] with the same acoustic correlates – are [Pal]. In such cases, a listener decides whether the given feature is a cue for [Pal] or not on the basis of the presence/absence of other cues. For example, a secondarily palatalized labial, which has [HighestF2/F3] but no friction, will be perceived as [Pal] because it is labial. The same set of phonetic properties does not mark [Pal] on velars. This approach is not unusual. Halle and Stevens (1989), cited after Anderson (1981), assume three kinds of motivation which could be the basis of a natural class of sounds: first, as expected, are the common details of articulation, second, the auditory properties of sounds, and third, the phonological behavior of sounds. The third criterion, according to them, requires neither clear articulatory nor acoustic correlates. I will alter this argument by saying that, in fact, these phonological features which do not have clear acoustic correlates are in fact perceptual: they denote contrasts, they group together classes of sounds which in our perception have something in common, though the basis of these classes are sometimes difficult to be measured by acoustics. My claim here is that perceptual features which can always be defined by means of clear acoustic correlates are only a special case of a perceptually grounded features. It seems that even frontness-backness of vowels cannot be clearly defined acoustically in terms of F2 alone: the height of F2 depends on the height of the vowel, and the same value of F2 might be characteristic for a high central vowel and a front mid vowel. Still, front vowels and back vowels form two natural classes in our perception, which results in that the speaker of a language makes a difference in treating both groups of sounds. Anderson (1981), while discussing the tenets of Halle and Stevens (1989), as an illustration for an auditory-defined class of sounds gives an example of rhotics. Originally, it has been proposed by Ladefoged (1975) and Lindau (1978) that the common property for rhotics is the lowered third formant; however, this hypothesis was based on material from English, and it turns out that F3 in some other languages has a relatively high value, cf. the discussion in chapter 1. At present, Lindau suggested that:

> (...) there is no physical property that constitutes the essence of all rhotics. Instead, the relations between members of the class of rhotics are more of a family resemblance.

What is meant is that there is a series of step-by-step similarities between different rhotics though not for the group as a whole. These, however, are more of an acoustic/perceptual nature than of an articulatory nature. Thus, the example of rhotics is rather about a feature with a complex set of correlates too, similar to the feature [Pal]. In this light, the proposed [Palatalization] feature is no exception at all.

Palatality is a an important dimension for expressing contrasts in many languages; however, different languages choose different realizations of [Pal] versus [non-Pal] segments.

In (79) a scale of palatality is depicted.

(79) Palatality dimension

F2/F3: Low << Neutral << Highest << Highest + Friction
(velarization) (plain) (secondary pal)

Non-palatalized Palatalized

<< High F2/F3 +Friction
(coronalization, affrication)

The strongest palatality is marked by highest F2 and F3 (correlates of secondary palatalization) and friction noise. This position take, for instance, prepalatals. A lower level of palatality is frication on [High F2/F3] consonants, i. e. coronals, or [Highest F2/F3] alone (that is: either frication of plain coronals, or secondary palatalization.) Neutral plain consonants are lower on the scale. At the other pole of the scale, sounds with [low F2/ F3] (that is velarized) appear. We do not meet languages which make use of all levels of the distinction, at least I am not aware of such a language. However, it is common that secondary palatalized sounds are contrasted with velarized sounds, e. g. Russian and Irish, and on the other hand, palatalized sounds with friction are contrasted with plain sounds, e. g. Polish and a northern dialect of Irish, see Padgett (2001b) for the discussion of Russian and Irish data. Also, affricated coronals contrast with plain consonants (e. g. English [k]–[s] alternation).

2.12 Articulatory Features

Apart from auditory/perceptual features, I adopt the articulatory features which correspond to the nodes of Feature Geometry, as in (80) below:

(80) **Articulatory features**

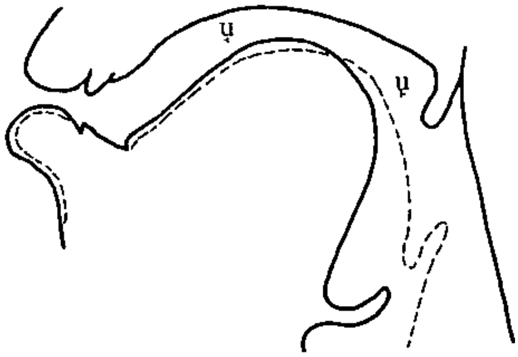
Coronal – sounds in the production of which the blade of the tongue including the tip, and/or the front part of the tongue are involved. The front part of the tongue is positioned opposite the hard palate and forwards, as postulated in Hume (1992). For the overview of different definitions, see Keating (1991).

Coronal articulation is either [anterior] or [non-anterior].

Velar – sounds articulated with the back of the tongue.
Labial – sounds articulated with the lips.
Advanced Tongue Root: [+ATR] and [−ATR] – sounds articulated with/without the advancement of the tongue root.

Some comments on [ATR] might be in order. An example of two vowels differing in [ATR] is given below:

(81) [+ATR] versus [−ATR] high back vowel of Igbo:
X-ray tracings of vowels in the words *obu* 'it is', and *íbú* 'weight' from Ladefoged and Maddieson (1996).



[ATR] is used to differentiate between more than three levels of vowel height in, for example, Bantu and Romance languages. In French and Italian, the distinction between e/ɛ and o/ɔ can be expressed as the difference in [ATR], cf. Calabrese (1988), Kenstowicz (1994). [ATR] was originally introduced by Stewart (1967) to analyze cross-height harmony systems in languages of West Africa, where high, mid and low vowels may be either [+ATR] or [−ATR], and the vowels within one word have to agree in the position of the tongue root (but not in the height).

The [+ATR] articulation is often connected with a raising and fronting of the tongue, as shown in Lindau (1975):[15]

[15] Apparently, Ladefoged and Maddieson (1996) reserve the use of feature [+ATR] to the cases where the tongue root is advanced, but there is no fronting and raising of the front of the tongue body. In terms of Ladefoged and Maddieson, the referred feature (where there is fronting of the tongue root connected with the raising of the front of the tongue) is [tense].

(82) [+ATR] leads to fronting and raising
Lindau (1975), represented after Vaux (1996, 396)

It is argued in this dissertation that the [ATR] distinction is also relevant for Polish to differentiate two series of front vowels, cf. chapter 3. In Polish, as described by Lindau, the position of the tongue root is correlated with the height and frontness of the tongue body. The use of [ATR] is in the analysis of Polish untypical because [ATR] refers here also to consonants. The correlate of [ATR] on consonants is claimed to be the same as on vowels, namely, it is the advancement of the tongue root. For the discussion, see chapter 3, and for the examples of analysis, chapter 5.

One more articulatory dimension is referred to in this dissertation, that is, Open:

(83) **Open** – the level of jaw opening

Feature [Open] appeared earlier in the literature, for instance, in Clements and Hume (1995), where it was defining height in vowels. Here, it is generalized to encompass the degree of jaw opening for consonants as well. Open might be expressed by a set of subfeatures, as in the case of formants; however, the argument refers to differences in degree of opening, thus, I adopt here a scalar approach, cf. scalar features in Flemming (2001):

(84) Open

high vowels	Open5
mid vowels	Open4
low vowels	Open3
glides	Open2
fricatives	Open1
stops	Open0

2.12.1 Remarks on the Universalism of Features

It seems reasonable to assume, following Boersma (1998), that articulatory feature dimensions will be universal in that each language may or may not make use of certain universal types of articulation. Articulatory features will be then universal because our articulators are universal. Also, in the case of perceptual features, one is inclined to assume that dimensions of contrast are universal. Our perceptual system is constructed for paying attention to and measuring certain properties, such as the value of formants, the frequency and intensity of friction, the presence-absence of silent phase, etc. These dimensions would be universal but their application to the inventories of different languages is not. Yet another point is the number of categories within a certain dimension. Whereas in respect to the absence – presence of some property, there is a binary choice, some other dimensions form rather a continuum of a changing quality. The number of categories into which the continuum will be divided seems rather a matter of the choice for the individual language (Boersma, 1998). Thus, we can have three categories as far as frontness-backness of the vowel is concerned, but there are also inventories which utilize only two categories, or do not make any distinction at all. It is a well-known fact that if there is no contrast, a segment takes the whole of the available perceptual space, and is not limited to, for example, the central value. If there is no distinction for frontness among low vowels, which is the case in Polish, [a] may be pronounced very much to the front or very much in the back of the mouth cavity – still being perceived as the same category.

Summing up the discussion above, we assume perceptual and articulatory underlying representations, as in (85), where the representation of the Polish word *kot* 'cat' is given:

(85) Example

Perceptual/auditory	LowF2/F3	LowF2/F3	High F2/F	
	NF1		NF4	
	k	o	t	'cat'
Articulatory	Dor	Dor	Cor,Ant	
		Lab		
	–ATR	–ATR	–ATR	

2.13 Previous Research on Perceptual Constraints and Contrast

An important topic in the current research is the emergence of contrast. The idea that constraints on articulatory features aim to reduce the articulatory effort and maximize articulatory ease is well established. However, the question as to how the articulatory constraints are balanced, and how the surface contrast is preserved, has been answered in various ways by different authors.

In recent years new ideas with respect to feature theory, contrast, and possible types of constraints have been developed by scholars such as Steriade (1993), (1995a) and (2001), Flemming (1995), (2001) and (2002), Boersma (1998), Padgett (2001a) and (2001b), Kirchner (1997) and (2001), Hume and Johnson (2001), and NiChiosain and Padgett (2001), or Łubowicz (2003). In the following, we will compare the assumptions adopted in this dissertation with some proposals by other researchers.

2.13.1 Dispersion Theory of Flemming

Flemming (1995) proposes auditorily grounded features in addition to traditional articulatory features. Further in his paper from (2001), he assumes that auditory features are scalar rather than gradient.

In Flemming (1995) phonology is driven by functionally-motivated conflicting powers: on the one hand, the articulation has to be easy and effortless, on the other hand, the speech signal has to be clear and distinct. Thus, constraints ensuring articulatory ease are in conflict with constraints of two families operating on perceptual (auditory) representations. These are:

(86) MaxContrast
Maintain maximal number of contrasts.

(87) MinDist
The perceptual distance between contrasting segments must be maximal.

The constraints from the two families in (86)–(87) stand in an inherent conflict. It is more advantageous from the point of view of communication to have more possibilities to express contrast; however, with the raising number of existing contrasts, the perceptual distance between contrasting segments necessarily decreases, which is not a welcome effect because it leads to misperceptions. In Flemming (2001), it is argued that the above perceptually motivated constraints together with the articulatory constraint against the articulatory effort are sufficient means to produce the existing surface contrasts. It is argued that MaxContrast and MinDist can substitute the faithfulness constraints, and that one can dispose of underlying form altogether, cf. similar approach in Burzio (1996).

As to the issue of eliminating the faithfulness constraints (Flemming, 2001), it seems justified to say that we have mental representations of words, and that our productions tend to reflect the stored information. It is not enough to have surface-true inventories of segments or even surface correct representations of words, as long as the relation between the stored representation and its surface realization is not secured. For the sake of maintaining communication, it is necessary to have a control mechanism which ensures a necessary degree of similarity of the produced output to the stored representation, that is, faithfulness constraints. Also, auditory faithfulness has the effect of constraining possible articulatory-driven improvements: it is only the innovations which are perceptually similar to the stored auditory representation that are plausible results of any articulatory-driven innovations, cf. discussion in the next section. Whether families of constraints Max Contrast and Minimal Distance are both justified when we acknowledge the role of Faithfulness is a different issue, which we do not intend to discuss here.

Another point of critique raised by Boersma (1998) was the fact that Flemming (1995) evaluates segment inventories and not candidates. Done this way, it is as if an extra module of phonology is created, using an extra set of constraints (Max Contrast), which do not seem to matter for the regular phonology. Even if we assume that it was not Flemming's intension to propose an evaluation of inventories separate from the evaluation of actual forms, and if we assume, as noted in NiChiosain and Padgett (2001), that the exposition of the problem in Flemming (1995) is kind of a shorthand to mean actual forms containing a given segment (and not a segment alone), another point of critique will still be valid. We cannot evaluate contrasts without taking into account the syntagmatic environment in which the segment appears. As noticed in Kirchner (1997), some contrasts may be realized or not, depending on their surface environment (including the position within syllable or word). This problem is not discussed in Flemming (1995).

2.13.2 Emergence of Contrast by Faithfulness Satisfaction

Boersma (1998) represents the classical OT approach to contrast emergence. The surface contrast is an effect of the faithful rendering of the underlying/input representation (and, indirectly, of the underlying contrasts between the underlying representations). This approach, however, does not seem sufficient. As argued in Ćavar (2001), there are cases when although the faithfulness constraints are crucially violated, still a contrast between two surface realizations will correspond to the contrast between the underlying representations. Boersma's approach fails on another issue. As it will be argued in chapter 4, and as it is argued in Flemming (1995) and Padgett (2001a) and (2001b), we need devices to evaluate the contrast on the surface – without a reference to the underlying representation. Thus, the approach of Boersma (1998) is insufficient to cover the whole range of data.

2.13.3 N-Words Family of Constraints

The system of constraints concerning contrasts and the emergence of inventories as proposed in this dissertation[16] has been developed independently from the proposals made by NiChiosain and Padgett (2001), though the two are admittedly very similar. The similarity results from the fact that both systems try to amend the proposal of Flemming (1995) and its major flaw consisting in the evaluating of sound inventories (instead of output).[17] Both, Ćavar (2001) and NiChiosain and Padgett (2001) assume evaluation not of sound inventories but of a language – Ćavar: of 'words of language', and NiChiosain and Padgett: of 'severely idealized languages as a whole'.

In NiChiosain and Padgett (2001), three families of constraints are responsible for the emergence of contrasts on the surface: First, articulatory markedness constraints, which in general disfavor more complex articulations, second, perceptual space constraints, where the bigger perceptual space between segments on a given perceptual dimension, the better (corresponding to proposed above IO-MinDist), and, finally, N-Word constraints, formulated as in (88).

(88) N-Word constraint (NiChiosáin & Padgett, 2001, 12)

a. Nwords: A language must have at least n contrasting words

b. 1word >> 2words >> ... >> N−1words >> Nwords

Constraint (88) is supposed to induce increasing the number of existing contrasts within a language.

Further, NiChiosain and Padgett show the working of their constraint on the example of an idealized language with the contrast within the palatalization dimension. Assuming that this language has only words of the form $C(^{j/\gamma})a$, one can derive in this way an idealized language containing three

[16] First presented at Poznań Linguistic Meeting, 27-29 April, 2001.

[17] Flemming (2002) makes the point that it was not his intention in the (1995) version to evaluate inventories, and the amended version deals with this problem.

potential words Ca, $C^j a$ and $C^\gamma a$ (assuming the nature of C is irrelevant). By changing the ranking of the three types of constraints discussed above, different attested surface contrasts are derived, but not the unattested contrast between a simply plain segment and a segment with a secondary articulation.

However, the formulation of a constraint increasing the number of existing contrasts as in (88) bears a potential problem. An important property of a human language is that the structure is recurrent. In principle, one cannot prevent a language from marking a contrast by adding an extra segment or an extra syllable using segments from the existing inventory, e. g. $C^j aC^j a$ will contrast with $C^j a$. In this way a number of possible words may be increased without triggering the other mechanism that, in this context, was supposed to be described – without introducing a new value on the perceptual dimension.

N-Word constraints induce the emergence of new contrasts, whereas the Minimal Distinction, as proposed here, acts only against losing existing contrasts, and the prediction is that new contrasts are not effects of goal-oriented developments, but rather they emerge as a side-effect of articulatory operations and perceptual reanalysis (Ohala, 1981). For these reasons, the Minimal Distinction family of constraints, as discussed in section 2.8.3, seems more appropriate as it refers directly to the systemic contrasts between segments and not to contrasts between words.

In NiChiosain and Padgett's paper, no underlying representations for the forms are assumed ("at least as crucial determinants of output well-formedness", p. 14). Consequently, no faithfulness constraints are employed for the evaluation of surface forms. The lexical entries correspond in their approach to surface representations, that are themselves subject to the output-based grammar like OT.

2.13.4 External Factors Influence Phonology

Hume and Johnson (2001) propose a model of the interaction of phonology with external factors. They admit that cognitive representations are influenced by, on the one hand, low-level external effects of phonetics including audition and recognition, as well as the coordination of articulation and aerodynamic tendencies, and on the other hand, higher level effects which refer to the general cognitive capabilities of humans and their psychological/social needs. These factors, however, are only indirectly reflected in generalizations drawn about cognitive representations on the basis of linguistic data, i. e. phonology. One could say that phonology in this approach becomes an emergent set of generalizations, and would be descriptive but not explanatory. The whole burden of the explanation is then on phonetics, and not on phonological theory. Additionally, this model would have problems in distinguishing between non-existing but possible grammars, and those which are simply impossible: if phonology has direct access only to the data reflecting the cognitive representations, and we cannot refer to the external factors directly, we have no way to predict possible and impossible grammars. This argument speaks for the direct incorporation of phonetic-determined information (something like P-map of Steriade (2001), compare the discussion below, but also for "articulatory" knowledge) into the phonological system.

A different approach is presented by Steriade (2001), who assumes that any speaker possesses a knowledge about the perceptual similarities between units of speech, dubbed P-map, being a module of knowledge that phonology can directly refer to. As argued by Steriade, P-map serves to identify the margins of articulatory freedom to realize a given segment, to identify more versus less salient morphological alternations, and generate judgments about similarity for rhyming, for loan adaptation, speech disguise, experimental situations etc. Other researchers (Flemming (2001), Boersma (1998), Kirchner (1997)) also admit fine phonetic detail into their phonological analysis. Flemming (2001) argued explicitly against making the distinction between phonetics and phonology, and Boersma (1998) claims that phonemes and categories (which distinguish phonological from phonetic effects) are emergent from the cognitive capacities of humans.

2.13.5 Theory of Emergence of Innovations

Another important point treated in Steriade (2001), (cf. Lindblom et al. (1995), Kohler (1990), Hura et al. (1992)) is the claim that the basis on which alternations are selected is at least twofold: first, a surface form should be articulatorily optimal under given conditions, second, any innovations are limited by perceptual similarity between the alternating forms. Whereas Steriade (2001) was referring to diachronic phenomena (only hinting the possibility of the application of this solution to synchronic phenomena), we apply this idea here to synchronic phonology.

2.13.6 Features

Some researchers working on perceptually-driven phenomena assume some kind of perceptual features. Flemming (1995) assumes the existence of two sets of features, articulatorily-defined, and auditorily-defined. In contrast, Boersma (1998) claims that all features are first of all perceptively grounded (not only auditory); that is, their definitions refer to the whole of sensual input in their production and perception (also priopriocept

ion, i. e. autosensation of the articulatory gestures). Steriade (2001) describes auditorily-motivated relations without designing a system of auditory features.

2.14 Elements of Other Models

Many models proposed by other authors (Kirchner, Boersma, Flemming) do allow fine phonetic detail in the underlying representation, thus, making no substantial difference between phonetic and phonological effects. This approach is basically adopted in the present study.

In the present study, similar to Boersma (1998), faithfulness constraints (unlike suggested by Flemming (2001)) play an important role.

In the present study, it is assumed that a language user possesses the knowledge about perceptual similarities, the same way as he or she has the knowledge about the possible ways of using articulators. The way certain universal statements about the relative difficulty/ease of certain articulations are directly incorporated into the system of constraints, so the perceptibility effects (discussed by Steriade (2001)) may be directly incorporated into the system of constraints, as soon as constraints refer to auditory features. On the other hand, one would need to assume still more implicit knowledge, namely, about the relations between articulatory and auditory features, which would exclude the surface representations which are simply articulatory-auditory incompatible. This issue is not further developed in the current study.

Some proposals adopted here are in fact very similar to those in NiChiosain and Padgett (2001). In fact, Preserve Contrast and N-Word constraints attempt to grasp the same issue, i. e. that if the underlying contrast is not rendered on the surface, it is a disadvantage for the communication. The difference between the two proposals is twofold. First, Preserve Contrast acts only against loss of the existing underlying contrast, whereas N-Words promotes the emergence of new contrasts. Second, N-Word does not affect directly the surface contrast either, since it may be satisfied through prolonging the string by another segment, as argued in 2.13.3.

Finally, constraint Uniform has been inspired by Hume and Johnson (2001), where external cognitive factors are discussed.

2.15 Summary of Assumptions

The general approach adopted in the present study is that of Optimality Theory with its basic tenets (section 2.2). It is supplemented by the external functionalism ideas as discussed in section 2.4. A model of phonology is proposed in which a distinction is made between articulatory- and auditory-driven mechanisms (constraints) which directly influence representations built in terms of articulatory features, and auditory features, respectively. Surface effects emerge from the interaction of three major factors: similarity to the stored representation, articulatory simplicity, and auditory requirements on the distinctivity of contrasting segments, both when standing in syntagmatic as well as in paradigmatic relations. The subsequent discussion of palatalization in Polish in chapter 4 is meant as a case study illustrating the interaction of the three groups of factors. Before we can turn to the analysis, we will have a closer look at the Polish system of sounds from the perspective of the model we presented.

Chapter 3

PHONETICS OF ALTERNATING SOUNDS

3.1 Overview

The aim of this chapter is to prepare the ground for the analysis in chapters 4 and 5. Assuming the model and the features as presented in chapter 2, we will make assumptions about the featural specification of sounds alternating in the palatalization processes, and provide the necessary phonetic arguments for the discussion of [ATR] phenomena in chapter 5. An overview of the Polish alternations is contained in section 3.2. Section 3.3 describes the articulation of Polish consonants and vowels, and 3.4 their acoustics. Section 3.5 offers a discussion of contrasts in Polish and section 3.6 is a summary of feature specifications assumed for Polish sounds.

3.2 Summary of Alternations

To briefly review the information given in (4) in chapter 1, the pairs of alternating sounds in the palatalization processes in Polish are represented in (1):

(1) Alternations in Polish

Process – Input	p b f v m	t d s z	w r	k g x	ts dz l tš dž š ž
Labial Palatalization	p^j(j) b^j(j) f^j(j) v^j(j) m^j(j)				
Coronal Palatalization		tɕ dʑ ɕ ʑ	l ž		
1st Velar Palatalization				tš dž/ž š	
Surface Velar Palatalization and Surface Palatalization	p^j b^j f^j v^j m^j	t^j d^j s^j z^j	w^j r^j	c ɟ ç	ts^j dz^j l^j $tš^j$ $dž^j$ $š^j$ $ž^j$

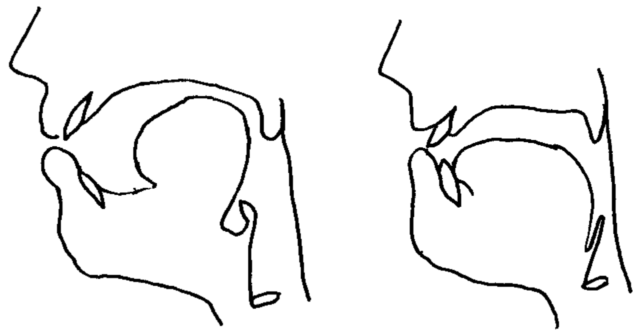
3.3 Place of Maximal Constriction

3.3.1 Plain Consonants (without Secondary Palatalization)

[p, b, f, v, m] are labial. [w] is also primarily labial, with a raising of the dorsum towards the velum. That is why sometimes it is referred to as a labial glide or sometimes as labio-velar glide. It differs from other labial sounds in the position of the body of the tongue: other plain labials are produced with the flat tongue body, in [w] the tongue is retracted and raised (velarized), cf. (2):

(2) The articulation of labial consonants, redrawn after Wierzchowska (1980)

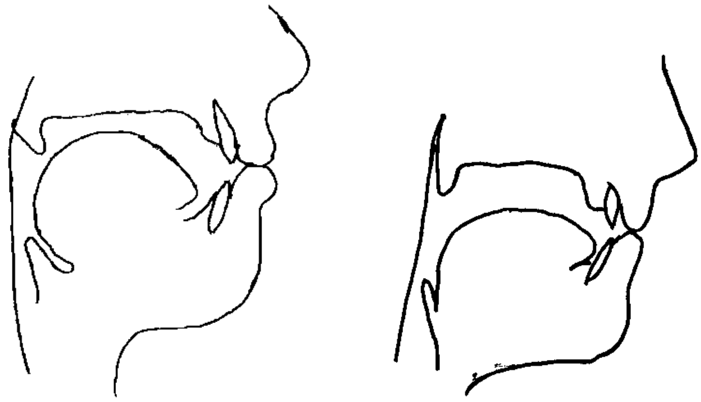
a. [w] b. [f]



Non-palatalized labial obstruents are not velarized. It will become clear when we compare a Polish non-palatalized labial with a Russian realization of a non-palatalized labial, as in (3):

(3) Lack of velarization in Polish obstruents in a non-palatalizing context

a. Russian [p] b. Polish [p]



Rubach (p. c.) points out that in the articulation of the Polish sounds the back of the tongue is retracted (though not raised, as normally in velarization). Yet, this might be also interpreted as resulting from the lack of fronting of the tongue root characteristic for the palatalized segments, cf. the discussion below.

In terms of articulatory features, plain labial consonants are Labial, and [w] is surface Labial, Dorsal. Notice, however, that [w] does not pattern phonologically with other labial non-palatalized sounds, because in the context of palatalizing suffixes it does not alternate with a secondarily palatalized labial, but with a coronal lateral, see (4):

(4) The behavior of surface labial sounds in the context of palatalizing –e (loc. sg.)

ła[p]+a	–	ła[p^jj]+e	'paw'
ży[w]+a	–	ży[l]+e	'vein'

Surface [w] does not behave like a velar either, as it does not trigger Surface Velar Palatalization, see (5).

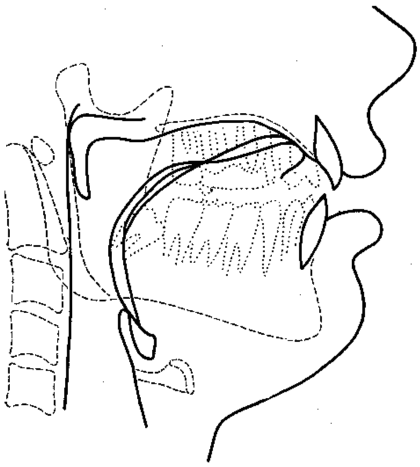
(5) Surface Velar Pal. does not apply to [w]

mak	–	ma[c]+em	'poppy seed', nom. sg. – instr.
versus			
wa[w]	–	wa[w]+em	'mound', nom. sg. – instr.

Rubach (1984) assumes that [w] is underlyingly a velarized coronal lateral, which would correspond to the historical and dialectal realization of this sound as dark [$l^ɣ$]. In fact, the [$l^ɣ$] realization was still standard untill the nineteen forties. The fact that it alternates with a non-anterior coronal lateral sound supports this suggestion. On the other hand, if we said that [w] is underlyingly a labial glide, we would expect that the alternation of [w] in a palatalizing context should be [j]. The alternant of [w] is however [l], and we assume that surface [w] is underlyingly a lateral.

[t, d, s, z, n] are dental sounds, produced by the tip of the tongue at the teeth ridge. As in the case of plain labials, the body of the tongue is lying flat at the bottom of the mouth cavity – there is no velarization. They are, thus, Coronal, anterior. In Wierzchowska (1967), other anterior consonants, i. e. [ts, dz, r, l] are said to be articulated by the tip of the tongue at the alveolar ridge, that is, slightly retracted in comparison to [t, d, s, z, n] but still Coronal[anterior]. However, when we regard the X-ray tracings of [l] from Koneczna et al. (1951), it is striking that the place of stricture is actually behind the corner of the alveolar ridge, see the pictures in (6):

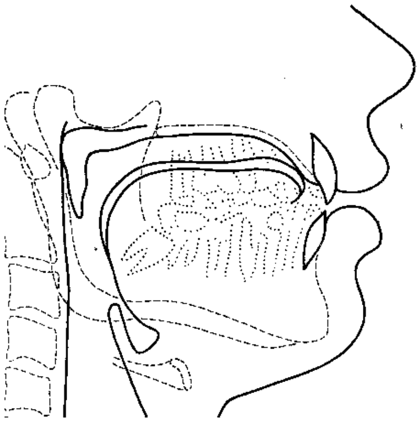
(6) [l] in Polish (redrawn from Koneczna et al. (1951))



From my introspection, it seems that [l] may be articulated also as a dental in Polish, however, the dental articulation never occurs before [i] or [e]. Actually, in most contexts [l] is post-alveolar.

Post-alveolars, i. e. [tš, dž, š, ž] are articulated just behind the alveolar ridge. The tongue rests on the bottom of the oral cavity, there is no raising neither towards the hard palate nor towards the velum, and the oral cavity forms one long resonator. In contrast to dentals and alveolars, post-alveolars are laminal. As far as the tongue root position is concerned, it is further back than prepalatals, see (7).

(7) Polish [ž]; from Koneczna et al. (1951)



[k, g, x] are articulated by the back part of the tongue, i. e. they are Dorsal.

3.3.2 Palatalized Consonants

Prepalatals, i. e. [ʨ, ʥ, ɕ, ʑ, ɲ], alternating with dental sounds, are laminal, with the major constriction made by the front part of the tongue rising towards the hard palate (cf. Wierzchowska (1980), Keating (1991), etc.). This position is very close to that assumed by the tongue in the articulation of the front vowel [i]. Hume (1992, 104) cites the description from Halle and Stevens (1989) who argue that:

> (. . .) alveopalatals are articulated like palato-alveolars in that the blade of the tongue is raised toward the alveolar ridge (. . .) (Halle & Stevens, 1989)

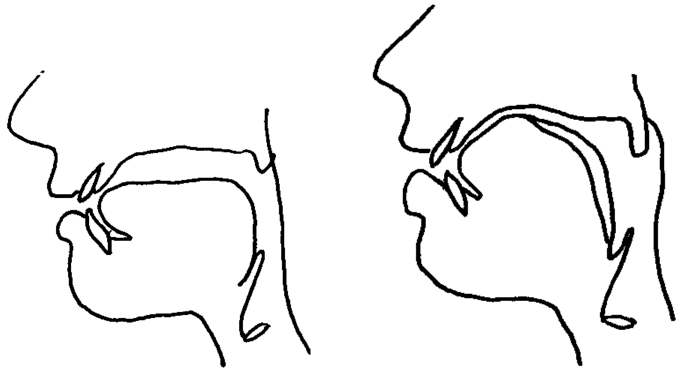
and

> (. . .) in addition, the front of the tongue is raised as it is for palatal consonants (. . .) (Halle & Stevens, 1989)

Keating (1991) also assumes that alveopalatals are something like a palatalized version of palato-alveolars, and describes them as involving both coronal and tongue-body articulation. Her analysis is based on the evaluation of X-rays of prepalatal consonants from Wierzchowska (1967) and (1980). In the pictures of prepalatal sound, the upper line marks the position of the sides of the tongue, and the lower is the position of the middle of the tongue. When we consider the position of the tongue root, we can observe that it is – in comparison to dentals, post-alveolars, plain labials and velars – substantially advanced with a larger widening at the pharynx, see (8).

(8) Prepalatals and post-alveolars in Polish (redrawn from Wierzchowska (1980))

a. Post-alveolar [š] b. Prepalatal [ɕ]



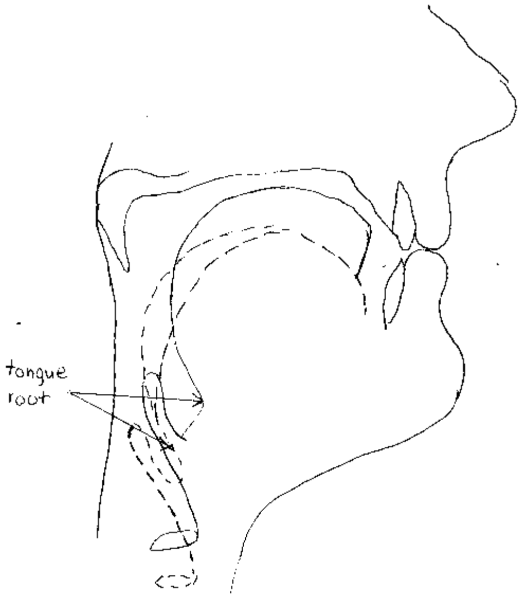
Additionally, as reported in Dogil (1990), prepalatals are "(. . .) pronounced with a great tension of the lingual muscles (. . .)" (Dogil, 1990, 7).

It is worth noting that muscle tension was assumed to be one of the correlates of the feature [tense], and tenseness has been often used interchangeably with the [ATR] feature. It is then plausible that [+ATR] sounds involve higher muscular effort, thus, when prepalatals are articulated with a great muscular tension, this fact supports additionally the claim that prepalatals are [+ATR].

The prediction of Stevens and Halle that prepalatals are "something like palatalized palatoalveolars" will be born out in the system proposed here. Thus, I assume that post-alveolars are Coronal[non-anterior][−ATR], whereas prepalatals are to be specified as Coronal[non-anterior][+ATR].

Palatalized labials [p^j, b^j, f^j, v^j, m^j] differ in the articulation from the plain series in the position of the tongue:

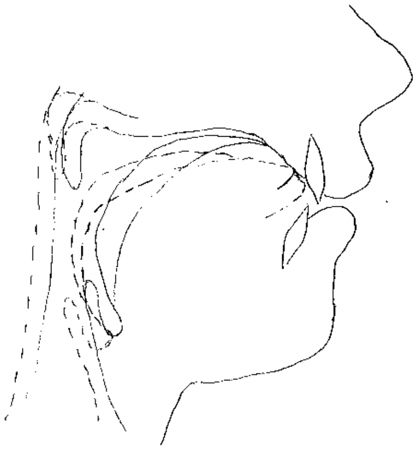
(9) Palatalized labial [p^j] (solid line) versus plain labial [p] (dotted line) (redrawn from Koneczna et al. (1951))



The whole tongue is moved forward for the palatalized labials: the tongue root is fronted, the middle part of the tongue raises towards the hard palate (secondary palatalization). The palatalized labials are to be described as Labial and Coronal[non-anterior][+ATR].

In a similar way, secondarily palatalized coronals [t^j, d^j, s^j, z^j, ts^j, dz^j, l^j, r^j, $t\check{s}^j$, $d\check{z}^j$, $\check{s}^j$, $\check{z}^j$] derived in the process of Surface Palatalization, cf. (1), as well as labials palatalized in Surface Palatalization, show no substantial change in the place of major constriction, but there is an additional raising of the tongue towards the hard palate accompanied by the fronting of the tongue root.

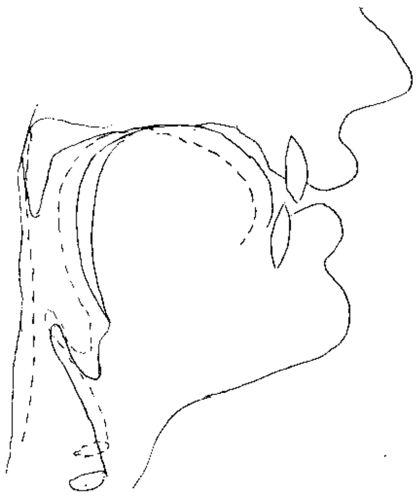
(10) [t^j] (solid line), contrasted with [t] (dotted line);
redrawn from Koneczna et al. (1951) pictures 68 and 80



As argued in Dogil (1990), secondarily palatalized post-alveolars [$tš^j$, $dž^j$, $š^j$, $ž^j$] do not differ substantially from prepalatals [ʨ, ʥ, ɕ, ʑ] in the formation of the constriction by the tongue, the only difference being the rounded versus spread lips.

Secondarily palatalized velars are fronted to the prevelar area, cf. (11).

(11) [ɟ] (solid line) versus [g] (dotted line);
redrawn from Koneczna et al. (1951) pictures 93 and 87



The whole of the tongue is advanced, creating a bigger pharyngeal cavity as in the case of the plain velar. The constriction is made by the back and middle part of the tongue. They are articulatory Dorsal and Coronal [non-anterior].

3.3.3 Front Vowels

Palatalization is an assimilation to the properties of front vowels. In the following, the properties of surface realizations of front vowels, as far as their articulation is concerned, are discussed in detail.

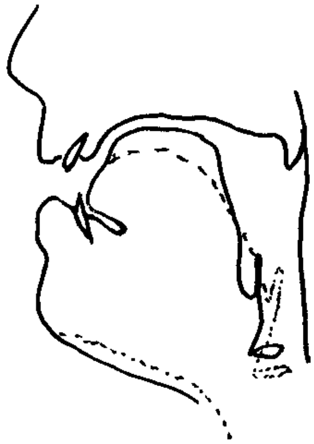
It is broadly accepted that Polish has at least two front vowels. High front vowel [i] and mid front vowel [e]. I will argue here that Polish [ɨ] is also a front vowel; that is, the biggest stricture is, in that case, in the coronal (non-anterior) area. I will also argue that the mid front vowel may appear in two allophonic variants: [e] and [ɛ] which differ in the position of the tongue root. The nature of the difference between the two types of high front vowels, as well as between the two types of mid front vowels, will be crucial for our further discussion.

The front vowel [i] is articulated with an extreme front position of the tongue, where the whole of the body of the tongue is advanced (Wierzchowska, 1980). When compared, for instance, to the English short [ɪ], it is higher and more fronted, rather closer to the position of the long tense [iː].

(12) Polish [i] versus English high front vowels

a. English high front vowels: solid line [iː], dotted line [ɪ]; redrawn after Ladefoged and Maddieson (1996)

b. Polish [i] (solid line), contrasted with [ɨ]; redrawn after Wierzchowska (1980)



In (12b), the advancement of the tongue root in [i] is particularly clear when contrasted with vowel [ɨ], which is marked with a dotted line.

Polish [ɨ] is another high vowel articulated with the front of the tongue (Wierzchowska, 1980), (Koneczna & Zawadowski, 1956). As illustrated in (12b) above, it is slightly lower than [i], however, the place of the constriction on the front-back axis is more or less the same. The position of the tongue root is, in comparison to [i], substantially retracted. Phonetic descriptions usually agree on the frontness of [ɨ] (Koneczna & Zawadowski, 1956; Wierzchowska, 1980) , , however, phonological studies differ in this respect: for example, Rubach (1984) describes [ɨ] as phonetically central and phonologically [+back]. Szpyra (1995) assumes that it is Dorsal [−back], but notably not Coronal, unlike [i]. Gussmann (1992) denied a separate phonemic status to [ɨ].[1]

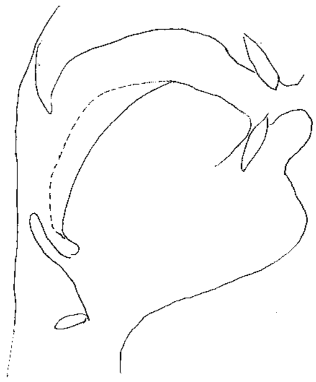
It is postulated here that the distinction between [i] and [ɨ] is to be described by means of feature [+ATR]. Otherwise, they are both to be described as Coronal[non-anterior]. For the arguments for treating front vowels as Coronal and not Dorsal, see Hume (1992), or Clements and Hume (1995).

The front mid vowel is also produced with the front tongue position, though closer to the neutral position than the high front vowel, see (13) below. It is often described as lax in the context of hard (phonetically without secondary palatalization) consonants, and tense in the unilateral or bilateral context of phonetically palatalized or prepalatal segments. Tense [e] is higher

[1] There is a serious argument against the unity of [i–ɨ], namely the nom. pl. ending of nouns is underlying -i (or a palatalizing vowel) for personal nouns, and underlying – ɨ (non-palatalizing vowel) for non-personal nouns. Without this assumption we cannot predict the surface form of nom. pl. See for the detailed discussion Rubach (1984).

than the lax [ɛ]. This realization of the front mid vowel is allophonic and usually not transcribed at all. For this reason, probably, there are no X-ray tracings of [e] available.

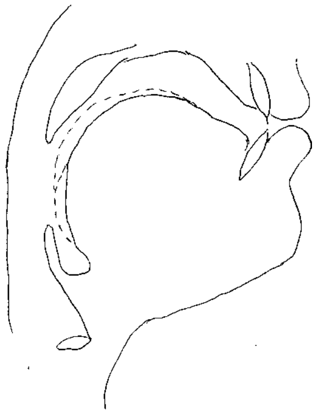
(13) Polish front mid vowel (Koneczna & Zawadowski, 1951)
[ɛ] (dotted line: the edges of the tongue, solid line the groove of the tongue)



In (13), we see that the maximal constriction in [ɛ] is made clearly by the front of the tongue. The same seems to be valid also for [e] (my introspection). [e] is even more advanced and higher, lips are strongly spread. Muscles are very tense and the jaws make a smaller opening than in the case of [ɛ]. It is clear to me that the position of the tongue is closest to that of prepalatals. Consequently, the assumption is that both surface realizations of the front mid vowel are Coronal, non-anterior; the difference lies in the value of [ATR].

There is another group of surface realizations transcribed often as [e], though phonetically they are rather [ɜ]: nasalized front vowel (orthographic ę) after denasalization. These are pronounced lower and more central than any other instances of a mid front vowel, see (14):

(14) [ɜ̃] in Polish



I assume that they belong to the class of back vowels and differ from [õ] in terms of lip rounding.

Summing up, front vowels are Coronal, non-anterior, and differ in terms of height and the position of the tongue root.

3.3.4 The Tongue Root Position

It seems that the position of the tongue root might be a parameter differentiating between vowels that regularly trigger palatalization of, for instance, coronal consonants ([i, e]), and those which have no such effect ([ɨ, ə̃]). We argued also that the position of the tongue root differentiates between secondary palatalized and respective plain consonants, and between prepalatals and post-alveolars. These claims are summed up in table (15):

(15) ATR in Polish

+ATR	p^j, b^j, f^j, v^j, m^j, t^j, d^j, s^j, z^j, ts^j, dz^j, r^j, l^j, tš^j, dž^j, š^j, ž^j, tɕ, dʑ, ɕ, ʑ, ɲ, j, c, ɟ, ç	i, e
−ATR	p, b, f, v, m, w, t, d, s, z, n, ts, dz, r, l, tš, dž, š, ž, k, g, x	ɨ, ə

3.4 Perceptual Properties of Polish Speech Sounds

In the following section we will focus on the acoustic properties of the sounds of Polish. The perceptual qualities of sounds of speech cannot be accessed in a direct way. Since we have no direct access to the perceptual qualities of sounds, we can only draw conclusions from the acoustic research supported by studies on the phonological patterning of sounds of speech. First, it is claimed that for the perception of place in consonants, an important cue are formant transitions. These will be discussed in sections 3.5.1-2. The formants of Polish vowels are discussed in section 3.5.3. The properties of noise in the production of the various sounds of Polish are described in 3.5.4. The perceptual feature [Palatality] is discussed in section 3.5.5.

3.4.1 Formant Transitions

It is generally assumed that F2 transitions are an important cue for the differentiating of place of articulation in, first of all, stops, cf. e. g. Pickett (1999).[2] In general, high F2 transitions are indicative of coronal sounds, and low indicative of labials and coronals. This distinction was the basis of the Jakobson's feature [acute].

Let us for a moment leave aside the differences between the environment of back/front vowels (that we will come back to in a moment), and concentrate on the differences between the places of articulation in a constant environment. For labials (in particular – a labial stop), according to Wierzchowska (1980, 56), F2 raises from about 1000 Hz to 1200 – 1400 Hz depending on the adjacent vowel, and it does not raise at all before [u]. In [w], formant transitions values are in the context of [e], for F2 equal 900 Hz, and for F3 – 3000 Hz, whereas, in the context of a back vowel, F2 is practically indistinguishable from F1 forming a concentration of energy up to 600 Hz. For anterior coronals, the acoustic effect is the presence of formant F2 at 1200 – 1700 Hz (Wierzchowska, 1967). In the measurements conducted with the help of Praat, version 3.9.36, I have obtained similar values in the environment of the back vowel [u], see table (16).[3]

(16) Formant values of anterior coronals in Polish (in Hz)
The environment of a back vowel [u]

	t	d	s	z	n	ts	dz
F3	3300	3200	3200	3400	3400	3400	3300
F2	1400	1400	1600	1600	1400	1600 (2100∗)	1600 (2100∗)
F1	500	500	400	300	400	300	300

∗ in the friction portion

F2 transitions for prepalatals start at an average of around 2200 Hz (before back vowel, cf. Ćavar and Hamann (2001)). What is interesting is that F2 is

[2] Formant transitions are so important especially for stops, because stops have only a weak and short burst of noise, which provides only weak cues for the recognition of the place of articulation, whereas fricatives may be recognized on the basis of the properties of noise.

[3] One female native speaker; recording with the use of Labtec LVA–7330 microphone connected to the computer, within Praat; the results rounded to 100 Hz.

often indistinguishable from F3, forming together a strong perceptual peak between 2200 and 3500 Hz, independent of the vocalic context. Dogil (1990) does not observe any energy concentration at the frequencies where usually F2 is located, which leads to the conclusion that F2 is so high that it merged with F3 (p. c. B. Pompino-Marschall) at around 2700 Hz for male speakers and 3000-3100 Hz for female speakers, which is much higher than for anterior coronals.

Post-alveolar affricates and fricatives also have F2 transition higher than average labials or velars: in the context of a back vowel, it starts at about 1300–1500 Hz (own measurements).

For velar stops [k] in the context of back vowel [a], F2 in my measurements started at around 1000 Hz and raised in the direction of the center of the vowel up to around 1500 Hz.

In (17), the values of F2 transitions for plain consonants in the context of a back vowel are summarized (the measurements of Ćavar and Hamann (2001) and those conducted for the present study have been taken at the very beginning of the visible transitions):

(17) Summary of F2 transitions (back vowel context): values in Hz

	labial	dental/ alveolar	post-alveolar	prepalatal	velar
Wierzchowska (1980)	1000–1200 / 1400	1200–1700	1500–1700	2500–3000	600 (1400)∗
Ćavar & Hamann (2001) or measurements conducted for this study[4]	900–1000	1400–1600	1300–1500	2200–3500 (broad peak together with F3)	1000∗∗–1500
Dogil (1990)				2700–3100	

∗ Before [a]. At which point of the transition (beginning or approaching the steady level in the vowel) is unclear from Wierzchowska's description.
∗∗The beginning value

The absolute values differ from study to study, depending on the methods used, gender and the size of the oral cavity of the speakers recorded, and on the vocalic context. In general terms, we can, however, see certain regularities, that are summarized in (18).

[4] The results are put together because 1. the same speaker has been recorded, 2. the same method has been used for the evaluation of the recordings.

(18) F2 value for various place of articulation (back vowel context)

	F2 beginning value	F2 feature specification
Labial	ci. 1000 Hz	Low
Coronal	1200-1700 Hz	High
Prepalatal	2200 Hz	High, Highest
Post-alveolar	1200-1500 Hz	High
Velar	ci. 1000 Hz	Low

It is often overlooked that the relative values of formants depend very much on the quality of the following vowel: the shape (raising, or falling, or steady), and the F2/F3 values for the same consonant differ substantially in the context of [i], [e], and, say, [u], as in (19):

(19) F2 for labial stop [p] in the context of different vowels (measured at the very beginning of the transition)[5]

Environment	Value of F2 in Hz	Shape of the transition; relation to other formants
upu	850	Upward into the vowel; very close to F1
epe	1800	Steeper upward into the vowel; F2 and F3 can be distinguished
ipi	2700	F2 and F3 melt

We can see that the F2 transition of the labial sound in the context of the front vowel, see (19), is, for example, higher than the scope of the F2 for the coronal sounds in the context of back vowels, compare (18).

Further, let us compare other consonants in the context of front vowels, as in (20) below:

(20) Average formant values before front vowel [i] in Polish (Ćavar & Hamann, 2001)

	average at the beginning of the transition into the vowel	
	F2	F3
ti	2378 Hz	3166 Hz
ci	2693 Hz	3433 Hz
tɕi	2700 Hz	3566 Hz
tš^{j}i	2561 Hz	3433 Hz

[5] Recordings of one female native speaker with the use of Labtec LVA-7330 microphone connected to the computer, measurements by Praat, version 3.9.36; the results rounded to 50 Hz.

From the data above, it is clear that formant transitions of coronal consonants in Polish are rather poor cues for the differentiating between the place of articulation in the context of front vowels. In Polish, a consonant before a front vowel [i] obligatorily assimilates to the place of articulation of the vowel. In other words, the end phase of the consonant is already articulated with the characteristic tongue position as for the front vowel, the transition from the consonant into the vowel takes place before it can be heard, so, consequently, what we hear is the formant values typical for the vowel. Since F2 is high for coronal sounds irrespective of the vocalic context, it is probably for this reason that consonants in the context of front vowels are often misperceived as coronals, compare Winitz et al. (1972), for labials, and Guion (1998), for velars.

3.4.2 Formant Transitions of Secondary Palatalized Consonants

Secondarily palatalized consonants are characterized by a very high value of F2, usually above 2000 Hz. In these cases, F2 is so high that it melts with F3, forming a broad peak somewhere between 2000 and 3500 Hz, similar to for prepalatals (compare the previous section). This observation is valid for both phonemic prepalatals, as well as for any phonemic or non-phonemic secondary palatalized labials, anterior coronals, post-alveolars as well as for prevelars (palatalized velars). Notice that the F2/F3 values for secondarily palatalized segments (e. g. palatalized velars) before [e] are higher than that for the [e] itself, reaching the values characteristic for the vowel [i].

3.4.3 Formants of Vowels

Wierzchowska (1980) gives the formant characteristics of vowels as summarized in (21):

(21) Formants of Polish vowels (in Hz) (Wierzchowska, 1980)

	i	ɨ	ɛ	e	u	a
F2	2500-3000	2000-2300	2000	?	600-800	1200-1400
F1	350-500	350-500	500	?	300	800-900

Wierzchowska (1980) does not distinguish between the two qualities of the front mid vowel. It is also difficult to evaluate this data because the environment in which the sounds were recorded is unknown. For comparison, I carried out measurements for all Polish vowels under discussion. Vowels were recorded in isolation, with the exception of [e]. [e] in Polish is strongly context-bound; specifically, it appears only with palatalized consonants. It is possible that a Polish native-speaker simply cannot pronounce the [e] vowel in isolation, and that is why the recording has been made twice: once in isolation and once in a typical context of [j].

(22) Formants in Polish vowels in Hz

<table>
<tr><th></th><th>F3</th><th>F2</th><th>F1</th></tr>
<tr><td>i</td><td colspan="2">2700-3500</td><td>200-400</td></tr>
<tr><td>ɨ</td><td>3000 - 3300</td><td>2000 - 2300</td><td>300-700</td></tr>
<tr><td>e</td><td>3200-3400</td><td>2200-2500</td><td>500-800</td></tr>
<tr><td>jej</td><td colspan="2">2700-3500</td><td>600</td></tr>
<tr><td>ɛ</td><td>3000-3300</td><td>2000-2300</td><td>600-1000</td></tr>
<tr><td>a</td><td>2900-3000</td><td></td><td></td></tr>
<tr><td>o</td><td>2900-3000</td><td></td><td></td></tr>
<tr><td>u</td><td>3000</td><td>150-900</td><td></td></tr>
</table>

It is evident that the absolute values of formant transitions are difficult to evaluate. However, we observe that the relative highest formants are characteristic for front vowels, and especially for ATR front vowels. I propose the following surface feature specification with respect to the F2/F3 dimension for Polish vowels in (23) below:

(23) Perceptual feature [F2] values for vowels

	i	ɨ	ɛ	e	u	o	a
F2	Highest High	High	High	Highest High	Low	Low	Low Lowest

3.4.4 Friction

The very absence or presence of a clear friction element may distinguish between classes of sounds. Thus, fricatives and affricates have clear friction in the signal but, on the other hand, stops and sonorants do not have a distinctive noise element:

(24) [Friction]

	Stops	Affricates	Fricatives	Sonorant consonants	Vowels
Friction		+	+		

Interestingly, stops also have a short burst of noise (substantially shorter as for fricatives and affricates, as argued in chapter 2), which has similar properties as in regular fricatives/affricates (e. g. noise frequency). Thus, for example, we argued that F2 transitions are most often not sufficiently reliable cues for the distinguishing between different coronal places of articulation. Anterior coronals may be distinguished perceptually from prepalatals and post-alveolars on the basis of features within the dimension of Noise Frequency:

(25) Noise Frequency

	x	š	ɕ	s
NF	1	2	3	4

3.4.5 Perceptual [Pal]

As noted in chapter 2, yet another perceptual feature is postulated for Polish, namely [Pal] (see section 2.11, for the discussion of its acoustic correlates). Here, let us review the phonological arguments for the class of [Pal] consonants in Polish.

First, Polish morphology assigns different sets of suffixes to different types of stems, depending on the quality of the stem-final consonant. For example, the nominative plural suffix is –e for so-called functional soft stems, and –i/–ɨ for the hard stems:

(26) –e/–ɨ(–i) distribution

a. hard stems take –ɨ(–i) suffix:

-p:	ma[p]+a	—	ma[p+ɨ]	'map'
-b:	grzy[b]	—	grzy[b+ɨ]	'mushroom'
-f:	lu[f]+a	—	lu[f+ɨ]	'barrel'
-v:	ka[v]+a	—	ka[v+ɨ]	'coffee'
-m:	ma[m]+a	—	ma[m+ɨ]	'mother'
-w:	wó[w]	—	wo[w+ɨ]	'buffel'
-t:	cha[t]+a	—	cha[t+ɨ]	'cabin'
-d:	bru[d]	—	bru[d+ɨ]	'dirt'
-s:	ma[s]+a	—	ma[s+ɨ]	'mass'
-z:	blu[z]+a	—	blu[z+ɨ]	'blouse, shirt'
-n:	wro[n]+a	—	wro[n+ɨ]	'crow'
-r:	ba[r]	—	ba[r+ɨ]	'bar'
-k:	ma[k]	—	ma[c+i]	'poppy flower'
-g:	no[g]+a	—	no[ɟ+i]	'leg'

b. soft stems take –e suffix:

-p^j	ko[p^jj]+a	—	ko[p^jj] +e	‘spear’
-b^j	jastrzą[b]	—	jastrzę[b^jj]+e	‘hawk’
-f^j	ma[f^jj]+a	—	ma[f^jj]+e	‘Mafia’
-v^j	cerkie[v]	—	cerk[v^jj]+e	‘catholic orthodox church’
-m^j	zie[m^jj]+a	—	zie[m^jj]+e	‘land’
-ts	ko[ts]	—	ko[ts]+e	‘blanket’
-dz	-wła[dz]+a	—	wła[dz]+e	‘authority’
-l	ku[l]+a	—	ku[l]+e	‘ball’
-tš	pła[tš]	—	pła[tš]+e	‘crying’
-dž	bry[dž]	—	bry[dž]+e	‘game of bridge’
-š	ka[š]+a	—	ka[š]+e	‘groats’
-ž	wró[ž]	—	wró[ž]+e	‘fortuneteller’
-tɕ	cio[tɕ]+a	—	cio[tɕ]+e	‘aunt’
-dʑ	Ma[dʑ]+a	—	Ma[dʑ]+e	‘fem. name. dimin.’
-ɕ	mamu[ɕ]+a	—	mamu[ɕ]+e	‘mother, dimin.’
-ʑ	Ka[ʑ]+a	—	Ka[ʑ]+e	‘diminutive of fem. name: Kazimiera’
-ɲ	ko[ɲ]	—	ko[ɲ]+e	‘horse’

The problem with these sounds is that not all of them are phonetically soft (secondarily palatalized). Not all of them are [Highest] (post-alveolars, dental affricates, the lateral). Not all of them are Coronal, non-anterior (alveolar affricates [ts], [dz]). We have no traditional feature to describe this class of sounds.

Second, the sounds in (26b) are all surface identical with possible outputs of some palatalization process, cf. (1). Palatalization is triggered by vowels which are surface always front, but not all front vowels trigger palatalization. Palatalizing vowels cannot be always described as [High], or [+ATR]; which leads to the conclusion that we have no traditional formal feature to express the commonness of the front vowels triggering palatalization in the functionally soft sounds.

Third, even if functionally soft sounds are underlying, when they are in a position within a word where they could be palatalized, they never undergo further palatalization (apart from Surface Palatalization, which I argue, is a separate phenomenon, see chapter 5):

(27) Functionally soft consonants do not undergo palatalization

ko[ts]	—	ko[ts]+ə, ko[ts]+ɨk	‘blanket’ — nom. pl., nom. sg. dimin.
pła[ts]+a	—	pła[ts]+e	‘payment’ — payment, nom. pl.

It is postulated here that functionally soft segments are [Pal]. They all differ perceptually from their non[Pal] counterparts in that they have distinctly higher F2 formant transitions, supported by the presence of friction, compare the discussion in chapter 2.

3.5 Feature Specifications of Polish Sounds

The following sections focus on Polish sounds from the perspective of possible contrasts, and the consequent featural specification of the input and output sounds in phonology.

3.5.1 Consonants

The surface inventory of Polish consonants is illustrated in (28), including contextual palatalized variants. Notice that “palatalized” denotes here surface secondary palatalization.

(28) Surface sounds of Polish: consonants*

	labials	dentals alv.	post-alveolars	prepalatals palatals	velars pre-velars
Stops	p b	t d			k g
Stops palatalized	p^j b^j	(t^j d^j)			c ɟ
Fricatives	f v	s z	š ž		x (ɣ)
Fricatives palatalized	f^j v^j	s^j z^j	$š^j$ $ž^j$	ɕ ʑ	(ç)
Affricates		ts dz	tš dž		
Affricates palatalized		ts^j dz^j	$tš^j$ $dž^j$	tɕ dʑ[6]	
Nasals	m (ɱ)	n			(ɳ)
Nasals palatalized	m^j			ɲ	
Liquids		l			
Liquids palatalized		l^j			
Rhotic		r			
Rhotic palatalized		r^j			
Glides	w			j	

* Contextually devoiced variants of sonorants are not included.

The aim of the following discussion is to state feature specifications for the consonants. In (28), the segments in brackets are unarguably surface contextual variants, and are of no interest for our further analysis. Also secondarily palatalized dentals, post-alveolars, the rhotic, and the surface liquid all appear exclusively in the context of a surface [i] and do not convey the underlying contrast to the plain counterparts. I assume that they are [+ATR] but not [Pal]. The more complicated cases of secondarily palatalized labials and velars are discussed in detail in the following.

It is claimed here that secondarily palatalized and plain velars do not contrast with respect to feature [Pal]. To support this thesis, first, we will consider phonotactics of the relevant sounds, and it will be shown that, unlike other palatalized sounds, plain and secondarily palatalized velars are in complementary distribution. Second, we will see that the perceptual contrast between [ce] and [kɛ] may and should be attributed rather to the systematic underlying contrast in the vowel and not in the consonants. Finally, it will

[6] Phonetically, it is difficult to say that the palatalization in prepalatals is a secondary articulation, because the prepalatal constriction is the major and the only one. However, I categorize them together with secondary palatalized sounds, because, in contrast to other groups of segments with just one place of constriction, the characteristic position of the tongue is like for secondary palatalized segments, that is raised towards the hard palate.

be argued that for velars there are not two groups of stems for the choice of soft-stem- or hard-stem-correlated suffixes.

Consider the data in (29) showing the phonotactics of secondarily palatalized segments:

(29) Distribution of palatalized segments

a. labials

[p^{j}jax]	'sand'	[pav^{j}j+a]	'peacock'
[p^{j}jes]	'dog'	[pav^{j}j+e]	'peacock,nom. pl'
[p^{j}isk]	'squeak'	[pav^j+i]	'peacock, gen. pl.'

b. dentals and post-alveolars

[d^{j}i]sko	'disco'	∗. . . [d^j]+i bru[d^j]# i	'dirt and'
[d^{j}j]adem	'diadem'	brud# albo	'dirt or'
[dž^{j}i]p	'jeep'	brud# elementarny	'basic dirt'

c. prepalatals

[tɕ]asto	'dough'	cio[tɕ]+a	'aunt'
[tɕ]epwo	'warm'	kro[tɕ]+e	'plenty'
[tɕ]icho	'silent'	wa[tɕ]+ik	'(piece of) cotton wool'

d. velars

[c]ilka	'several'	ma[c]+i	'poppy flowers'
[ce]dy	'when'	ma[c]+em	'poppy flower, instr. sg.'
[cj]oto	'Kyoto'		
ma[cj]avelli	'Machiavelli'		

Whereas palatalized labials (29a) and prepalatals (29c) may be followed by both front and back vowels (whether morpheme-internally or stem-final), in the case of secondarily palatalized dentals, palatalized post-alveolars, and, as argued here, secondarily palatalized velars, a special environment is necessary. Dentals and post-alveolars clearly need a context of [i] or [j], and then they are palatalized even across word boundaries, as in (29b). Secondarily palatalized dentals and post-alveolars never occur morpheme-finally before a following suffix. Even in dialects which produce no palatal glide [j] after a secondarily palatalized dental, a pronunciation like [d^{j}ament], where a secondarily palatalized segment appears on the surface before a back vowel, occurs in words which are new borrowings containing in the source languages sequences with an orthographic or pronounced front vowel or [j]. Palatalized velars also appear only before [i], [j], and [+ATR][e]. They appear at the end of a morpheme before another suffix starting with a surface front vowel, but in this environment a non-palatalized [k] is excluded.

Palatalized velar fricative [ç] appears only in the context of [i, j],[7] morpheme-internally, where the non-palatalized variant is banned: [ç]–[x] is clearly not contrasting. Palatalized velar stops are a more complicated case. Morpheme-internally there are contrasting morpheme-internal surface sequences of [ce] versus [kɛ], as in forms in (30), both in native and in foreign vocabulary:

(30) Distribution of [c]–[k]

[ce]dy	kiedy	'when'
[kɛ]ndy	kędy	'which way'
[ce]rmasz	kiermasz	'fair' (from Germ. Kirmes)
[kɛ]lner	kelner	'waiter' (from Germ. Kellner)

On the basis of data like in (30), it has often been argued that [c] and [k] are two independent phonemes of Polish. If both [c] and [k] appear before a front mid vowel, then the distribution of [c]–[k] is unpredictable, and consequently, they are both phonemes of Polish. However, one fact is usually disregarded, namely, the difference in the quality of the vowel following the velar sound. [e] is always a context for [c], and [ɛ] follows [k]. Instead of claiming that the [e/ɛ] distribution depends on the quality of the consonant, one could assume that the vowel distinction is underlying, and the [c/k] distribution belongs to the realm of contextual allophones. The analysis, which treats [c, ɟ] as effects of articulatory agreement with the vowel, becomes even more plausible if we notice that we have to make a distinction between two sets of front mid vowels anyway: those that palatalize velars (but not only velars) at the morpheme boundary, and those which do not have the power to trigger palatalization at the morpheme boundary. If [c]–[k] distribution is motivated by the underlying contrast in vowels, then, [c]–[k] distinction itself is not relevant for the listener, and [c] is not perceptually [Pal].

Interestingly, there is no surface contrast between [c] and [k] nor between [ɟ] and [g] at the morpheme boundary: morpheme-final velar stops are realized as prevelars [c, ɟ] before vowels which do not trigger palatalization of, for instance, coronals, and as [tš, dž] before a palatalizing vowel.

Notice also that [c] is obligatorily followed by [j] if some other than front vowel follows:

[7] And possibly ATR [e].

(31) [c] before back vowels
[cj]anti 'chianti'
To[cj]o 'Tokyo'
[cj]osk 'kiosk'

Also notice that the words with [c]+vowel other than [i] or [e] are all borrowings and they all can be traced back to foreign forms which unarguably in speech or in orthography contain [i] or [j]. These [i] or [j] might be also underlyingly there in Polish (and the palatalized consonant is contextual).

Another argument to support the thesis that [c/k] is not phonemic (and does not have to be marked by perceptual features) is provided by the facts connected with the choice of suffixes. Labials might be soft, i. e. palatalized, and then they will surface as secondary palatalized before a vowel, and take characteristic suffixes for the soft stems. There are also hard labial stems, taking characteristic suffixes for the hard stems. For coronal stems the same pattern holds: there are soft stems (prepalatals), and hard stems (dentals). However, the behavior of velars is different. There are not two groups, hard and soft, instead velars behave inconsistently. For instance, all velar stems always take a plural nominal suffix that is characteristic for hard stems (the data given in (32a)). For locative singular suffixes (31b), however, in feminine gender they behave as if they were soft, and in masculine and neuter, as if they were hard.

(32) Distribution of hard-stem versus soft-stem suffixes

a. nom. pl. suffixes

Hard stems	Soft stems
grzyb, grzyb+y 'mushroom'	paw, pa[v^jj]+e 'peacock'
młot, młot+y 'hammer'	łoś, ło[ɕ]+e 'elk'
brak, brak+i 'lack'	————

b. loc. sg. suffixes

Hard stems	Soft stems
mam+a, ma[m^jj]+e 'mother'	paw, pa[v^j_+j]+u 'peacock'
rat+a, ra[$tɕ_+$]+e 'rate'	ło[ɕ]+u 'elk'
bułk+a, buł[ts]+e 'bread-roll', fem.	brak, brak+u 'lack, masc.'
	ok+o, ok+u 'eye'

The interpretation of these facts is that for velars there is no underlying distinction in terms of softness, parallel to the distinction in labials, or coronals.

Thus, palatalized velars are analyzed here as contextual variants and not independent phonemes, and are not specified for [Pal]. In chapter 5, an analysis will be proposed which treats prevelars as an effect of a constraint requiring an agreement with the following vowel in terms of the position of the tongue root and the place of constriction.

At first sight, the status of palatalized labials might seem in this light also problematic: one could argue that, since secondarily palatalized velars are not phonemic, it is also the case with secondarily palatalized labials. Palatalized labials are very often (if not regularly) realized as a sequence of a labial stop and palatal glide [j] (33c), and, additionally, they surface only before vowels, and never at the end of the word or before another consonant. However, as already mentioned above, unlike in the case of velars, there seems to be an underlying systematic distinction between palatalized and non-palatalized labials, compare (33):

(33) Soft and hard labial-final stems

a. choice of pl. suffix conditioned by soft-hard distinction
pa[v] – pa[v^jj+e] 'peacock' versus
ró[v] – ro[v+ɨ] 'groove'

b. choice of adj. masc. nom. sg. ending
głu[p^j+i] 'stupid', nom. sg. masc. versus
gru[b+ɨ] 'thick'

c. palatalized labial versus non-palatalized labial surfacing before adj. fem. ending –a
głu[p^j j]+a 'stupid', nom. sg. fem. versus
gru[b]+a 'thick', nom. sg. fem.

Unlike in the case of velars, without assuming that palatalized labials are phonemic (carry over an underlying contrast), a number of regularities would remain without any account.

In contrast, secondarily palatalized dentals should be regarded, like secondarily palatalized velars, as contextual realizations of plain consonants (but see Szpyra (1995)). They appear only in the context of [i], and the distinction between [d^ji] and [dɨ], or dental followed by any other vowel, may be attributed to the vowel.

In the following analysis, I assume that palatalized labials (and prepalatals and post-alveolars) are underlyingly featurally distinct from their plain counterparts with respect to feature [Pal]. For the time being, it should be sufficient to state the inventory of contrasts as in (34).

(34) Underlying contrasts in consonants in Polish

	labials	dentals/ alv.	post-alveolars	prepalatals palatals	velars
Stops + nasals	p b m	t d n		ɲ	k g
Stops palatalized	p^j b^j m^j				
Fricatives	f v	s z	š ž	ɕ ʑ	x
Fricatives palatalized	f^j v^j				
Affricates		ts dz	tš dž	tɕ dʑ	
Liquids			l		
Rhotic		r			
Glides	w			j	

This implies the following specifications in terms of some most important features, see (35):

(35) Underlying specification of Polish consonants

	Labial	Coronal anterior	Coronal non-anterior −ATR	Coronal non-anterior +ATR	Velar
Open0	p b	t d			k g
Open1	f v	s z			x
Open1 PAL	f^j v^j		š ž	ɕ ʑ	
Open0 PAL	p^j b^j	ts, dz	tš dž	tɕ dʑ	
Lateral Formant	w		l		
Rhotic Formant		r			
Open2 Formant				j	

3.5.2 Vowels

Rubach (1984) gives the following inventory of major Polish vocalic segments:

(36) Vocalic inventory of Polish (Rubach, 1984, 27)
[i] – front unrounded
[ɨ] – central unrounded; classified as [+back]
[u] – back rounded
[e] – front rounded
[o] – back rounded
[a] – low central vowel; classified as [+back]

Additionally, Polish has nasalized vowels: mid front and mid back. These are derived in Rubach's system via Vowel Nasalization, in which vowels get surface nasalized before nasal glides [w̃], and [j̃], those derived in the earlier stage from nasal stops. The front nasalized vowel never triggers palatalization. As it has been argued earlier in this chapter (section 3.3.3), they are also surface lower and more central than any other occurrence of a front mid non-nasalized vowel. Thus, they do not have in their representation features triggering palatalization, whatever their representation should be, and they are not discussed here further.

Rubach (Rubach, 1984, 27) mentions also the surface segment, which has been discussed in section 3.3.3, namely, tense [e]. For Rubach, it is an allophone of a front mid vowel, derived by the raising of a standard lower mid /e/ (IPA: [ɛ]) in the context of surface [ɕ, ʑ, tɕ, dʑ, ɲ, j], and it differs from the standard mid front vowel with respect to the feature [+tense].[8] Rubach discusses briefly only the difference between mid front vowel allophones in the context of prepalatals, but Biedrzycki (1978) mentions that parallel alternations are also to be observed for mid back vowels and low vowel [a]. Whereas I do not intend to discuss the alternations of back vowels, it is assumed here, that the difference between [e] and [ɛ] (though for mid vowels it does not introduce perceptual contrast) is characteristic for the Polish system in general and lies in the advancement of the tongue root. It might be then also a reflex of the underlying distinction in [Pal]. The feature [ATR] is also claimed here to be the core distinction between [i] and [ɨ]: this claim has been supported by the phonetic description of the respective sounds in section 3.3, and will be further supported by phonological arguments in chapter 5.

In sum, the following surface specifications of vowels are assumed in the present study with respect to articulatory features:[9]

(37) Surface vowels of Polish (disregarding minor allophones)

		Coronal non-anterior	Dorsal
Open3	+ATR	i	u
	−ATR	ɨ	
Open4	+ATR	e	o
	−ATR	ɛ	
Open4 Nasal	Lab		õ
			ɔ̃
Open5		a	

Further, we have to make a distinction between phonologically palatalizing front vowels, which contain in our model perceptual feature [Pal], as elaborated on in chapter 4, and the front vowels which do not contain [Pal], and have no power to trigger phonological palatalization. [Pal] front vowels by default surface as [+ATR], non-Pal front vowels are by default [−ATR] on the surface. However, we have to say that [+ATR] is not distinctive for vowels, and only inserted by default phonetic implementation or inserted for the sake of surface requirements on the agreement in the consonant+vowel

[8] Notice that if the raised allophone of the mid vowel appears only in the context of prepalatals and palatal [j], then prepalatals should be the source of tenseness. Rubach does not define the rule of e-raising, and does not specify prepalatals in respect to tenseness. Tenseness for vowels plays in his system no further role, apart from distinguishing yers from the regular high vowels.

[9] Following, for example, Clements and Hume (1995), front vowels are Coronal, back vowels are Dorsal, see section on the phonetics of the respective sounds.

sequence in respect to the position of the tongue root. The emerging underlying system is illustrated in (38).

(38) Vocalic inventory of Polish: default values

	Coronal Pal	Coronal non-Pal	Dorsal
Open3	i[Pal]	ɨ	u
Open4	e[Pal]	ɛ	o
Open5	a		

Additionally, for the vowel-Ø alternation, it is assumed that the underlying segment is a floating [Coronal, non-anterior] (devoid of root, or a timing slot), which may or may not possess the palatalizing perceptual feature [Pal]. The prediction from (38) would be that Coronal [Pal] vowels will trigger perceptual palatalization, and those Coronal vowels which do not posses feature [Pal] do not trigger palatalization, as developed in chapter 4.

3.6 Summary: Contrasting Features of Polish

Polish has the following underlying contrasts, as in (39):

(39) Polish underlying contrasts
Place: Coronal – labial – dorsal
Anteriority: Anterior – non-anterior
Voicing: Voiced-Ø
Rhoticity: rhotic-Ø
Lateral: Lateral-Ø
Nasal: Nasal-Ø
Open: 0-1-2-3-4-5
TongueRoot: +ATR- −ATR
Formant: Formant-Ø
NasalFormant: NasalFormant – Ø
F2: HighestF2- HighF2 -LowF2-LowestF2
Palatality: Pal – Ø
Noise: Friction – Ø
Stridency: Strident-Ø
NF: 1-2-3-4

I assume that the discussion whether a particular segment is underlying or not is better targeted if we focus on the question whether a particular contrast is underlying or not. Thus, a contrast between [p] and [p^j] is underlying, and can be encompassed in terms of the feature [Pal], and, on the other hand, there is no underlying distinction between [c] and [k], or between [ts] and [ts^j]. Contrasts do not have to be binary. They refer to features which, I assume, are in the most cases monovalent (Steriade, 1995b). In cases of some feature dimensions, however, all values seem to be active in phonology; for example, [+ATR] and [−ATR] can spread, thus, I treat them both as two monovalent features in the dimension ATR. From the given system of underlying contrasts, a given set of surface segments emerges with the following feature specifications:

(40) Surface features of Polish sounds

	Perceptual									Articulatory									
	formant	pal	low F2	high F2	highest F2 F3	strid	friction	NF	Nas formant	open	lat	rhot	voice	lab	cor	ant	dor	ATR	nas
p			+					1		0			−	+				−	
p^{j}		+		+	+			1		0			−	+	+	−		+	
b			+					1		0			−	+	+	−		+	
b^{j}		+	−	+	+			1		0			+	+	+	−		+	
f			+				+	1		1			−	+				−	
f^{j}		+	−	+	+		+	1		1			−	+	+	−		+	
v			+				+	1		1			+	+				−	
v^{j}		+	−	+	+		+	1		1			+	+	+	−		+	
m	+		+						+	0			(+)*	+				−	+
m^{j}	+	+		+	+				+	0			(+)*	+	+	−		+	+
w	+		+							2			(+)*	+			+	−	
t				+				4		0			−		+	+		−	
t^{j}				+	+			4		0					+	+/−		+	
d				+				4		0			+		+	+		−	
d^{j}				+	+			4		0			+		+	+/−		+	
s				+		+	+	4		1			−		+	+		−	
s^{j}				+	+	+	+	4		1			−		+	+		−	
z				+		+	+	4		1			+		+	+		−	
z^{j}				+	+	+	+	4		1			+		+	+/−		+	
ts		+		+		+	+	4		0			−		+	+		−	
ts^{j}		+		+	+	+	+	4		0			−		+	+/−		+	
dz		+		+		+	+	4		0			+		+	+		−	
dz^{j}		+		+	+	+	+	4		0			+		+	+/−		+	
l	+	+		+						0	+		(+)*		+	−		−	
l^{j}	+	+		+	+					0	+		(+)*		+	−		+	
r	+		+							0		+	(+)*		+	+		−	
r^{j}	+			+	+					0		+	(+)*		+	+/−		+	
tš		+		+		+	+	2		0			−		+	−		−	
$tš^{j}$		+		+	+	+	+	3		0			−		+	−		+	
dž		+		+		+	+	2		0			+		+	−		−	
$dž^{j}$		+		+	+	+	+	3		0			+		+	−		+	
š		+		+		+	+	2		1			−		+	−		−	
$š^{j}$		+		+	+	+	+	3		1			−		+	−		+	
ž		+		+		+	+	2		1			+		+	−		−	
$ž^{j}$		+		+	+	+	+	3		1			+		+	−		+	
tɕ		+		+	+	+	+	3		0			−		+	−		+	
dʑ		+		+	+	+	+	3		0			+		+	−		+	
ɕ		+		+	+	+	+	3		1			−		+	−		+	
ʑ		+		+	+	+	+	3		1			+		+	−		+	
ɲ		+		+	+				+	0			(+)*		+	−		+	+
j	+	+		+	+					2			(+)*		+	−		+	
k			+					1		0			−				+	−	
c				+	+			2		0			−				+	+	
g			+					1		0			+				+	−	
ɟ				+	+			2		0			+				+	+	
x			+				+	1		1			−				+	−	
ç				+	+		+	2		1			−				+	+	
i		+/−		+	+					3			(+)*		+	−		+	
ɨ		+/−		+						3			(+)*		+	−		−	
e		+/−		+	+					4			(+)*		+	−		+	
ɛ		+/−		+						4			(+)*		+	−		−	
o		−	+							4			(+)*	+			+	+/−	
u		−	+							3			(+)*	+			+	+/−	
a		−	+							5			(+)*				+	+/−	

* Articulatory voicing is not distinctive for sonorants.

Chapter 4

THE ANALYSIS OF PALATALIZATION

4.1 Coronal Palatalization, 1st Velar Palatalization, and Labial Palatalization

The most widely-recognized monograph on Polish phonology, i. e. Rubach (1984), and the many followers afterwards, treated the palatalization of sounds articulated at different places of articulation as separate processes, differing in the target, output, and – importantly – trigger. Thus, there was Coronal Palatalization of coronal sounds, Labial Palatalization of labials, and Velar Palatalization of velar sounds. The reason for separating these processes is obvious: Coronal Palatalization produces prepalatals as an output, labial palatalization – secondarily palatalized labials, and the alternants of velars are post-alveolars. This approach, on the one hand, allowed for ordering the data, and on the other hand, led to designing analyses where one set of data is accounted for, but the rest is fully neglected. In fact, all the OT accounts of Polish that I am aware of went this path.

There were also earlier approaches that proposed a general palatalization rule (Steele, 1973), though it produced an unwelcome effect, that is, a number of intermediary stages (see for a similar approach in feature geometry: Szpyra (1995), arguments against in Gussmann (1978), Rubach (1981), Rubach (1984)). To preempt the discussion, let me state, however, that the conclusion of the analysis proposed here is rather that we have to do with one palatalization process in Polish, which occurs in the context of palatalizing vowels and takes as its target labials, coronals, and velars. It will be argued here that the output of alternations is different depending on the place of articulation, because the underlying contrast between labials, coronals, and velars must be preserved on the surface.

4.2 Organization of the Chapter

The present chapter offers a new analysis for the set of palatalization processes which are triggered by no obvious, regular surface trigger and result in the perceptually salient effect. The discussion of surface effects involving Surface Palatalization and Surface Velar (cf. the overview in chapter 1), triggered exceptionlessly by surface [i] and surface [e], respectively, will be postponed till chapter 5.

The chapter is organized in the following way. In section 4.3, we discuss the role of the input-output perceptual faithfulness constraints. It will be argued that input-output perceptual faithfulness has to "license" any surface amendments in the first place (section 4.3.1.), and then they may be responsible for the choice of the "best" candidate from among the "good" ones (section 4.3.2). In section 4.4, we take up the issue of the nature of the trigger of palatalization in Polish and show that it cannot be defined in surface terms by referring to articulatory features. In section 4.5, it is proposed that Polish palatalization is triggered by the perceptual feature [Pal]. Section 4.6 is devoted to the discussion of the morpheme boundary effects. The topic of section 4.7 is the perceptual strengthening hypothesis: it is argued that prepalatals in Polish emerge because [Pal] is rendered by a bigger number of cues in prepalatals than in secondary palatalized dentals. Section 4.8 is devoted to the discussion of the role of Preserve Contrast constraints. In 4.8.1, it is shown how Preserve Contrast constraints force a more complex articulation to surface. Section 4.8.2. demonstrates another situation: when Preserve Contrast constraints cannot be violated, and constraints on complex articulation may have the chance to influence the surface output, even at the cost of the loss of the surface articulatory regularity. Section 4.9 concentrates on the set of data where palatalization occurs without a surface trigger. This effect is due to the working of constraint Ident[Pal]. Section 4.10 continues the topic of Ident[Pal] from the perspective of the blocking of Labial Palatalization. It is argued that palatalization cannot surface on labials if there is no possibility to secure the sufficient perceptual salience of the feature. In section 4.11, yet another apparent irregularity of the palatalization data is brought forward, namely, spirantization of the voiced output in the palatalization of an underlying velar stop. This is argued to be an example of lenition, which is typical in the positions between two sounds articulated with a relatively wider jaw opening. Section 4.12 is devoted to the question, as to why affricates do not undergo any alternations in palatalizing contexts. Section 4.13 summarizes proposed rankings of constraints, and section 4.14 recapitulates the findings of the chapter.

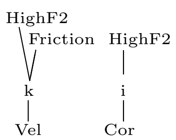
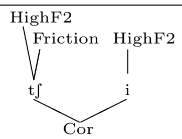
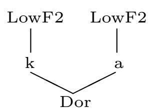
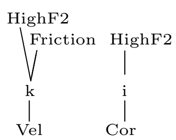
4.3 Perceptual Similarity between Input and Output

4.3.1 Licensing of Surface Advantageous Alternations

It has often been observed that whereas palatalization is a common process cross-linguistically, other types of a consonant-to-vowel assimilation are not frequent. I propose here that the necessary condition for a consonant-to-vowel interaction is that its result does not diverge too dramatically from the underlying perceptual representation (cf. Steriade (2001), for diachronic consonantal cluster assimilations). The output must be sufficiently similar, that is, faithful enough, to the input perceptual representation. This requirement is not absolute; it does not require absolute identity of perceptual features, because otherwise we would not have any alternations on the surface. It requires, however, that the output realizes sufficient number of most important perceptual features of the input, so that the input could be recovered from the output.

This mechanism allows for the realization of an underlying /ki/ as a surface [tši] but excludes output [ka], which would also satisfy the articulatory and perceptual agreement requirements, see (1).

(1) Perceptual IO-Faithfulness

	Ident [Friction] Ident [HighF2]	[HighF2]Agr PlaceAgr [LowF2]Agr
☞ a. 		
b. 	*!*	
c. 		*

The underlying /ki/ contains perceptual features [HighF2] and [Friction]. By Lexicon Optimization, the underlying representation contains the same features as the standard faithful realization (c). Since a velar voiceless stop before a front vowel usually might be produced with a substantial friction, and the F2 transition is relatively high, these features are contained in the underlying representation. If articulatory faithfulness constraints play no role, but on the other hand, constraints favoring place and perceptual agreement are high ranked, two kinds of articulatory amendment are plausible: an assimilation of the consonant to the vowel (a), or an assimilation of the vowel to the consonant (b). Usually, it is the former that applies because the structure in (a) renders the underlying perceptual features faithfully enough. Consequently, this mechanism might allow for the realization of an underlying sequence velar+front vowel e. g. /ki/ as a perceptually similar surface [tʃi] (or as [tši], or as [tsi], which all have the same perceptual features [HighF2] and [Friction]) compare (a), but excludes rendering of the underlying /ki/ as a radically different surface [ka] as in (b).

4.3.2 Fixed Alternations

Continuing the topic of the role of perceptual IO-faithfulness for Polish palatalization, let us preempt a little the discussion and turn to the following issue. Coronals and velars undergo palatalization. Dentals alternate with prepalatals in the palatalizing environment, velars alternate with post-alveolars. The question arises on what account the opposite setting, that is, hypothetical ∗dentals-to-post-alveolars and ∗velars-to-prepalatals, cf. (2), is excluded.

(2) Fixed Sets of Alternants

a. Actual alternations
   t – tɕ
   k – tš
b. Hypothetical alternations
   k – tɕ
   t – tš

As argued in Ćavar and Hamann (2001), such alternations (k – tɕ, t – tš) are not excluded in general, and can be found cross-linguistically. In the following, the Perceptual Faithfulness Hypothesis (Ćavar & Hamann, 2001) will be discussed.

The proposal is that the fixed choice of alternations for coronals and velars, respectively, results from the requirement for the perceptual faithfulness, or in other words, similarity in terms of less important perceptual features such as [Noise Frequency]. Since the relevant pairs are all similar in terms of

[HighF2] and [Friction], the claim is that [k] alternates with [tš] because, in the relevant contexts, [k] is more perceptually similar to [tš] with respect to [Noise Frequency] than to [tɕ]. And the other way round, [t] should be perceptually more similar to [tɕ] than to [tš]. In particular, it is proposed that velars, dentals, post-alveolars and prepalatals can be differentiated on the basis of features referring to [Noise Frequency], and that the alternating pairs are sounds which are not too distinct in this dimension, due to the constraint that I propose in (4).

(3) Noise frequency (repeated)

	x	š	ɕ	s
NF	1	2	3	4

(4) MaxDist-IO(NF) = 1
The input has a corresponding equal value or differs maximally in one grade in the dimension of Noise Frequency.

Since velars differ from post-alveolars in one grade only, and prepalatals differ from velars more radically with respect to [Noise Frequency] level, the optimal alternant for the velar sound will be post-alveolar. On the other hand, dentals are more similar to prepalatals than to post-alveolars, and this is reflected by the alternation between dentals and prepalatals. In (5), two strings are evaluated simultaneously: one with an underlying coronal and one with an underlying velar sound. Perceptual features other than those referring to NF are skipped, since, as noted above, all the coronal non-anterior affricates are perceptually similar to [k] in the context of a front vowel in general, and what makes them different is NF:

(5) 1st Velar Palatalization – perceptual similarity analysis

		Ident [HighF2] [Friction]	PAL	MaxDistIO (NF)=1
	[NF1] Pal [NF4] Pal zame k + ek zame t + e Dor Cor[−antCor[+ant Cor[+ant			
a.	[NF1] Pal [NF4] Pal zamek ek zamet e Dor Cor[−ant Cor[+ant Cor[−ant		∗! ∗!	
☞ b.	[NF2] Pal [NF3] Pal zametš ek zametɕ e Cor[−ant Cor[−ant			
c.	[NF3] Pal [NF2] Pal zametɕ ek zametš e Cor[−ant Cor[−ant			∗! ∗!

4.4 Trigger of Palatalization in Polish: Articulatory or Auditory?

Palatalization is traditionally treated as an assimilation. The assimilated features in the traditional approaches can only be of articulatory character: depending on the framework either [−back] or Coronal. This approach cannot be excluded a priori in the functional approach recognizing the role of perception. Assimilation of place features in the neighboring segments saves articulatory energy. On the other hand, palatalization processes discussed here might be triggered by perceptual factors. It has been argued in chapter 2 that it is of benefit for the listener if perceptual features are as salient as possible, and there is a family of constraints favoring spreading of perceptual features. In what follows, I propose that Polish palatalization is driven by a perceptual mechanism, and that articulatory factors alone are not powerful enough to trigger the palatalization with the change of major place of articulation in Polish.

Palatalization in Polish is, generally speaking, bound to the context of a front vowel. Let us investigate this statement in more detail. Polish anterior coronals [s z t d n w] alternate with [ɕ ʑ tɕ dʑ ɲ l], respectively, in the context of surface i-initial suffixes, some examples given below in (6):

(6) Palatalization before [i]

a. dim. –ik:
samochó[d] – samocho[dʑ]+ik ‘car’ – ‘car’ dim.
dru[t] – dru[tɕ]+ik ‘wire’ – ‘wire’ dim.

b. adj. –ist+y:
kwia[t] – kwie[tɕ]+isty ‘flower – flowery’
wyraz – wyra[ʑ]+isty ‘expression – expressive’

c. adj. -iw+y:
prawd+a – praw[dʑ]+iwy ‘truth’ – ‘true’
ze+mst+a – m[ɕtɕ]+iw+y ‘revenge’ – ‘revengeful’

d. profession names -ist+a:
klarnet – klarne[tɕ]+ista ‘clarinet player’
puzon – puzo[ɲ]+ista ‘trombone player’

e. verbalizing suffix –i:
gło[s] – gło[ɕ]+i+ć ‘voice’ – ‘to announce’
poró[d] – ro[dʑ]+i+ć ‘birth’ – ‘to give birth’

f. adj. nom. pl. masc-pers. –i:
zło[t]+y – zło[tɕ]+i ‘gold’, nom. sg. – nom. pl.
ły[s]+y – ły[ɕ]+i ‘bald’, nom. sg. – nom. pl.

g. nominal nom. pl. -i:
Francu[z] – Francu[ʑ]+i ‘Frenchman’ – ‘Frenchmen’
mitoma[n] – mitoma[ɲ]+i ‘sufferer’ – ‘sufferers’

For labials, there is normally only secondary palatalization before -i-morphemes:

(7) a. dim. –ik:
głą[b]+a – głą[b^j]+ik ‘heart of cabbage’
kra[m]+y – kra[m^j]+ik ‘market stand’, nom. pl. – dim.

b. adj. –isty:
naro[w]+y – naro[v^j]+isty ‘wild’, ‘uncontrolled behavior’ – ‘wild’
osob+a – osob[b^j]+isty ‘personal’

c. profession names -ista:
WO[p] – WO[p^j]+ista ‘memeber of WOP’[1]
harf+a – har[f^j]+ista ‘harp – harp player’

d. verbalizing suffix –i:
ro[b]+ota – ro[b^j]+i+ć ‘job’ – ‘to do’
łu[p] – łu[p^j]+i+ć ‘loot’ – ‘to plunder’

e. adj. nom. pl. masc. –i:
gru[b]+y – gru[b^j]+i ‘thick’, nom. sg. – nom. pl.
chro[m]+y – chro[m^j]+i ‘lame’, nom. sg. – nom. pl.

[1] WOP (Wojska Ochrony Pogranicza): acronym for “border protection forces”.

f. nominal nom. pl. -i:
chło[p]+a – chło[p^j]+i ‘peasant’ – ‘peasants’

The picture gets blurred when we take into consideration stems with velars in the final position. The -i- suffixes demonstrated above have to surface as -ɨ- after velars. Although they surface as -ɨ-, they trigger the palatalization with a major change in the place of articulation, as exemplified in (8):

(8) Palatalization before surface ɨ-initial suffixes

bark	‘arm’	bar[tš]+[ɨ]s+ty	‘broad-armed’
mąk+a	‘flour’	mą[tš]+[ɨ]st+y	‘of flour-like quality’
nauk+a	‘education, science’	nau[tš]+ɨ+ć	‘to teach’
dług+a	‘long’, nom. sg. fem.	przedłu[ž]+ɨ+ć	‘prolong’

On the other hand, surface -i- suffixes will not cause deep palatalization in velars (no change to post-alveolars) but merely a surface secondary palatalization. Some examples are given in (9):

(9) No 1st Velar Palatalization in the context of [i]

a. Nom. pl. of non-virile nouns:

nom. sg.	nom. pl.
ró[g] ‘horn’	ro[ɟ]+i
krok ‘step’	kro[c]+i

b. nom. sg. of adj. masc.

drug+a ‘second’, fem.	dru[ɟ]+i ‘second’, masc.
wysok+a ‘tall’	wyso[c]+i ‘tall’, masc.

Surface -ɨ-initial suffixes do not trigger any palatalization of labials or coronals, compare:

(10) ɨ-initial suffixes do not trigger palatalization of coronals

ła[p]+a ‘paw’	ła[p]+[ɨ] ‘paws’
gru[b]+ość ‘thickness’	grub+[ɨ] ‘thick’, masc. nom. sg.
mo[v]+a ‘speech’, nom. sg	mo[v]+[ɨ] gen. sg.
ru[f]+a ‘stern’	ru[f]+[ɨ] gen. sg. & nom. pl.
gro[m] ‘thunder’, nom. sg.	gro[m]+[ɨ] nom. pl.
mło[d]+ość ‘youth’	mło[d]+[ɨ] ‘young’
wa[t]+a ‘cotton wool’	wat+[ɨ] ‘cotton wool’, gen. sg.
ros+a ‘dew’	ros+[ɨ] ‘dew’, nom. pl.

As far as mid vowels are concerned, it is impossible to state any regularity, whether or not differentiating between surface [e] and [ɛ]. So, before tense [e], there is clear palatalization with [j] insertion for labials, and palatalization of coronals:

(11) Palatalization before ATR [e]

gru[b]+a 'thick', fem.	zgru[bj^j]+[e]+ć 'to get thicker'
lo[t] 'flight'	le[tɕ]+[e]+ć 'to fly'

On velars, these palatalizing suffixes are, however, realized as non-ATR [ɛ], still triggerring palatalization:

(12) non-ATR [ɛ] triggerring palatalization:

mil[k]+ną+ć	'to become silent'	mil[tš]+[ɛ]+ć	'to be silent'
be[k] 'bellying'		be[tš]+[ɛ]+ć	'to belly'

Otherwise, non-ATR-initial suffixes do not trigger palatalization of labials or coronals:

(13) No palatalization by non-ATR mid vowel:

grub+[ɛ]mu 'thick', adj. dat. sg. masc.
dobr+[ɛ]mu 'good', adj. dat. sg. masc.
grub+[ɛ]go 'thick', adj. gen. sg. masc.
dobr+[ɛ]go 'good', adj. gen. sg. masc.

Finally, the non-palatalizing suffixes of labial and coronal stems surface after velar stops with an ATR vowel (similar to the case of high vowels), and then, instead of the regular, deep palatalization with a change of major place of articulation, there is a secondary palatalization. One interesting thing is that we do not observe [j] insertion, as in the case when labials are secondarily palatalized. The second interesting thing is that, for the velar fricative, the vowel is non-ATR (like after labials and coronals), and we do not observe any palatalization at all:

(14) ma[c]+[e]m 'poppy seeds', instr. sg.
pługɟ...

Summing up, the situation is as illustrated in table (15):

(15)

	i	ɨ	e	ɛ
Labial	Secondary Palatalization	Ø	Secondary Palatalization+ j-Insertion	Ø
Coronal	Major Place Palatalization	Ø	Major Place Palatalization	Ø
Velar	Secondary Palatalization	Major Place Palatalization	Secondary Palatalization / Ø	Major Place Palatalization

It is clear that it is impossible to derive a solution based on surface articulatory features of the triggering vowel.

4.5 Perceptual Mechanism of Palatalization

We have seen in the previous section the problems with stating a generalization about the trigger in terms of articulation. The trigger is a front vowel, but not all front vowels trigger palatalization, and the same front vowels do not always trigger palatalization with the change of major place of articulation for all three places of articulation. I propose here to exclude from the discussion of phonological palatalization the effects of secondary palatalization on velars,[2] and assume here that the palatalization of labials, coronal, and velars in Polish is triggered by a constraint PAL(ATALIZATION) favoring the prolongation of perceptual feature [Pal] (as defined in chapter 2) from the vowel onto the preceding consonant. [Pal] on the vowel is not very salient in Polish and in some situations it can only be perceived if it anchors on a consonant: for example, if the [Pal] vowel is a yer and the yer is not licensed to surface. Articulatory constraints are ranked lower than PAL, thus, are neither powerful enough to force palatalization, nor to block it.

(16) PAL >> CorAgr, IdentPl, DepPl

[2] The effects of secondary palatalization by surface ATR vowel will be ascribed to ATR harmony and discussed in detail in chapter 5.

(17) Palatalization in Polish

lub+, kvas+, krok+ + i + ć (Pal on i)	PAL	IdentPl, DepPl, AgrPl
lu[b]ić (Pal on i)	*!	*
kva[s]ić (Pal on i)	*!	*
kro[k]ić (Pal on i)	*!	*
☞ lu[bʲ]ić (Pal on bʲ and i)		*
kva[ɕ]ić (Pal on ɕ and i)		*
kro[tš][ɨ]ć (Pal on tš and ɨ)		*

This approach draws on earlier research by Rochoń (2000), who states that palatalization in Polish is triggered by a lexical feature [Palatalization] attached to some lexically specified morphemes. The approach in this dissertation is different in at least three respects. Perceptual features seek phonetic correlates, that is, an independent justification. I refer the reader to the discussion of feature [Pal] in chapter 2. Further, an approach utilizing perceptual features is functional, in that it is ready to provide an external explanation of why something happens in terms of a gain from the point of view of the listener or a gain from the point of view of the speaker. Thus, palatalization involving the feature [Pal] is advantageous for the listener, because [Pal] originally docked on the vowel (and the important contrast marked this way) is more salient when it is additionally docked on the consonant. Finally, perceptual features are not limited to lexically specified morphemes. They will occur also stem-internally, though no alternation can be seen.

4.6 Limiting the Context of Palatalization: Alternating Environment

Palatalization, whether of labials, coronals, or velars applies across morpheme boundaries, and it does not apply morpheme-internally, as demonstrated in (18):

(18) The condition of morpheme boundary

a. Morpheme boundary – the context is met

ma[s]a 'mass'	ma[ɕ]+e dat. & loc. sg.
brą[z] 'brown color'	brą[ʑ]+e loc. & voc. sg.
bra[t] 'brother'	bra[tɕ]+e loc. & voc. sg.
mo[d]+a 'fashion'	mo[dʑ]+e dat. & loc. sg.
Ja[n] 'Jan', masc. name	Ja[ɲ]+e loc. & voc. sg.
pa[r]+a 'steam'	pa[ž]+e dat. & loc. sg.
szko[w]+a 'school'	szko[l]+e dat. & loc. sg.
kro[k] 'step'	kro[tš]+[ɛ]k dim.
móz[g] 'brain'	móż[dž]+[ɛ]k dim.
wa[g]a 'scales'	wa[ž]+[ɨ]ć 'to weight'
su[x]+y 'dry'	su[š]+[ɨ]ć 'to dry'
ma[p]+a 'map'	ma[p^{j}j]+e dat. sg.
ba[b]+a 'ugly woman'	ba[b^{j}j]+e dat. sg.
ma[m]+a 'mom'	ma[m^{j}j]+e dat. sg.
so[f]+a 'sofa'	so[f^{j}j]+e dat. sg.
ka[v]+a 'coffee'	ka[v^{j}j]+e dat. sg.

b. No morpheme boundary

[s^j]inus	'sinus'
[s]en	'sleep'
[z^j]ina	'Zina', name
[z]enon	'Zenon', name
[t^j]ik	'tick'
[t]ektur+a	'cardboard'
[d^j]inar	'dinar, currency'
[d]elta	'estuary'
[r^j]ita	'Rita', name
[r]ebus	'a puzzle'
[w^j]isconsin	'Wisconsin'
[w]eb	'head'
[c]ij	'stick'
ro[kɛ]r	'rocker'
[ɟ]itar+a	'guitar'
[gɛ]st	'gesture'
[ç]in+y	'China'
[xɛ]rbat+a	'tea'
[p]estk+a	'stone of the fruit'
[b]eton	'concrete'
[m]etk+a	'tag'
[f]etor	'strong bad smell'
[v]esel+e	'wedding'

Notably, the forms in (18b) do not display palatalization with the change of the major place of articulation. After -i- word internally (like after -j-), there is always secondary palatalization. I would like to argue here that this effect has nothing to do with the feature [Pal] but rather is to be explained by ATR harmony, the discussion of which is postponed till chapter 5.

Since palatalization applies only in an alternating environment, as discussed and defined in chapter 2, we propose that palatalization in Polish is actually an effect of PAL ∨ Uniform, repeated here as (19), and that the disjunction of PAL and Uniform is higher ranked than IdentPl, whereas PAL alone is ranked lower and in the end does not have influence on the surface form, cf. (20).

(19) PAL ∨ Uniform
Palatalize when the environment is not uniform.

(20) PAL ∨ Uniform >> PAL, Uniform

PAL ∨ Uniform (19) is responsible for blocking palatalization in the lack of morpheme-boundary context, as illustrated for clarity in (21):

(21) Local disjunction of PAL and Uniform

	PAL	PAL ∨ Uniform	Uniform
a.		∗	
b.	∗		
c.			∗
d.	∗	∗	∗

PAL applies (without violation of the disjunction) if Uniform is violated, that is, if we have an alternating environment (case (21c)); if Uniform is not violated (uniform environment), then the only way to satisfy the disjunction (19) is not to apply PAL (case (21b)). The situation when both members of the disjunction would be obeyed is excluded[3] (case (21a)). Finally, if the environment is alternating (Uniform is violated), and if PAL does not apply, then the disjunction is violated as well (case (21d)).

If PAL ∨ Uniform is ranked higher than IdentPlace, (and PAL alone), a candidate with palatalization in the alternating context will be optimal, as in (22):

(22) Palatalization

[Pal] [Pal] //sinus + ik//	PAL ∨ Uniform	PAL, Uniform
a. [Pal] [Pal] s i n u s i k	∗!	∗∗(PAL) ∗Uniform
☞ b. [Pal] [Pal] s i n u ɕ i k		∗(PAL) ∗Uniform
c. [Pal] [Pal] ɕ i n u ɕ i k	∗!	∗Uniform

Faithful candidate (22a) violates the conjunction PAL ∨ Uniform, because the perceptual feature [Pal] is not docked on the consonant in the alternating environment. Candidate (22c) violates the same constraint: the word-initial [s] does not violate Uniform, so it should violate PAL, yet it does not, so the disjunction is violated. Candidate (22b) is selected, which shares the features of the vowel with the consonant: they agree in perceptual feature [Pal].

[3] The Polish example calls for an exclusive OR (logical alternative) rather than the inclusive OR, cf. section 2.9.

4.7 Perceptual Strengthening

One problem becomes clear if we consider a secondarily palatalized dental as a possible candidate to the ranking in (22), see (23):

(23) Coronal Palatalization: wrong result

[Pal] //mat + e// [ant] [n-ant]	PAL ∨ Uniform	Ident[anterior]
a. [Pal] t + e [ant] [n-ant]	∗!	
☜ b. [Pal] t^j + e [ant] [n-ant]		
☞ c. [Pal] tɕ + e [n-ant]		∗!

The faithful candidate in (23a) violates the conjunction Pal ∨ Uniform. The intended optimal candidate is actually the form with a prepalatal in (23c). However, since candidate (23b), a secondarily palatalized dental, renders faithfully the underlying Coronal[non-anterior] specification, it is more optimal than (23c). Thus, there must be further factors blocking the selection of secondary palatalized dentals.

In what follows, we will consider two hypotheses: that the emergence of prepalatals is either articulatory- or auditory-driven. It will be shown that more arguments speak for the auditory origin of prepalatals.

4.7.1 Emergence of Prepalatals as an Articulatory Driven Mechanism

From the articulatory perspective, a prepalatal is objectively easier than a secondarily palatalized dental which involves gestures of both the tongue tip and tongue blade, which can be formalized by constraint (24):

(24) ∗[Cor, anterior, non-anterior]
A coronal segment is not simultaneously anterior and non-anterior.

The problem is that the constraint in (24) does not hold absolutely. As mentioned earlier, morpheme-internal secondary palatalized dentals may surface, as demonstrated earlier and repeated in (25):

(25) Morpheme-internal secondarily palatalized coronals

[s^j]inus	'sinus'
[z^j]imbabwe	'Zimbabwe'
[d^j]iva	'opera diva'
[t^j]ina	'Tina', name

In other words, prepalatals appear only in the context or as a carrier of feature [Pal]. This suggests that the mechanism of the emergence of prepalatals in Polish might be after all perceptual.

4.7.2 Emergence of Prepalatals as Perceptual Feature Enhancement

As to the other hypothesis, a secondarily palatalized dental differs from the plain dental in the relative value of F2 transitions. Since the tip of the tongue is the most flexible articulator, one would expect that the transitions and the noise period of the plosive would also be relatively shorter than for other articulators, hence, difficult to hear. Introducing an additional cue to mark the perceptual feature [Pal], namely [Friction], is an advantage for perception. Generally, sequences with palatalized coronals should be disfavored before front vowels, since the listeners tend to reanalyze the cues for secondary palatalization of the consonant as vocalic cues (Ohala, 1992). If then the contrast between a palatalized and a non-palatalized consonant is worth preserving, it is of benefit – if not of vital importance – to enhance it with cues which cannot be reanalyzed as belonging to the vowel. Consequently, I propose to analyze the emergence of prepalatals in terms of a constraint from the Minimal Distinction family, discussed in chapter 2 and repeated here as (26):

(26) Minimal Distinction(f_{Aud}) = XCues
The minimal distinction between contrasting segments in a given auditory dimension is equal X cues.

The constraint in (26) prefers cuing of a distinction by a higher number of cues, the minimal sufficient number of cues for the satisfaction of the constraint being X. An instantiation of the constraint in (26) is (27):

(27) Minimal Distinction([Pal]) = 2Cues
Perceptual feature [Pal] is cued optimally by at least two cues.

(28) Emergence of prepalatal affricates

[Pal] //mat + e//	MinDist[Pal]=2Cues	PAL ∨ Uniform	IdentPl
a. [Pal] t e		∗!	
b. [Pal][HighF2/F3] t^j e	∗!		
☞ c. [Pal] Friction [HighF2/F3] tɕ e			∗

Faithful candidate (28a) violates constraint Pal ∨ Uniform. Candidate (28b), with a secondarily palatalized dental stop is not optimal because the perceptual feature [Pal] is cued by formant transitions alone. MinDist[Pal] = 2Cues is, however, satisfied in candidate (28c), a prepalatal affricate, thus, (28c) is the optimal candidate.

The auditory analysis of the emergence of prepalatals seems to be supported by some arguments that will be discussed now. One argument refers to the behavior of velars. A velar sound in the context of a palatalizing vowel is substituted by a(n) (a)ffricated coronal sound. A velar before a surface front vowel which does not carry the [Pal] feature will never be realized with affrication, though it is articulatorily assimilated to the vowel in that it receives secondary palatalization.

In the case of labials, nothing speaks against the secondary palatalization alone either, yet, in the context of the [Pal] vowel we observe different repair strategies which cannot be directly attributed to some articulatory requirements. I refer here to j-insertion in WPK,[4] and the secondary frication of labials in the dialects of Masovia, Pomorze, and Kurpie. First, we turn to j-insertion. As we observed earlier, palatalized labials surface before a front mid vowel as a secondary palatalized labial+j sequence. I repeat the data in (29):

(29) Labial Palatalization

nom. sg.	dat. & loc. sg.	
ma[p]+a	ma[p^jj]+e[5]	‘map’
tor[b]+a	tor[b^jj]+e	‘bag’
ra[f]+a	ra[f^jj]+e	‘reef’
ra[m]+a	ra[m^jj]+e	‘frame’
ka[v]+a	ka[v^jj]+e	‘coffee’

[4] WPK = Warszawska Polszczyzna Kulturalna: Warsaw educated dialect.

[5] Rubach (Rubach, 1984, 167) analyzes the forms like in (29) with [j] belonging to

According to MinDistPal=2Cues, the output of palatalization, apart from having high F2 transitions, should be marked with an additional cue. For labials, an output that obeys this constraint by inserting [Friction] is rather problematic for articulatory reasons. First, a labial affricate [pf] is a less common sound cross-linguistically than coronal affricates (Ladefoged & Maddieson, 1996). Second, a candidate fulfilling the constraint MinDistPal=2Cues should be additionally secondary palatalized, that is, it should be [$p^{ɕ}$, $b^{ʑ}$] or [pf^{j}, bv^{j}]. An output with secondary palatalization where the stricture is narrow enough to produce friction, is articulatorily very complex, because it combines a labial gesture with a palatal gesture, where both have to be controlled with respect to the timing of release and grade of opening. Thus, it seems that the constraints against $*p^{ɕ}$ and *pf are high-ranked in Polish.

(30) $*p^{ɕ}$
No secondarily palatalized non homorganic labial-prepalatal affricates.

(31) $*pf^{j}$
No secondarily palatalized homorganic labial affricates.

j-insertion might be seen as a way to satisfy MinDist[Pal] requirements instead of [Friction] insertion: inserting [j] results in a substantial prolonging of the the formant transitions, and makes them distinct enough, even without additional friction. I assume that a realization [p^{j}j] satisfies MinDist[Pal], see the tableaux (32):

the suffix, e. g. $torb^{j}$+je, which follows from his analysis. He assumes that the sequence is a result of the j-insertion rule which further triggers secondary palatalization of the consonant, cf. chapter 1.

(32) Labial palatalization

[Pal] //torb + e// Lab Cor[−ant	∗pᶝ ∗pfʲ	MinDistPal =2Cues	Pal ∨ Uniform	Dep(root)
a. [Pal] torb e Lab Cor[−ant			∗!	
b. [Pal] torbʲ e Lab Cor[−ant		∗!		
☞ c. [Pal] torbʲj e Lab Cor[−ant				∗
d. [Pal] torbᶽ e Lab Cor[−ant	∗!			
e. [Pal] torbvʲ e Lab Cor[−ant	∗!			

Candidate (32a) violates PAL ∨ Uniform. All the other candidates do not violate PAL ∨ Uniform, because they all dock the perceptual feature [Pal] on both the vowel and the consonant. Candidate (32b) is not optimal because it does not cue the feature [Pal] with a sufficient number of cues. [Pal] in (32b) differs from non-PAL candidate (32a) only in that it has higher formant transitions. Candidates (32d) and (32e) fail for articulatory reasons: they violate constraints (31), or (30) against too complex combinations of gestures. The optimal candidate (32c) satisfies Pal ∨ Uniform, and articulatory constraints.

In fact, the sounds marked as [pᶝ, bᶽ] actually do occur in Polish dialects of Masovia, Kurpie and Pomorze, where palatalized labials are realized as labials with strong friction produced in prepalatal area, cf. Zduńska (1965), Lorentz (1958), as in (33):

(33) The realization of secondary palatalization on labials

Standard WPK	Dialects	Gloss
[pʲj]es	[pᶝ]es, [pᶜ̧]es	‘dog’
[pʲj]asek	[pᶝ]asek, [pᶜ̧]asek	‘sand’

In these dialects, notably, j-insertion does not operate, which constitutes an argument that j-insertion and friction insertion are two ways of resolving the same problem. In the dialects where there is no j-insertion, we have to assume that a constraint against insertion of an additional consonantal root is higher ranked than the constraint banning [$p^ɕ$] (cf. (33)), otherwise the analysis would proceed in an analogue way as in (32).

(34) DepRoot >> $*p^ɕ$

The strategy of [j] insertion can be successful only before a mid vowel. Before a high palatalizing vowel, [j] is not inserted, and only secondary palatalization is observed in WPK, as in (35):

(35) No j-insertion before i

krok	'step'	kro[tš]+y+ć	'to march'
kos+a	'scythe'	ko[ɕ]+i+ć	'to mow'
versus			
łup+y	'loot', nom. pl.	łu[p^j]+i+ć	'to plunder'
rop+a	'pus'	ro[p^jj]+e+ć	'to suppurate'

Many languages have constraints on the occurrence of sequence [ji], which was accounted for in terms of OCP (Yip, 1988) or in terms of perceptual distinctivity (Ohala, 1992). Here we adopt the latter theory. It is argued here that the reason why [j] is not inserted before [i] is the too small perceptual difference between [j] and [i] itself. Polish avoids the sequence [ji] in general. There are only two words which contain the sequence [ji], both borrowings that appear only in a formal style: [jin] 'yin' and [jidɨš] 'Yiddish'. In the native vocabulary [ji] is avoided exceptionlessly, and a number of simplification is endless. For instance, the stem of word 'my' is [moj], yet when an i-initial suffix [–ix] is concatenated, the form is [moix] and not ∗[mojix].Thus, it is proposed here that there is a universal constraint ∗ji, as in (36), and that this constraint is high ranked in Polish:

(36) ∗ji
Sequences j+i are banned.

∗ji constraint is probably just a special case of a more general Enhance constraint (cf. chapter 2), prohibiting syntagmatic sequences of segments which are too similar in terms of perceptual features. I assume that ∗ji is high-ranked in Polish, and the actual occurrence of the two words with [ji] sequence can be only ascribed to faithfulness constraints, which happen to show effect with the foreign words.

(37) Max[ji] >> ∗ji

As to the ranking of ∗ji itself with respect to other high-ranked constraints, there is no obvious evidence, and for the purposes of our analysis, I assume here that it is unordered with respect to AgrATR and ∗$p^{ɕ}$, ∗$b^{ʑ}$.

The analysis of labial palatalization before [i] is illustrated in (39). If insertion of [j] cannot provide an additional cue, then Minimal Distance ([Pal])=2Cues is not satisfied. The forms with palatalized labials realized as [p^{j}] (candidate (b)) is insufficient to satisfy the constraint inducing enhancement (Minimal Distiance). Actually, in this situation, we would expect depalatalization because it is more economic from the point of view of articulation. Still, the labial in the context of [i] surfaces with secondary palatalization. This can be attributed to the general requirement that the consonant agrees with the following vowel in the position of the tongue root, proposed in chapter 2, repeated here as (38):

(38) Agr (C, V)(ATR)
For vowel V, and the immediately preceding it consonant C, C and V have the same value of [ATR].

A more detailed analysis of phenomena connected with ATR agreement is proposed in chapter 5. For a moment, let us observe, that ATR agreement excludes non-secondarily palatalized consonants before [i], in tableau (39)– the candidate (39a). When candidate (39a) is excluded, two second-best candidates (39b), and (39c) have to be considered.

(39) Labial palatalization before [i]

[Pal] //rob + i + tɕ//	∗$p^{ɕ}$ ∗ji ∗pf AgrATR	MinDistPal =2Cues	Pal ∨ Uniform
a. [Pal] b i -ATR +ATR	∗!		∗
☞ b. [Pal] b^{j} i		∗!	
c. [Pal] b^{j}j i	∗!		

4.8 Contrast Preservation

4.8.1 Contrast of Place in Obstruents

Let us consider the evaluation of the output of palatalization from yet another perspective. If we consider the outputs of palatalization for, for instance, dental stops, yet another candidate might be taken into account, i. e. a palato-alveolar sound like English [tʃ], whose articulation is somewhere in between post-alveolars and prepalatals.[6] We argue that this candidate is excluded by a constraint from the family Preserve Contrast, as defined in chapter 2, and repeated here in (40)–(41):

(40) Preserve Contrast[C1–C2]
The underlying distinction between C1 and C2 is marked by at least 1 cue.

A relevant distinction here is Place: underlyingly, inputs containing stem final –k and –t differ in the specification of articulatory features, that is, the former is Dorsal, the latter is Coronal. This distinction has to be marked by at least one feature, and since the differences in the height of formants are too small and too unreliable, the distinction has to be made on the basis of the properties of the friction. The relevant feature dimension is Noise Frequency.

(41) PreserveContrast(Cor-Dorsal)
Underlying place distinction coronal-dorsal is marked on the surface by at least one cue.

As argued in chapter 3, the values for Noise frequency in Polish consonants are as in (42):

(42) Noise Frequency

	x	š	ɕ	s
NF	1	2	3	4

In (43), it is illustrated how the evaluation proceeds:

[6] [tʃ], in contrast to Polish sounds, is not flat like Polish [tš], but on the other hand, the raising of the tongue is far less extreme than in Polish prepalatals.

(43) Candidate [tʃ] / [tš] / [tɕ]

		Preserve Contrast$_{(Cor-Dor)}$	MinDist [Pal] = 2Cues	PAL	MaxDist (NF) = 1
	[NF4] [Pal] //met+e// [NF1] [Pal] //zamek+ek//				
	a. [Pal] [Pal] t ɛ k ɛ			∗!	
	b. [Pal] [Pal] [HighF2/F3] [HighF2/F3] Friction Friction [NF2-3] [NF2-3] tʃ e tʃ e	∗! ∗!			(∗) (∗)
☞	c. [Pal] [Pal] [HighF2/F3] [HighF2/F3] Friction Friction [NF3] [NF2] tɕ e tš ɛ				
	d. [Pal] [Pal] [HighF2/F3] [HighF2/F3] Friction Friction [NF2] [NF3] tš ɛ tɕ e				∗! ∗!

Candidates in (43b), (43c), and (43d) are very similar: they all satisfy Uniform ∨ PAL. However, candidates in (43b) violate the constraint Preserve Contrast, because both coronal and a velar are rendered on the surface the same. Notably, candidates in (43b) do not necessarily violate MaxDist(NF)=1, because I assume [tʃ] lies on the perceptual scale somewhere between [tɕ] and [tš], yet so close to each of them that it might be interpreted as either of them: this is why I assume the [NF] value of [ʃ] as either 2 or 3. For the candidates in (43c), the surface realizations of the underlying place contrast are not rendered faithfully, yet the contrast is preserved. Yet another candidate set, (43d) is as good as (43c) from the point of view of contrast preservation, yet (43c) is more optimal with respect to Noise Frequency faithfulness: in (43d) the surface values of Noise Frequency differ too radically from the underlying ones.

4.8.2 Palatalization of Liquids

In the previous section, we observed how Preserve Contrast forces the emergence of cross-linguistically rare sounds, that is post-alveolars and prepalatals. On the other hand, as long as Preserve Contrast is not violated, all kinds of articulatory simplifications are licensed to occur. We will discuss this issue using the example of Polish liquids.

In modern Polish [w] alternates with [l] in the palatalizing context, and [r] in the same contexts alternates with [ž], for instance:

(44) Alternations involving liquids

bia[w]+y	–	bie[l]+eć	'white', adj. – 'turn white', verb
szko[w]+a	–	szko[l^j]+i+ć	'school' – 'to educate'
kar+a	–	ka[ž]+e	'punishment', nom. sg. – dat. sg.
gitar+a	–	gita[ž]+yst+a[7]	'guitar' – 'guitar player'

The alternations have usually been discussed in connection with the alternations of coronals. The problem of the earlier approaches was that dental stops and fricatives alternated with cross-linguistically rare and highly marked prepalatals [ɕ ʑ tɕ dʑ], which differ from other [non-anterior] sounds in that they are inherently palatalized (that is, they are produced with the raising of the tongue as for secondary palatalization). In contrast, the output of palatalization of [w] and [r] is in surface terms not secondarily palatalized, i. e. traditionally [−back]. In other words, exactly that feature which was claimed to trigger palatalization altogether is absent from the ultimate surface form in liquids. Within the approaches using only articulatory features, the alternation could only be explained in historical terms.

Historical excursion

In historical terms, the alternation was completely regular and motivated articulatorily. In Old Polish (till the end of 15th century) the opposition was between (most probably) the velarized lateral and the palatalized lateral,[8] which paralleled the opposition between palatalized and non-palatalized (presumably velarized) dentals.

[7] [ž] cannot be followed by [i], palatalizing high vowel surfaces after [ž] as [ɨ], see the discussion in chapter 5.

[8] In the case of palatalized sounds, the change from secondarily palatalized dental stops to prepalatal affricates is evidenced in orthography: the former were transcribed as ty, dy whereas affrication involved spelling with s or c (Klemensiewicz, 1985). What the development of fricatives was can only be stipulated, though, in general, it is assumed that their development was parallel to that of stops. We have, however, no direct evidence on whether non-palatalized segments were velarized or not: it was not marked in spelling. On the other hand, modern languages with distinctive secondary palatalization (e. g. Russian or Irish), contrast palatalized sounds with velarized sounds (and not plain). Phonological evidence comes from the fact that the presumably velarized historical lateral surfaces as a labio-velar glide, and the velar part of the articulation of the glide may descend from the orignal velarization.

(45) The opposition of palatality in Old Polish

Non-palatalized (velarized)	sˠ zˠ tˠ dˠ rˠ lˠ
Palatalized	sʲ zʲ tʲ dʲ rʲ lʲ

The obstruents transformed, and so did the liquids. Palatalized obstruents shifted to prepalatal place, non-palatalized sounds lost clear velarization (46a-b). Liquids lost the secondary palatalization, the velarized lateral started being realized as a surface labio-velar glide (46c-d). The palatalized rhotic started being affricated, and finally in Modern Polish is realized as a post-alveolar voiced fricative, whereas the non-palatalized rhotic lost velarization and is realized as a plain alveolar rhotic (46e-f):

(46) Diachronic development of dentals and liquids

a. sʲ zʲ tʲ dʲ → ɕ ʑ tɕ dʑ
b. sˠ zˠ tˠ dˠ → s z t d
c. lʲ → l
d. lˠ → w
e. rˠ → r
f. rʲ → rᶻ → ř → ž

The changes in (46) are diachronic developments, however, they have been often treated as synchronic rules of Polish (e. g. Gussmann (1980), Rubach (1984), or Szpyra (1995), compare the discussion in chapter 1), and the evidence for the diachronic stages were treated as evidence for the synchronic stages in derivation. In the following, we consider only the synchronic variation.

The lateral

In the discussion of coronal obstruents, we argued that the alternations referred to as palatalization are induced by a prolonging of the perceptual feature [Pal]. We proposed also that perceptual [Pal] on obstruents has to be expressed by at least two features, that is, [HighF2/F3] or [Highest F2/F3], and [Friction]. Unfortunately, the output of palatalization of the surface [w], i. e. [l], has on the surface neither [Highest F2/F3] nor friction, thus, it contains only one cue. Clearly, realizing friction or secondary palatalization on a lateral comes at a cost, which is too high to pay: Polish does not realize the lateral in the palatalizing context neither as a lateral fricative [ɮ], nor as a palatal lateral [ʎ], and also not as a secondarily palatalized alveolar lateral [lʲ].[9] Neither does Polish render the lateral in the non-palatalizing context as velarized lateral [lˠ] or as a velar lateral [L]. Laterals are difficult sounds to produce; they are acquired by children relatively late, after obstruent consonants. Fricatives are said to require more precision during their production than stops (Kirchner, 2001). Combining the two kinds of articulation would result in a segment involving relatively more articulatory effort and skills. This claim may be supported by typological studies. According to Ladefoged and Maddieson (1996), laterals are cross-linguistically most often approximants. For palatalized and prepalatal laterals, apart from the control over the lateral stricture, simultaneously a complicated task of raising the middle part of the tongue to the hard palate has to be performed. Thus, a fricative lateral as well as palatalized or prepalatal laterals seem to be articulatorily more difficult than plain alveolar lateral. A non-anterior lateral also seems to be more difficult than an alveolar lateral, as it requires retraction of the front of the tongue which makes a lateral closure more difficult. Thus, constraints in (47) seem cross-linguistically well established:

(47) Articulatory constraints against complex lateral realizations

a. ∗ɮ "No lateral fricatives"
b. ∗ʎ "No palatal lateral"
c. ∗l̠ "No non-anterior lateral"
d. ∗L "No velar lateral"
e. ∗lˠ "No velarized lateral"
f. ∗lʲ "No coronal lateral with secondary palatalization"

The articulatory constraints as in (47) against articulatory difficult combinations of gestures must be high-ranked in Polish: except for (47f) they are not violable.[10]

Still, [L, lˠ, ʎ, ɮ] are possible – they do occur in the languages of the world. Why are they excluded in Polish, especially when there are parallel alternations in obstruents? One could approach this issue from the perspective of the discussion of the contrasts among laterals in Padgett (2001b). Consider the existing contrast among laterals as illustrated in (48):

(48) Contrasts among laterals (adopted from Padgett (2001b, 196))

a. lʲ – l – lˠ (Bernera Scots Gaelic)
b. lʲ – – – lˠ (Russian, most Irish dialects)

[9] Except in the context of [i], where it is argued that ATR agreement has to be satisfied, cf. chapter 5.

[10] For [lʲ] to occur, we necessary have to have surface [+ATR] vowel, and [lʲ] is claimed to be a way to satisfy unviolable AgrATR, cf. the discussion in chapter 5.

c. – – l – – (many languages)

Plain, articulatory neutral laterals would be favored from the point of view of universal markedness theory. The prediction would be that if a palatalized sound is in the inventory of a language, this should imply the presence of a plain segment within this inventory. This prediction is not borne out. Russian (cf. (48b)) does not make use of a plain lateral altogether, but instead it utilizes a pair of sounds involving more complex articulation. The conclusion might be that this happens because of the need for optimal contrasts. A pair l^j – l^{γ} constitutes a better perceptual contrast than a pair l^j – l because the former pair is more dissimilar, see the discussion in chapter 2. Secondary articulations appear here for the sake of contrast saliency.

We can extend this argumentation for Polish. In Polish, the only distinctive surface lateral is [l], the underlying non-palatalized lateral surfaces as a labial glide. In this light, the Polish case may be interpreted as an exemplification of (48c). There is no point to invest articulatory energy in the production of palatalized laterals, since there is no contrast between two or more surface laterals as in (48a-b). Similarly, one can argue that a lateral fricative does not surface because there is no need for contrast, thus, we can spare on the articulatory effort. Notice, that in all languages that Ladefoged and Maddieson (1996) quote, affricate laterals do co-occur with a number of other laterals with which they contrast in terms of voice/manner/place of articulation or of the air stream mechanism.

In Polish, the phonologically palatalized laterals do not need to be realized with a phonetic secondary palatalization.[11] In surface terms, the articulation is simplified. The choice of the surface realization is, however, determined not only by articulatory simplicity but also by perceptual factors, that is, surface realizations must be in the first place "licensed" by Contrast Preservation, as repeated in (49).

(49) PreserveContrast(Pal)
The distinction in the dimension palatality is marked by at least 1 feature.

Preserve Contrast(Pal) would be violated if the outputs of underlying palatalized and non-palatalized laterals would merge on the surface.

On the other hand, to account for the surface realization of the non-palatalized lateral, we assume constraints against secondary velarized consonants in Polish, and against velar approximants:

[11] Unless directly followed by [i], which is argued in chapter 6 to result from the requirement on ATR Agreement.

(50) $*C^{\text{ɣ}}$ "No secondary velarized consonants."
$*$ɰ "No velar glide."

Polish seems to disfavor the articulation in the back of the oral cavity in general. It has no voiced velar fricative, and the only clear velarization may be observed on the labial glide: no obstruent in Polish is velarized. Apart from the language specific bias, the sound [ɰ] is relatively rare cross linguistically. Ladefoged and Maddieson (1996) give just one example of a language (Axininca) that has in its inventory a velar glide.

Another specific constraint is Preserve Contrast(Lateral):

(51) PreserveContrast(Lateral)
An underlying lateral and a palatal glide are not to merge on the surface.

(52) Emergence of surface [l-w] contrast

/l+Pal/ – /l/	Preserve Contrast [Lateral]	Preserve Contrast(Pal)]Lateral	$*$ɰ, $*$L, $*$ʎ	MinDist(Pal)= 2Cues	$*l^{\text{ɣ}}$, $*l^j$
l^j – $l^{\text{ɣ}}$					$*!*!$
l^j – l				$*!$	$*$
l – l		$*!$			
l^j – w					$*$
☞ l – w					
l – L			$*$		
j – w	$*$				

Most of the output candidate pairs violate some articulatory constraint. [ɰ] would admittedly satisfy the faithfulness constraints as an output of the underlying non-palatalized lateral (it would be [Formant], [LowF2/F3]), and would not violate any Preserve Contrast constraint. Yet, candidate pair [l-w] is more optimal for the sake of the ease of articulation. If the pair [l-w] violated Preserve Contrast, some other pair might turn out optimal even if the lower-ranked articulatory constraints were violated.

The rhotic

As already mentioned, historically the palatalized rhotic developed into a sound with some dose of friction, and only later into a modern voiceless post-alveolar fricative.

(53) r^j > $r^{\text{ʑ}}$ > ř > ž

Klemensiewicz (1985) assumes that as early as in the 14th century the palatalized rhotic turned into a soft complex segment with a secondary frication. Further, the sound was depalatalized, as assumed by Klemensiewicz, at the same time as other affricates and fricatives, that is in the 16th century. One could suspect that the sound was similar or the same as modern Czech [ř]. Klemensiewicz based his assumption on the spelling (rz, rs instead of r) in old writings, as well as on the basis of the description of grammarian Mesgnien (1649),[12] and on the basis of characteristic rhymes in poetry. These latter are illustrated in (54), where the first word is (and was) pronounced with a sequence [rž] and the second word contained originally the palatalized rhotic:

(54) Evidence from poetry

a. Hypothetical Old Polish pronunciation which justifies the existence of the rhyme:
dzie[rž]y – sze[ř]+y

b. Modern Polish pronunciation (no rhyme):
dzie[rž]y – sze[ž]y

If the palatalized rhotic could rhyme with the rhotic plus fricative sequence, we can draw a conclusion that they were pronounced in a similar way.

This kind of rhyme disappeared at the end of 18th century, from which one concludes that the palatalized realization of the rhotic lost its rhotic quality and turned into a Modern Polish non-anterior voiced fricative.

What were the reasons for the historical developments described above? It seems that the reason was the relative articulatory complexity of the sound. Fricative rhotic produced by the tip of the tongue is an extremely rare sound cross-linguistically, cf. a similar discussion in Rochoń (2001)). Ladefoged and Maddieson (1996) mention a fricative alveolar rhotic in the KiVunjo dialect of KiChaka (1982), and as an optional realization in Czech (1923), and in Edo. In Edo, according to Ladefoged (1968), there are voiced and voiceless fricative alveolar rhotics (contrasting further with an approximant alveolar rhotic).[13] Even Australian languages which in general employ up to four coronal series for stops, nasals, and laterals, limit the contrasts for rhotics to two or maximally three rhotics, which differ in place of articulation and manner (approximant versus trill). In Australian Warlpiri, it is said that the three rhotics are flap, trill and an approximant – trills have only very

[12] François Mesgnien-Meninski or in French François Mesnyen-Meninski (1649).

[13] However, Ladefoged and Maddieson (1996) quote also Elugbe (1973) and Amayo (1976), who describe the same Edo set of rhotics as containing alveolar voiced and voiceless trills and a voiced approximant, without any mention of frication.

weak trilling with some associated friction, however, the authors make the distinction on the basis of the place of articulation and the trill-flap contrast, and not on the basis of friction.

In any case, a fricative trill must be assumed to be a more complex (and more difficult) articulatory than a trill alone or a fricative alone. I propose then a constraint (55) against fricative rhotics to be high ranked in Polish.

(55) ∗ř
No frication on the rhotic.

One could claim that rankings as those in (56) hold universally, where a ban against more complex segment is higher than that against a simple one, whereas the ranking of the constraints against the simple articulation is not universally ranked with respect to each other (Boersma, 1998).

(56) Universal ranking of articulatory constraints
∗ř >> ∗r
∗ř >> ∗frication

Also, secondary palatalization on rhotics is not very common. From the study by Hall (2000), we know that palatalized rhotic sounds are cross-linguistically rare. Consequently, they are potentially subject to all sort of "amendments".

(57) $*r^j$
No palatalized rhotics.

(58) $*r^j >> *r$

The production of rhotic sounds involves a high degree of precision, and consequently, rhotics are among sounds that are acquired late by children. This high degree of precision, combined with the necessity to control the post-anterior part of the tongue (for secondary palatalization), makes a palatalized rhotic a very complex sound. On the other hand, as argued by Hall (2000), cf. Rochoń (2001), secondarily palatalized apicals in general are more marked than plain apicals; that is, apicals are not stable hosts for palatalization. Notice that in Polish, sounds which are distinctively secondarily palatalized are laminal, thus, the following constraint can be postulated, repeated here as (59):

(59) ∗[Cor, anterior, non-anterior]

We have argued, however, that the constraint in (59) does not hold absolutely. Word internally, also a palatalized rhotic may occur before surface [i], such as in words like *riksza*, *ring*, and some others.

Finally, one has to notice that the most common place of articulation for rhotics is alveolar; in systems where there is just one surface rhotic, it is most probably always alveolar, and rhotics articulated in other places of articulation appear only in systems where there are more rhotic phonemes.

(60) $*\underline{\mathrm{r}}$
No non-anterior rhotics.

(61) $*\underline{\mathrm{r}} >> *\mathrm{r}$

Given the articulatory difficulty with the production of a palatalized rhotic, palatalized fricative rhotic, or non-anterior rhotic, (which would satisfy the requirement for the two cues marking palatalization contrast), it is natural that a simplification of articulation occurs. This, however, could not jeopardize the existing system of contrasts. Notice also, that the pair [r-ž] is very distinct even if they do not differ very radically in the height of formant transition: what differentiates them in the first place is the presence versus absence of very distinct formants throughout the duration of the segment. Thus, it is assumed here that MinDistPal=2Cues is satisfied by the differences in [Friction] and [Formant]. The emergence of surface realizations of the palatalized and non-palatalized rhotics is shown in (62):

(62) Emergence of surface [ž-r] contrast

/r+Pal/ – /r/	Preserve Contrast [Rhotic-Lat]	∗ř	Preserve Contrast(Pal)]Rhotic	MinDist(Pal) =2Cues	$*C^j$ $*C^{\gamma}$
$r^j - r^{\gamma}$					∗!∗
$ř^j$ – r		∗!			
r – r			∗!		
☞ ž – r					
r – w	∗!				

As to the ranking of articulatory constraints, ∗ř is unviolable in Polish, but $*r^j$ and $*r^{\gamma}$ are violated, given the right vocalic context. The problem is that secondary palatalization/velarization is only possible as an effect of ATR harmony (as argued in chapter 5). Yet, given that all sets of candidates satisfy IO-faithfulness requirements, and Preserve Contrast requirements, $*r^j$, and $*r^{\gamma}$ will exclude the candidate set (a), even if they are ranked lower. The emergence of synchronic output of palatalization for the rhotics is illustrated in (63):

(63) Coronal Palatalization of the rhotic in Polish

[Pal] | //kar+e//	∗ř $*\check{r}^j$	MinDistPal =2Cues	Preserve ContrastPal]Rhotic	Pal ∨ Uniform	$*C^j$
a. [Pal] | r e				∗!	
b. [Pal] r^j e		∗!			∗
c. [Pal] [Frict] $\check{r}^j$ e	∗!				∗
☞ d. [Pal] [Frict] [HighF2] ž e					

In candidate (63a), the [Pal] feature is not prolonged: Pal constraint is violated. Candidate (63b) with a secondarily palatalized apical rhotic does not satisfy MinDistPal=2Cues, apart from violating the articulatory constraint against doubly articulated [anterior, non-anterior] rhotics. Candidate (63c) would be optimal if it were not for its articulatory difficulty: it violates high-ranked ∗ř, and $*\check{r}^j$. Candidate (63d) satisfies constraint Pal: [ž] is marked with [Friction] and [HighF2], which is sufficient to mark [Pal].[14]

Summing up, the output of palatalization of the rhotic is a voiced post-alveolar fricative [ž] because a segment which would optimally satisfy PAL (that is a segment which would be secondarily palatalized, fricative rhotic) is banned for articulatory reasons. Palatalized rhotic may not simplify to post-alveolar or alveolar [r], because it would then violate Preserve Contrast(Pal).

[14] A careful reader will observe that the output of velar palatalization might be in certain contexts identical with the output of palatalization of /r/. We have to assume that in general the ranking of Preserve Contrast constraints depends on the statistical frequency of occurrence of particular contrasts. Those which are more frequent in the given system, are more worth being preserved. Thus, a preservation of the contrast between palatalized and non-palatalized rhotics seems more important than the contrast between the palatalized rhotic and the palatalized voiced velar plosive in some well defined context, which results in the surface merging of outputs of the two underlying representations.

4.9 Palatalization without Obvious Surface Trigger

There are a number of instances of palatalization where the trigger is apparently not present on the surface. The most broadly-known examples involve palatalization of velars, like in (64a), but we will observe similar effects also for coronals, see (64b):[15]

(64) Palatalization without surface context

a. krok 'step'

	singular	plural
nom.	kro[tš]+ek	kro[tš]+k+i
gen.	kro[tš]+k+u	kro[tš]+k+uv
dat.	kro[tš]+k+ovi	kro[tš]+k+om
acc.	kro[tš]+ek	kro[tš]+k+i
instr.	kro[tš]+ki+em	kro[tš]+k+ami
loc.	kro[tš]+k+u	kro[tš]+k+ach

b. kwa[ɕ]+n+y 'sour', cf. kwas 'acid'
gło[ɕ]+n+y 'loud', cf. głos 'voice'

Stems and suffixes where we observe vowel-zero alternations are traditionally analyzed as containing underlying yers.[16] Yers were historically short vowels in Old Slavic and underwent a series of diachronic changes: in so-called weak positions (when not followed in the next syllable by another yer) they were deleted, in strong positions – they turned to [e/ɛ].[17] Interestingly, even when they are surface deleted, they affect the neighboring consonants: if it was a front, that is, a palatalizing yer, the palatalization on the consonant is preserved in Modern Polish, resulting in the palatalization without a surface trigger, as in (64). Back yers never triggered palatalization and they never do in Modern Polish, cf. (65):

[15] There are no instances of palatalization of labials without a surface trigger, see the analysis in section 4.10.
[16] For the question of representation and capturing the surface behavior of yers, see among others Gussmann (1980), Rubach (1986), Rochoń (2000).
[17] There are also marginal cases where yers surface as [i] in certain specified morphological contexts, cf. Rubach (1984) and (1986).

(65) No palatalization by a back yer

position		
strong	weak	gloss
pło[t+ɛ]k	pło[t]+k+i	‘fence’ dim. nom. sg. – nom. pl.
do[m+ɛ]k	do[m]+k+i	‘house’, dim. nom. sg. – nom. pl.
[dɛ]+n+y	[dn]+o	‘bottom’, adj. – noun

In this study, we adopt the analysis of Rubach (1986) treating yers as floating feature matrices, that is, in our case – a floating [Pal, Coronal] specification for the palatalizing yer.[18] Leaving aside the conditions for yer surfacing, we have to admit that, whether or not it surfaces on the vowel, the feature [Pal] tends to anchor on the consonant, thus, a constraint in (66) seems to be important for Polish:

(66) Ident-IO-([Pal])
An underlying feature [Pal] has a correspondent [Pal] in the surface representation.

Although the feature does not always receive an extra root on its own, faithfulness with respect to [Pal] is satisfied by docking the feature on the consonantal root. Forms with palatalization in the absence of the surface trigger are optimal in yet another respect: they satisfy OO-Correspondence to the forms in the paradigm in which a yer is realized as a surface front vowel and there is surface spreading of palatalization features.

(67) OO-Correspondence([Pal])
[Pal] in the string s_1 has a correspondence in [Pal] in string s_2, where s_1 and s_2 belong to one paradigm.

This constraint might be important for forms like *kroczek* when compared with *krok*: all diminutive forms – whether or not with a front vowel in the surface representation – will contain [Pal]. The basic neutral form *krok* does not.

An example of an analysis is given in (69). I assume the assignment of the root to the floating feature aims to ensure the compliance to SSG, however, the detailed analysis of the interaction of constraints resulting in the surfacing of the yer or its deletion goes beyond the scope of the study. For the sake of our analysis, let us assume a cover constraint Yer Surface, as in (68):

[18] One would probably like to assume that it is a floating feature bundle containing also the articulatory feature Coronal, to differentiate palatalizing and non-palatalizing yers.

(68) YerSurface
Assign a root and a syllable node to the floating feature only to ensure SSG is satisfied.[19]

(69) Palatalization without surface trigger

Pal zamek+ k+a Dor Cor Dor	Yer Surface	Ident[Pal]	Pal *vee* Uniform	Ident-IO-Art
a. zamekka		∗!		∗(OO-Corr)
☞ b. Pal zametška				∗(Ident)
c. Pal zamekɛka	∗!		∗	∗(OO-Cur)
d. Pal zametš ɛka	∗!			

Candidate (69c) ‘zamekeka’ violates Yer Surface (the conditions for assigning the root are not met) and Palatalization. (69d) (‘zametšeka’) violates Yer Surface again. As optimal emerges ‘zametška’: with palatalization though without the trigger.

4.10 Blocking of Palatalization of Labials: Perceptual Account

Unlike for coronals and velars, labials will never be palatalized when there is no surface vowel. In fact, also underlying palatalization of labials is blocked from surfacing if it appears before a surface consonant, as well as – interestingly – word-finally. Below, I propose a common account for these three effects. Unlike in earlier approaches, the account proposed here crucially refers to perceptual properties of speech sounds.

To start with, secondary palatalization does not surface word-finally. Secondary palatalization of soft labial-final stems can only be seen on the surface when an attached suffix follows the stem-final labial. This is illustrated in (70):

[19] Specifying the conditions for the nucleus insertion goes beyond the scope of the study. I refer the reader to the literature on yers, as mentioned earlier.

(70) No secondary palatalization word-finally and before another consonant

no palatalization	palatalization
gołą[p], 'pigeon', nom. sg.	gołę[bʲj]e nom. pl.
gołą[p]ka 'pigeon', dim. gen. sg.	gołę[bʲj]a gen. sg.[20]
jedwa[p] 'silk', nom. sg.	jedwa[bʲj]om dat. pl.
jedwa[b]ny 'silk', adj.	
kar[p] 'carp', nom. sg.	kar[pʲj]e nom. pl.
	kar[pʲj]a gen. sg.
pa[f] 'peackock', nom. sg.	pa[vʲj]e nom. pl.
	pa[vʲj]a gen. sg.
Rado[m] place name, nom. sg.	Rado[mʲj]a gen. sg.
zie[m] 'soil', gen. pl.	zie[mʲj]a nom. sg.
zie[m]ski adj.	
[p]sa 'dog', gen. sg.	[pʲj]es nom. sg.
[pɲ]a 'trunk', gen. sg.	[pʲjeɲ] nom. sg.

Rochoń (2001) demonstrates that palatalized labials are underlying here and analyzes such examples in terms of the interaction of the constraint prohibiting complex articulation in the coda position and a faithfulness constraint. Her proposal has been discussed in chapter 1.

Also, in the cases where Labial Palatalization should apply, it does not – if the vowel does not surface. Relevant cases, with the underlying palatalizing yer marked as PAL, are given in (71):

(71) **No Labial Palatalization in palatalizing context**

No context for pal.	Context for pal.
ku[p]+ov+ać 'to buy'	ku[p]+n+y //UR: kup+PALn+y// 'bought', adj.
zgu[b]+a 'loss', 'disaster'	zgu[b]+n+y // UR: zgub+PALn+y// 'disastrous'
versus	
kva[s] 'acid'	kva[ɕ]+n+y //UR: kvas+PALn+y// 'sour'

Thus, there is in standard Polish a ban on palatalized labials before a word boundary or before another consonant. Interestingly, no such prohibition holds in dialects as soon as the secondary palatalization is produced with an addition of friction, see the forms in (72).

[20] The voice alternation is due to final devoicing and regressive voice assimilation.

(72) $\text{p}^{\text{ɕ}}$ allowed word-finally

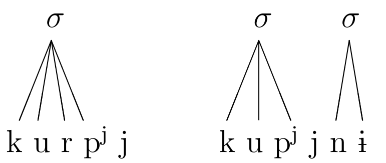
standard Polish	dialect
Kur[p] – Kur[p^{j}j]e	Kur[$\text{p}^{\text{ɕ}}$] – Kur[$\text{p}^{\text{ɕ}}$]e

‘Kurp, a person from the region of Kurpie’, nom. sg. – nom. pl.

In (72), the standard Polish form ‘Kurp’, though obviously with an underlying palatalized labial (the palatalized labial surfaces in the plural form, the stem selects soft-stem declensional suffixes), does not render palatalization on the surface word-finally. In contrast, the dialectal form has palatalization word-finally.

The non-occurrence of palatalized labials at the end of the word and before another consonant has a common perceptual background. Palatalized segments ([Pal]) are not allowed when the formant transition would be the only cue for their perception. This is expressed by the constraint MinDist([Pal])=2Cues, which was proposed earlier. This constraint is satisfied for palatalized labials in standard Polish by the insertion of [j]. However, [j] cannot be inserted when the resulting string would dramatically violate the Sonority Sequencing Generalization, as in (73):

(73) [j] insertion excluded



[j] cannot be inserted in the hypothetical form ∗‘Kurp$^{\text{j}}$j’ because then it would have to be syllabified as a coda, when the preceding segment [p^{j}] is less sonorous. In the hypothetical form ∗‘kup$^{\text{j}}$jnɨ’, [j] cannot be syllabified either as a coda, because [p^{j}] is less sonorous, or as an onset because [n] is also less sonorous.

On the other hand, we cannot insert a vowel, because the conditions for root insertion are not met, and Yer Surface is notably higher ranked than Ident-IO-[Pal].

(74) Blocking of palatalization

		SSG	$*p^{ɕ}$ $*pj^{j}$	Yer Surface	MinDistPal =2Cues	Ident ([Pal])	Pal ∨ Uniform
	[Pal] kup+PALnɨ						
	a. [Pal] [HighF2][HighF2] kup^{j} j nɨ	∗!					
	b. [Pal] [HighF2] kup^{j} nɨ	∗!			∗		
	c. [Pal] [HighF2] [Friction] $kup^{ɕ}$ nɨ		∗!				
☞	d. kupnɨ					∗	
	e. [Pal] [HighF2] kup^{j} j e nɨ			∗!			

All candidates in (74) except for (74d) try to render faithfully the underlying [Pal]. Candidate (74a) satisfies Minimal Distance(Pal) by inserting [j] (and vacuously PAL ∨ Uniform), however, [j] cannot syllabify without violating SSG. Candidate (74b) does not satisfy Minimal Distance(Pal). (74c) fails on the articulatory constraint $*p^{ɕ}$. Candidate (74e) inserts a root for the floating [Pal], and the resulting structure satisfies PAL ∨ Uniform. Insertion of [j] does not violate here SSG. It could syllabify without problem as an onset of the inserted vowel. However, candidate (74e) violates Yer Surface. The winner is candidate (74d), which does not render [Pal] faithfully.

The same ranking accounts for the loss of an underlying palatalization both word-finally and word-internally when an underlying palatalized labial should surface before another consonant, as in [pɲa] ‘trunk’, gen. sg. (UR: p^{j}jPALɲ+a):

(75) Loss of underlying palatalization

[Pal] p^jj+PALɲ+a	SSG SSG	Yer Yer Surface	MinDist [Pal] =2Cues	Pal ∨ Uniform	Ident ([Pal])	Dep (root)
a. [Pal] [HighF2][HighF2] p^j j ɲ a	∗!					∗
b. [Pal] [HighF2] p^j ɲ a			∗!			
c. [Pal] [HighF2] p^j j e ɲa		∗!				∗∗
☞ d. p ɲ a					∗	

In (75), the optimal candidate does not render on the surface the underlying feature [Pal]. Still, it comes off better than other candidates: Candidate (75a) violates SSG, while in candidate (75b), [Pal] is cued by an insufficient number of features, and candidate (75c) violates Yer Surface.

The word [pɲa] provides us with an argument that the responsible constraint blocking palatalization is of perceptual – and not articulatory – nature. Notice that the nasal is prepalatal, thus, articulated with the same tongue root position and the same raising of the tongue to the palate – as the secondary palatalized labial. Still, more optimal is the form where the plain labial is followed by the palatalized coronal; that is, when the consonants in the cluster do not agree in terms of articulatory features.

Finally, let us focus on the word-final underlying palatalization, cf. (76):

(76) Palatalization word-finally

	[Pal] kurp+PAL	SSG	Yer Surface	MinDist[Pal] =2Cues	Ident([Pal])	Pal ∨ Uniform
	a. [Pal] [HighF2][HighF2] kurp^j j	∗!				
	b. [Pal] [HighF2] kurp^j			∗!		
	c. [Pal] [HighF2] kurp^j j e		∗!			
☞	d. kurp				∗	

Candidate (76a) would have to syllabify [j] as a coda, when it would be preceded by a less sonorous [p^j]. (76b) cues [Pal] by high formant transition alone, (76c) inserts a root when the conditions are not met. The optimal (76d) does not render the underlying [Pal] on the surface.

By assuming a constraint MinDistPal=2Cues, three phenomena, which have until now been separately analyzed, find a common account: the blocking of a regular palatalization of labials, as in *kupny*, the depalatalization of underlying soft stems word-finally, as in *Kurp*, and depalatalization of underlying palatalized labials word-internally before a consonant, as in *pnia*.

4.11 Spirantization of Velars

Let us now come back to the details of the palatalization of velar sounds. The output of the process are post-alveolar sounds. For the underlying voiceless fricative – the output is a voiceless fricative, for the voiceless stop – an affricate. For the underlying voiced stop, the output might be either an affricate (preserving the original underlying non-continuant manner of articulation) – when following an obstruent, or a fricative (unexpected change of the manner of articulation). The relevant facts are repeated here as (77) and the data is summarized in (78).

(77) Spirantization of the output of palatalization
k → tš
x → š
g → dž or g → ž (change of the original manner of articulation)

(78)

kro[k] 'step'	kro[tš]+ek dim.
su[x]+o 'dry', adv.	su[š]+ej 'dry', adv. comp.
Bó[g] 'God'	Bo[ž]+e 'God', loc. & voc. sg.
móz[g] 'brain'	mó[ždž]+ek 'brain', dim.
róz[g]+a 'rod'	ró[ždž]+ek 'divining rod', gen. pl.

In (79), it is demonstrated that the voiced stop [g] alternates with [dž] when preceded by an obstruent, and with [ž], when after a sonorant.

(79) Distribution of [g] alternants
Bó[g] – Bo[ž]+e 'God', nom. – loc./voc. sg.
piar[g] – piar[ž]+ek '(in the mountains) heap of stones', dim.
[wg]+a+ć – [wž]+e 'to lie', inf. – 3rd p. sg.
móz[g] – mó[ž dž]+ek 'brain' – dim.
róz[g]+a – ró[ždž]+ek 'rod' – 'divining rod'

Notice that [dž] may occur when preceded by a vowel even in the context of a morpheme boundary, if there is no corresponding input velar stop. That is, if [dž] is underlying, then there is no spirantization, e. g. (80).

(80) No spirantization of underlying [dž]
bry[dž] – bry[dž]+yk 'game of bridge' – 'game of bridge', dim.
ró[g] – ro[ž]+ek 'horn' – 'horn', dim.

It will be argued here that the constraint rendering the spirant output of Velar Palatalization might be of articulatory nature. First, notice that the change should be seen as a lenition process. In many languages, there is spirantization of stops and this process has been often acknowledged to be articulatory-driven, as an effect of articulatory 'laziness'. As noted by Kirchner (2001), the idea is not novel (cf. e. g. Hock (1991)); however, the classic generative phonology, expressing lenition in terms of a rewrite rule, did not fulfill the general requirement that the simplicity of the formalism should explain its naturalness. Thus, a lenition process is, in the classic generative approach, as natural as strengthening:

(81) Lenition versus fortition
$[-\text{nasal}] \rightarrow [+\text{cont}]$ / V __V
$[-\text{nasal}] \rightarrow [-\text{cont}]$ / V __V

Within a Feature Geometry framework, lenition was accounted for as a spreading of [+continuant] from an adjacent trigger (cf. e. g. Harris (1984), Kirchner (2001), and references therein). For the evaluation of this approach, see Kirchner (2001). Kirchner proposed an effort-based approach to lenition, namely, he argues that the production of stops requires a greater displacement of the articulator (tongue) from the neutral position, thus, it is disfavored because it costs more articulatory effort. Stops are then excluded and substituted by fricatives on the surface by means of constraint LAZY 'effort minimization constraint' (Kirchner, 2001, 21).

Substituting a stop or an affricate with a spirant is particularly advantageous, if the target is surrounded by segments which do not have complete closure, or have a lower degree of closure than a stop. Lenition, if triggered by some particular environment, happens most often in the intervocalic position. Many languages restrict the alternations to the cases where the environment precedes as well as follows the target sound, an example being the intervocalic flapping of dental stops in English dialects. Sometimes, particular consonants may also trigger spirantization. Kenstowicz (1994) gives an example of Spanish. In Spanish the voiced stops [b, d, g] and the corresponding fricatives [β ð ɣ] are in complementary distribution, with stops occurring word-initially and following the nasal, and on the other hand, with fricatives after [r]. In the process in Spanish, [l] environment produces different outputs depending on the place of articulation of the obstruent.

As mentioned before, in classical terms lenition was treated as spreading of [+continuant]. Notice that this solution may not be adopted for Polish. If in Polish lenition does not occur after a fricative, then the environment may not be stated in terms of the feature [+continuant].

Finally, let us observe, that [dž] is in Polish a marginal phoneme. It appears as an effect of palatalization, and in two native words *dżdżu* lit.: 'rain', gen., *dżdżownica* 'earthworm'.[21] Otherwise, it is present in a number of borrowings.

Having drawn the facts together, let us propose a constraint against [dž] as in (82):

(82) ∗dž
No voiced post-alveolar affricate.

∗dž is articulatorily motivated; it is a constraint against a maximal displacement of the articulator in the production of voiced post-alveolar sounds. On its own, it is low-ranked, because, as noted above, there are lots of new borrowings containing [dž]: *dżem* 'jam', *bandżo* 'banjo', *brydż* 'game of bridge', *Dżerba* 'Djerba', *dżentelmen* 'gentleman', *dżinsy* 'jeans', *dżuma* 'pest', *dżul* 'joul', etc.

[21] *Dżdżu* and *dżdżownica* are related to *deszcz*, the first [dž] was originally [d] assimilated in the cluster.

The environment for spirantization is a sonorant sound. I propose that the rationale for the change is to reduce the difference between the sound requiring a bigger jaw opening and those with a complete closure.

(83) $*$Open0 / Open$\geq$2___ Open$\geq$2
No closure between sounds which are produced with opening equal or bigger than 2.

This constraint forbids sequences where a stop or an affricate is flanked by sonorants. Constraint (83) alone also must be low-ranked in Polish, because we can find lots of examples containing sequences like –ata-, -atça-, etc. However, when disjoint,[22] the constraints in (82) and (83) have the effect of weakening [dž] to [ž]:

(84) $*$dž $\vee$ $*$Open0 / Open$\geq$2___ Open$\geq$2
No [dž] if it is preceded and followed by a sonorant.

Let us see, how exactly (84) acts. In (85) a number of possible relevant sequences is listed. Recall that for an inclusive disjunction it is enough to satisfy one member of the disjunction to satisfy the disjunction. It is violated only if a form fails on both members of a disjunction.

(85) Which forms satisfy $*$dž $\vee$ $*$Open0 / Open$\geq$2___ Open$\geq$2 ?

		$*$dž	$*$dž $\vee$ $*$Open0 / Open$\geq$2 __ Open$\geq$2	$*$Open0 / Open$\geq$2 __ Open$\geq$2
i.	oge	OK	OK	$*$
ii.	odže	$*$	$*$	$*$
iii.	ože	OK	OK	OK
iv.	ždže	$*$	OK	OK
v.	žže	OK	OK	OK

The form (85i) does not contain dž: $*$dž is satisfied and the disjunction is satisfied. Form ii. violates $*$dž, and the [dž] is located between two sonorants, thus, $*$Open0/Open$\geq$2 ___ Open$\geq$2 is also violated. Form (85ii) violates the disjunction. Form (85iii) [ože] does not contain [dž] and satisfies the disjunction as well. Further, the form (85iv) which is interesting for us, violates $*$dž, but satisfies the other member of the disjunction. Specifically, non-continuant [dž] is not located between two sonorants, and consequently the disjunction is not violated. Form (85iv) also satisfies the disjunction because it does not contain [dž] and the structural description of constraint (84) is not met either.

[22] Inclusive disjunction.

In the following, an analysis of spirantization is proposed, where the effect is seen as a weakening of non-continuant [dž] in the environment of sonorants articulated with a lower degree of closure:

(86) Spirantization in Polish

[Pal] rog + ek; Open4 Open0 Open4	Pal ∨ Uniform	∗dž ∨ ∗Open0 / Open≥2 _ Open≥2	∗dž ∗Open0 / Open≥2 _ Open≥2
a. [Pal] o g e; Open4 Open0 Open4	∗!		∗
b. [Pal] o dž e; Open4 Open0 Open4		∗(disjunction)	∗! ∗
☞ c. [Pal] o ž e; Open4 Open1 Open4		∗(IdentOpen0)	

In candidate (86a), palatalization does not occur (Pal ∨ Uniform is violated). Candidate (86b) contains [dž], and the [dž] appears between two sonorants: violation of a disjunction results. The violation of ∗dž excludes candidate (86b) from further evaluation. (86c) remains as an optimal form although it violates the input – output faithfulness constraint with respect to feature [Open0].

Now, for comparison, let us look at an underlying form where the palatalized velar is preceded by an obstruent.

(87) Spirantization blocked

[Pal] m o z g + e k Open0 Open1 Open4	Pal ∨ Uniform	IdentOpen0 ∗dž ∨ ∗Open0 / Open≥2 _ Open≥2	∗dž ∗Open0 / Open≥2 _ Open≥2
a. [Pal] z g e Open0 Open1 Open4	∗!		
☞ b. [Pal] ž dž e Open0 Open1 Open4			∗
c. [Pal] ž ž e Open0 Open1 Open4		∗!	

Candidate (87a) fails on Pal ∨ Uniform. (87b) and (87c) both satisfy disjunction ∗dž ∨ ∗Open0/Open≥2 ___ Open≥2: in fact, (87b) violates ∗dž but it is not crucial for the case because the constraint against non-continuants between sonorants is not violated; consequently, the disjunction is also satisfied. The decisive effect is brought about by the constraint Ident[Open0]: candidate (87b), which faithfully renders [Open0] on the surface, wins, and (87c) is excluded.

To complete the analysis of the spirantization data, let us finally turn to the forms where the underlying [dž] does not undergo weakening to [ž] as in forms like: *dżdżu* 'rain', defective noun gen. sg., *dżdżownica* 'earthworm', *dżem* 'jam', *bandżo* 'banjo', etc. It is clear that we did not look at yet another factor, namely, that for the underlying affricate, it is more important to preserve the original grade of stricture than to simplify the pronunciation. This ranking seems natural, providing that we stated that the post-alveolar affricate is in some way a marginal sound in Polish:

(88) IdentOpen0]$_{Friction}$
Preserve underlying [Open0] on the surface if [Friction] is underlying.

(89) IdentOpen0]$_{Friction}$ >> IdentOpen0, ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2

This additional constraint has no influence on the forms where palatalization is legitimate. It has no influence on an underlying [g], since it has no underlying [Friction], and also no influence on [x], because its degree of jaw opening is equal [Open1]. The evaluation of a form with an underlying [dž] is represented in (90).

(90) Underlying [dž] is not subject to weakening

bridž+ik Open0 Open3 Open3	Pal ∨ Uniform	Ident Open0]$_{Friction}$	IdentOpen0 ∗dž ∨ ∗Open0 / Open≥2 _ Open≥2	∗dž	∗Open0 / Open≥2 _ Open≥2
☞ a. bridž+ik Open0 Open3 Open3			∗	∗	∗
b. bri ž+ik Open0 Open3 Open3		∗!	∗		

Candidate (90b), which would be optimal taking into account markedness constraints and the "regular" IdentOpen0, is eliminated by a higher-ranked constraint IdentOpen0]$_{Friction}$, which targets only underlying affricates.

One question still remains, namely, why it is only voiced post-alveolar affricates that undergo spirantization. Limiting the target of the process to voiced sounds is obviously nothing unusual. Recall, for instance, that also in the Spanish example, only voiced stops and fricatives were in the complementary distribution. It is also unclear why only the post-alveolar affricate undergoes lenition in Polish. For comparison, standard Croatian has lenition of both post-alveolar and dental voiced affricates resulting from palatalization, as in (91).

(91) Spirantization in Standard Croatian

ru[k]+a 'hand'	ru[tš]+e voc. sg.
vra[g] 'devil'	vra[ž]+e voc. sg.
du[x] 'ghost'	du[š]+e voc. sg.
pau[k] 'spider'	pau[ts]+i nom. pl.
biolo[g] 'biologist'	biolo[z]+i nom. pl.
du[x] 'ghost'	du[s]+i nom. pl.

Croatian, like Polish has the sound [dž] in its inventory, though, it is also a segment that would appear in loan words, e. g. [dž]ep 'pocket', [dž]emper 'pullover', etc., or is a contextual allophone of [tš], e. g. promo[dž]ba 'promotion'. [dz] is only an allophone of [ts] before a voiced consonant, e. g. across word boundary in a sentence: *Ota[dz] ga je vidio* 'Father saw him'.[23]

It seems that the former question might have an articulatory solution, yet at present no formal solution can be proposed.

4.12 What about Coronal Affricates?

As already mentioned earlier, dental affricates do not undergo coronal palatalization. Instead, similar to post-alveolar coronals, they trigger a retraction of the high front vowel [i] to [ɨ], cf. (92).[24]

(92) i-retraction
Koza[ts]+[ɨ] 'Cossacks' (but cf. Francu[ʑ]+i 'Frenchmen')
ko[tsɨ]k but ∗ko[tsi]k 'blanket', dim.

I assume that dental affricates are already underlyingly [Pal], and for this reason, no further surface adjustment happens when in the context of a palatalizing vowel. Additional support to this claim comes from morphology. The choice of particular suffixes in Polish depends often on whether a given stem ends in a palatalized or non-palatalized consonant. Dental affricates function as soft (together with prepalatals, palatalized labials, j) for the selection of suffixes. Finally, they emerged in many cases originally as effects of historical palatalization processes, and there is still a morphologically limited process (2nd Velar Palatalization, cf. chapter 1) which produces dental affricates in the context of three lexically specified morphemes.

The same arguments are also valid for the underlying post-alveolars and prepalatals: they do not exhibit any further alternations because they already contain [Pal].

4.13 Relative Ranking of Constraints in Polish

Three groups of constraints emerge from the analysis of Polish: those unviolable, those which interact, and those which are ranked so low they cannot influence the surface output.

[23] One could stipulate that the answer has to do with a phonemic status or frequency of the occurrence of the sound in a given language.

[24] Retraction itself will be discussed in chapter 5.

The inviolable constraints in Polish are: Ident[HighF2], Ident[Friction], SSG, articulatory constraints against ∗pf, ∗pɕ (in standard Polish), ∗ř, ∗L, affricated liquid ∗ɮ, and palatal liquid ∗ʎ. Also, AgrATR will be argued to hold absolutely in Polish, see the discussion in chapter 5.

Those constraints which usually have no influence on the surface output are: AgrPlace, PAL, and Uniform, further IdentPlace, DepPlace, Dep(Root), further ∗dž, and ∗Open0/Open≥2 ___ Open≥2.

There are also a number of interactions between constraints to be observed. So, PAL ∨ Uniform is of course only possible because it does not violate Ident[HighF2], Ident[Friction], thus the ranking is as in (93):

(93) Ident[HighF2], Ident[Friction] >> PAL ∨ Uniform

PAL ∨ Uniform is higher ranked than PAL and Uniform separately, and – additionally – it is higher ranked than IdentPl, because the successful candidates are selected though they are unfaithful with respect to Place.

(94) PAL ∨ Uniform >> PAL, Uniform, IdentPl

It seems that PAL ∨ Uniform is lower-ranked than MinDistPal=2Cues: we have seen that if MinDistPal=2 is violated, e. g. in the case of labial blocking (section 4.10), palatalization will not occur, that is, PAL ∨ Uniform will be violated in the successful candidate.

(95) MinDistPal=2Cues >> PAL ∨ Uniform

PreserveContrastPl]$_{Obstruents}$ seems also to be higher ranked than PAL. For example, in the cases where palatalization of labials may not surface in the normal way (secondary palatalization), it is not realized at all, rather than surfacing as a segment which would be a typical alternant of another place of articulation and losing a place distinction. For instance, a prepalatal is not a good candidate for the underlying labial even if the labial should be palatalized.

(96) PreserveContrastPl]$_{Obstruents}$ >> PAL ∨ Uniform

On the other hand, the contrast between [Pal] and non-[Pal] seems to be more or less important, depending on the place of articulation. This might be connected with the functional load of particular contrasts. Thus, Preserve Contrast(Pal) on velars cannot be violated. On the other hand, palatalization may not surface on labials, when MinDistPal=2Cues would be violated.

(97) PreserveContrastPal]$_{Velars}$ >> PreserveContrastPal]$_{Lab}$

Yer Surface is high ranked, yet, it is controlled by SSG.

(98) SSG >> Yer Surface

IdentPal is assumed to be ranked together with PAL ∨ Uniform, as it undergoes the same kind of restrictions on surfacing as PAL ∨ Uniform.

A constraint against sequences of sounds which involve overly huge differences in the jaw opening on its own is low-ranked. Similarly, ∗dž is low ranked, yet there is an environment where ∗dž is absolutely banned, that is, in the context where [dž] is not underlying, and when flanked by two segments of a much bigger jaw opening.

(99) ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2 >> ∗dž, ∗Open0 / Open≥2 ___ Open≥2

IdentOpen0 seems to be unordered with respect to ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2:

(100) ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2, IdentOpen0 >> ∗dž, ∗Open0 / Open≥2 ___ Open≥2

A more targeted constraint IdentOpen0$]_{Friction}$ is ranked above both IdentOpen0 and ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2:

(101) IdentOpen0$]_{Friction}$ >> ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2, IdentOpen0

Pal ∨ Uniform is never blocked by ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2 but rather the output is modified, thus, it seems that the former ranks above the latter.

(102) PAL ∨ Uniform >> ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2

Finally, articulatory constraints against secondarily palatalized sounds, and secondarily velarized sounds seem violable (because these sounds do occur to satisfy the unviolable ATRAgr) but still may influence the surface output, by eliminating segments with secondary articulations in the presence of other candidates which are equally good from the point of view of higher-ranked constraints.

(103) ATRAgr, Ident[HighF2], Ident[Friction] >> PreserveContrast >> ∗Cor[+anterior, −anterior], ∗$C^{ɣ}$

The emerging ranking would be then summarized in (104):

(104) Ranking of constraints for Polish
SSG, Ident[Friction], Ident[HighF2], ∗pf, ∗pˠ, ∗ř ,∗L, ∗ɮ, ∗ji, ATRAgr
>> PreserveContrastPlace]$_{Obstruents}$, YerSurface >>
>> MinDistPal=2Cues >>
>> Ident[Pal], PAL ∨ Uniform >>
>> PreserveContrastPal]$_{Lab}$ >>
>> ∗dž ∨ ∗Open0 / Open≥2 ___ Open≥2, IdentOpen0 >>
>> PAL, Uniform, IdentPlace, ∗dž, ∗Open0 / Open≥2 ___ Open≥2, Dep(Root)

4.14 Summary and Conclusion

In this chapter, a new analysis of the palatalization data in Polish has been proposed. We postulated that the palatalization of all the three groups of sounds, that is, labials, coronals and velars, is triggered by a perceptual [Pal] feature in an alternating environment.

Palatalization in Polish (and many other languages) is possible because the alternation does not violate Ident[Friction] and Ident[HighF2]. These are very salient cues for the perception of consonants, thus, an alternation which would be violating these conditions is unlikely to be accepted by the users of the language: if the output is not sufficiently similar to the input, the hearer cannot recover the input from the output, and the communication suffers.

The surface difference between the outputs of palatalization of labials, coronals and velars is ascribed to the requirement to preserve the underlying place contrast on the surface. Thus, the underlying contrast between coronal and velar is on the surface rendered as an opposition between prepalatals and post-alveolars. The outputs of palatalization are assigned by its relative perceptual similarity to the underlying specification. In our analysis, coronals in the palatalizing context will be realized as prepalatals, and not post-alveolars, because prepalatals are more faithful with respect to Noise Frequency. On the other hand, underlying velars in the palatalizing context will surface as post-alveolars, because velars and post-alveolars both have relatively lower Noise Frequency. Further, the lack of secondary palatalization on liquids is explained by the fact that, for liquids, Preserve Contrast is not violated even if the articulation is strongly simplified.

Emergence of prepalatals is in our account driven by auditory considerations. It is claimed that prepalatal affricates better mark the distinction between [Pal] and non-[Pal] segments. As an argument for the influence of the latter factor, the data from Polish dialects are presented. The insertion of [j] in palatalized labials is accounted for by the same auditory requirement to enhance the palatality contrast in labials.

Chapter 5

THE ROLE OF [ATR] IN POLISH PHONOLOGY

5.1 Overview

In the previous chapter, some phenomena connected with palatalization were purposefully omitted. They include Surface Velar Palatalization, Velar Fronting,[1] and Surface Palatalization (cf. the overview in chapter 1). Another outstanding problem that was not discussed in the context of palatalization of velars is that of the so-called Retraction of the underlying palatalizing high front vowel to surface [ɨ]. It will be argued here that the aforementioned alternations have a different trigger than the previously discussed palatalization processes, namely, that they are articulatory driven. In the present chapter, we will propose an analysis in which the surface form of the consonant – vowel sequences is conditioned by the requirement of harmony with respect to articulatory feature [ATR].

We will start the discussion by introducing the data of Retraction in section 5.2. Sections 5.3-4 offer an analysis of the phenomenon. In section 5.5, we will support the proposed analysis by a reference to phonetics of relevant segments. Section 5.6 brings forward further phonological evidence from languages other than Polish for the claim that secondary palatalization may be an effect of the tongue root advancement. The proposed mechanism accounts also for Surface Palatalization. In section 5.7, co-occurrence constraints on sequences involving either a coronal or labial consonant, followed by a front vowel, are discussed. In section 5.9, we proceed to discuss the co-occurrence constraints on sequences involving a velar consonant followed by a front vowel. It is argued that, as to the surface distribution of variants of velar sounds and front vowels, apart from the agreement in terms of [ATR], an agreement in terms of the place of constriction is also valid. Further, the

[1] Velar Fronting: non-palatalizing suffix vowel -ɨ surfaces after [k, g] as [i], cf. e. g. Rubach (1984).

data of Velar Fronting (section 5.10) and Surface Velar Palatalization (section 5.11) are analyzed in the light of the previous discussion of the co-occurrence constraints. Finally, section 5.12 is devoted to the discussion of the proposal in chapter 2 with respect to the Derived Environment problem. It will be argued that the Alternating Environment solution, unlike the solution proposed by Łubowicz (1998), has a broader application, since it can account for the set of data involving the surface palatalization of velar stops triggered by morpheme-internal yers. Section 5.13 summarizes the postulated constraint rankings and section 5.14 concludes the discussion in this chapter.

5.2 Retraction Data

A palatalizing vowel after a surface post-alveolar will surface as [ɨ], whereas, in the context of other consonants, the palatalizing vowel is always [i], as in (1).

(1) Retraction

a. mo[v]+a vs. mó[vʲ]+[i]+ć ‘speech’ – ‘to speak’
opła[t]+a vs. opła[t͡ɕ]+[i]+ć ‘payment’ – ‘to pay’

b. kro[k] vs. kro[tš]+[ɨ]+ć ‘step’ – ‘to step’
na[g]+ość vs. obna[ž]+[ɨ]+ć ‘nakedness’ – ‘to make’/‘turn naked’
su[x]+o vs. su[š]+[ɨ]+ć ‘dry’, adv. – ‘to dry’

As shown in (1), the infinitival suffix of the verbs will surface as [i] in the context of surface soft consonants (prepalatals), and as [ɨ] after post-alveolars. This correlation is absolutely regular. There is no single suffix starting with surface [i] when it follows a surface post-alveolar.

The above set of data has often been mentioned in literature. Let us consider the additional data in (2). The palatalizing mid vowel surfaces regularly as [ɛ] after post-alveolars and as [e] after prepalatals:

(2) e/ɛ distribution

gru[b]+o ‘thick’, adv.	zgru[bʲj]+[e]+ć ‘become thick’
zdro[v]+o ‘healthy’, adv.	wyzdro[vʲj]+[e]+ć ‘to become healthy’
żół[t]+o ‘yellow’, adv.	zżół[tɕ]+[e]+ć ‘turn yellow’
ły[s]+y ‘bald’	wyły[ɕ]+[e]+ć ‘become bald’
dro[g]+o ‘expensive’, adj.	po+dro[ž]+[ɛ]+ć ‘become more expensive’
d[r]+ę ‘I tear’	d[ž]+[ɛ]+ć ‘tear’, inf.
ró[ž]+a ‘rose’	ró[ž]+[ɛ] ‘roses’, nom. pl.

This data has never been discussed before in the context of palatalization of velars: e/ɛ distribution has been disregarded as allophonic. Notice that all kinds of surface post-alveolar sounds will be compatible with [ɛ] only, whether they result from palatalization of coronals, velars, or underlying.

In what follows, it will be argued that the data in (1) and (2) can be accounted for in terms of the adjustment of the position of the tongue root.

5.3 A Solution: ATR Harmony

It is proposed here that prepalatals and post-alveolars of Polish differ in surface terms with respect to features [+ATR]/[−ATR], as defined in chapter 2. Also, it is argued that the pairs of front vowels: [i] versus [ɨ], and [e] versus [ɛ] differ in terms of the position of the tongue root, as summarized in (3):

(3) Specification of sounds with respect to [ATR]

[+ATR]	[−ATR]
prepalatals: ɕ ʑ tɕ dʑ ɲ	post-alveolars: š ž tš dž
vowel [i]	vowel [ɨ]
vowel [e]	vowel [ɛ]

The specifications in (3), are motivated by phonetic facts, as shown in chapter 3, and summarized in (4).

(4) ATR in Polish

+ATR	pʲ, bʲ, fʲ, vʲ, mʲ, tʲ, dʲ, sʲ, zʲ, tsʲ, dzʲ, rʲ, lʲ, tšʲ, džʲ, šʲ, žʲ, tʲ, dʲ, ɕ, ʑ, tɕ, dʑ, j, c, ɟ, ç	i, e
−ATR	p, b, f, v, m, w, t, d, s, z, n, ts, dz, r, l, tš, dž, š, ž, k, g, x	ɨ, ɛ

Further, a surface requirement for the harmony between the vowel and the preceding consonant in terms of the tongue root position has to be observed, yielding the following sequences possible:

(5) ATR harmony
prepalatals + [i]
prepalatals + [e]
post-alveolars + [ɨ]
post-alvoelars + [ɛ]

Under the proposed account, the palatalization of velars to post-alveolar [tš], [dž], [š] and of coronals to [ɕ, ʑ, tɕ, dʑ], respectively, is induced by three factors. First, palatalization is spreading perceptual [Pal]. Second, the exact non-anterior place (post-alveolar, and not palato-alveolar, or prepalatal) is determined by the need to produce a perceptual contrast between the results of palatalization of velars and the result of palatalization of coronal obstruents. And third, the choice of alternants is determined by the relative faithfulness of the output to the input in terms of [NF]. [NF] conditions the choice of the matching value of [ATR].[2]

(6) Default [NF]–[ATR] mapping
NF2 $\Rightarrow$ $-$ATR
NF3 $\Rightarrow$ +ATR

Thus, the contrast between palatalized velars and palatalized dentals is made in articulatory terms by inserting the distinction in the tongue root position: the palatalization of velars produces [$-$ATR] sounds, the palatalization of coronals produces generally speaking [+ATR] sounds. On the other hand, the surfacing of [ɨ] instead of the expected [i] (Retraction) results from the assimilation of the vowel to the consonant in terms of ATR.

The distinction between [i] and [ɨ] has been traditionally understood as a difference in terms of backness: [i] was analyzed as [$-$back], [ɨ] – as [+back], see e. g. Rubach (1984). This specification is, however, not supported by phonetic facts. As argued in chapter 3, both [i] and [ɨ] are coronal, in contrast to real back vowels [u] or [o].

The distinction between [e] and [ɛ] in the context of palatalization data was simply disregarded in earlier accounts. Both instantiations of a mid front vowel were [$-$back]. The appearance of [e] was attributed by Rubach (1984) to an allophonic rule of tensing in the context of prepalatals. If one accepts this view, it is impossible to see the parallels between the behavior of high and mid vowels in the context of post-alveolars and prepalatals. For high vowels, the consonant and the vowel would be claimed to agree in the feature [$-$back], and for mid vowels, the consonant and the vowel would be assumed to agree in the feature [tense].

In what follows, I propose an analysis accounting for both the Retraction of a high vowel in the context of post-alveolars, and for the Tensing of mid vowels in the context of prepalatals. Further, this analysis will be extended to other phenomena, which in earlier approaches had to be analyzed independently.

[2] The auditory-articulatory matching might be considered as universally unviolable constraints, excluding unpronounceable strings.

5.4 Analysis of Retraction in the Context of Post-alveolars

In chapter 2, a constraint was proposed, here repeated in (7):

(7) Agr (C, V)(ATR)
For the preceding consonant C, and the following consonant V, C and V agree in the position of the tongue.

Under the assumption that the output and the trigger of palatalization have to agree in the general tongue position, which serves the purpose of saving articulatory effort, we are able to account for i-retraction in Polish, see tableau (8).

(8) The interaction of Velar Palatalization and i-retraction

[Pal] krok+ić	ATRAgr	MinDistPal	Pal ∨ Uniform
a. [Pal] k+i [−ATR] [+ATR]	∗!		∗
b. [Pal] c+i [+ATR]		∗!	
c. [Pal] [Friction] tš+i [−ATR] [+ATR]	∗!		
☞ d. [Pal] [Friction] tš+i [+ATR]			

The underlying /krok+ić/ has to be palatalized (due to Pal ∨ Uniform). The consonant will surface as [tš] and not [c] to satisfy MinDistPal=2Cues. However, the palatalizing front vowel cannot surface as [i], because ATRAgr would be violated. The form surfaces with [ɨ] (candidate (8d)) – high front vowel which agrees in ATR values with the preceding consonant.

The ranking of constraints as in (8) accounts without any further reservations for the allophonic surface variation between front mid vowels, see (9a) and (9b).

(9) a. Mid front vowel following a post-alveolar

[Pal] ryk+e+ć [Dor] [Cor]	ATRAgr	Preserve Contrast [Cor-Vel]	MinDistPal	Pal ∨ Uniform
a. [Pal] k+e [−ATR] [+ATR]	*!			*
b. [Pal] c+e [+ATR]			*!	
c. [Pal] [Friction] tš+e [−ATR] [+ATR]	*!			
☞ d. [Pal] [Friction] tš+ε [−ATR]				
e. [Pal] tɕ+ε [+ATR]		*!		

b. Mid front vowel following a prepalatal

[Pal] //ma t + e// [Cor] [Cor]	ATRAgr	MinDist(Pal) =2Cues	Pal ∨ Uniform
a. [Pal] t+ɛ [−ATR]			∗!
☞ b. [Pal] Friction [HighF2/F3] tɕ+e [+ATR]			
c. [Pal] Friction [HighF2/F3] tɕ+ɛ [+ATR] [−ATR]	∗!		

In (9a), the ranking selects the non-ATR correspondent for the underlying palatalizing vowel, due to ATR Agreement (and in the first place, due to NF faithfulness, and NF-ATR correspondence). The vowel has to agree with respect to [ATR] with the post-alveolar consonant. Candidate (a) violates Pal ∨ Uniform. Candidate (b) marks the palatalization contrast by formant transitions alone, without friction, and violates Minimal Distance. Candidate (e) is identical to the output of the palatalization of a coronal. The underlying contrast between coronal and velar is not rendered on the surface, hence, Preserve Contrast is violated. The optimal candidate (d) contains a non-ATR [ɛ].

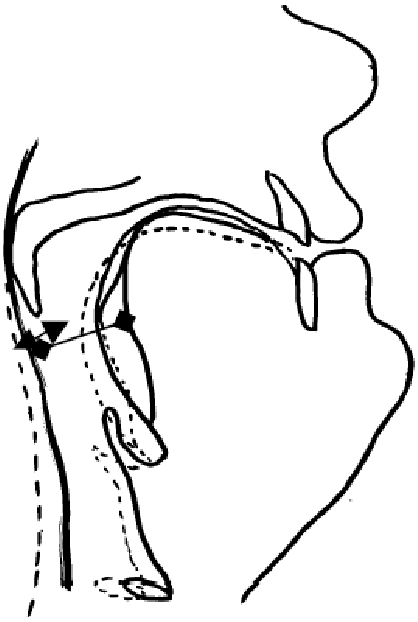
The tableau (9b) evaluates the output of forms containing prepalatals followed by a front mid vowel. The inviolable ATR Agreement selects an ATR vowel in the context of a prepalatal. The choice of a prepalatal is determined by faithfulness constraints, the constraint inducing palatalization, and constraints against the loss of the underlying oppositions. Thus, candidate (a) violates Pal ∨ Uniform, candidate (c) contains a disharmonic in terms of [ATR] sequence. Candidate (b) is optimal with the sequence consonant + vowel agreeing in terms of the position of the tongue root.

5.5 Phonetic Evidence

The ATR analysis is supported by phonetic studies. In the following section, we will repeat some arguments from chapter 3, focusing on the the tongue root position in the articulation of front high vowels, prepalatals, and post-alveolars.

Compare first the Polish vowels [i] and [ɨ] (redrawn from Koneczna et al. (1951), pictures 43, 51) in (10). For each vowel, two or three lines mark the contour of the surface of the tongue: the top line(s) correspond to the edges of the tongue, and the lower line corresponds to the groove along the middle of the tongue. Koneczna et al. do not specify the contexts at which the vowel were pronounced for the x-ray pictures.

(10) [i] (solid line) and [ɨ] (dotted line)



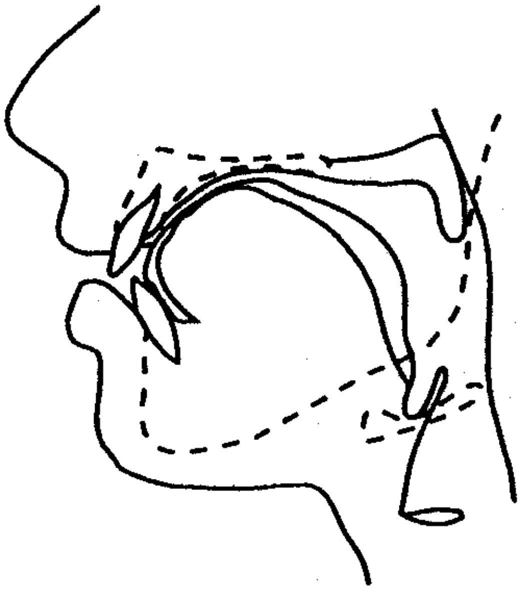
↔ the width of the pharyngeal cavity for [ɨ]
↦ the width of the pharyngeal cavity for [i]

As argued in chapter 3, [ɨ] is produced similarly to [i], with the front tongue position, which means the maximal constriction is made by the front part of the tongue. They differ in that the tongue root position is for [i] more advanced than for [ɨ]. When we look at the lines corresponding to the middle part of the tongue we see that the whole laryngeal cavity is substantially enlarged in [i]. Also Wierzchowska (1980), contrary to the phonological analysis treating [ɨ] as [+back], counts [ɨ] as a segment produced with front position of the tongue: it is front, though less advanced than [i], the difference lying also in the position of the root (my observation), and higher position of the larynx in the case of [i] (Wierzchowska, 1980, 88). For this reason, it is assumed here that [ɨ] is a [Coronal, −ATR], whereas [i] is [Coronal, +ATR].

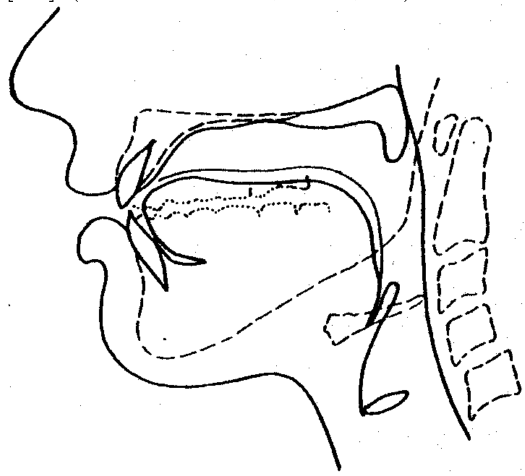
Now, let us compare the articulation of Polish prepalatals and post-alveolars:

(11) x-ray tracings of non-anterior coronals

a. [ɕ] (Wierzchowska, 1980)



b. [tš] (Wierzchowska, 1980, 64)



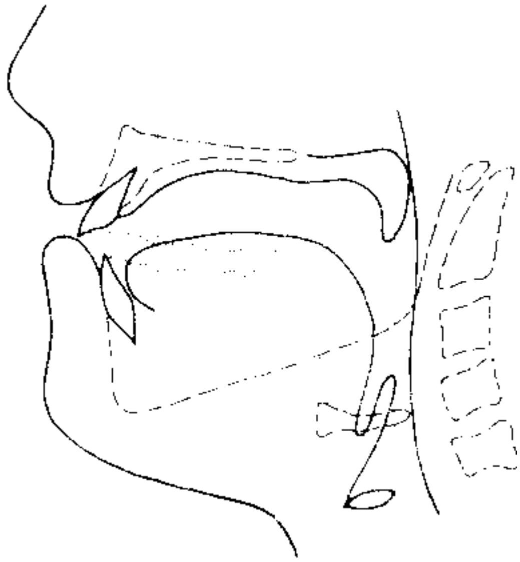
Apart from the difference in the position of the front of the tongue, it is clear that the tongue root in the articulation of prepalatals [ɕ, ʑ, tɕ, dʑ] is advanced in comparison to the articulation of [tš, dž, š, ž].

Also, as reported in Dogil (1990), prepalatals are articulated with a "great tension of the lingual muscles". Recall that muscular effort has been claimed to be one of the correlates of the feature tense, which is often understood as the same as [ATR]. Post-alveolars are in this respect different, and pattern with non-palatalized sounds.

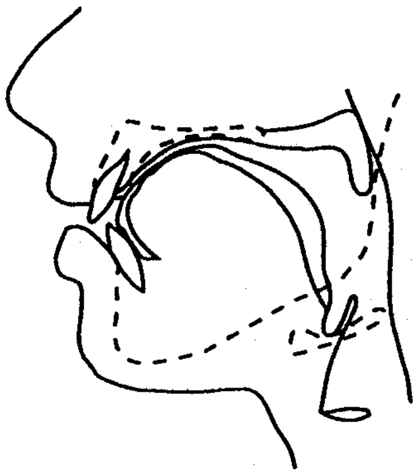
In general, all phonetically secondarily palatalized consonants are articulated as [+ATR]. For illustration, the x-ray tracings of [f] and [fʲ] are reproduced in (12)– notice the difference in the tongue root position.

(12) Palatalized versus non-palatalized labials

a. [f] (Wierzchowska, 1980, 60)



b. [fʲ] (Wierzchowska, 1980, 97)

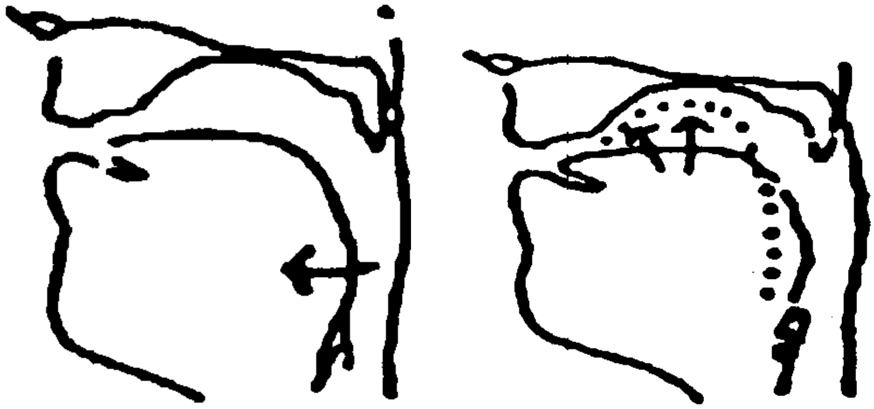


5.6 Relation between Secondary Palatalization and ATR

Secondary palatalization in Polish (cf. chapter 1) has been so far described in terms of features [+high, −back]. By arguing for [+ATR] specification of sounds, I do not argue against claims that Polish secondary palatalized sounds are [−back] and [+high]. It is rather argued that the generalizations about the patterning of sounds have to be made by reference to the feature [+ATR].

The fact that the [+ATR] sounds of Polish are also [−back] and all [+ATR] consonants are [+high] in classical terms fits into the general pattern. The relation between the tongue root movements and the effects on the tongue front is not surprising, considering the mechanics of the tongue movement. Lindau (1975, 30) observes that advancing the tongue root tends to push the tongue body up and forward, as illustrated in chapter 2, here repeated in (13):

(13) [+ATR] leads to fronting and raising
(Lindau (1975), represented after Vaux (1996, 396))



In fact, for many languages spell-out rules like in (14) have been proposed:

(14) Cross-linguistically reappearing vowel spell-outs (Vaux, 1996)

a. [α ATR] → [α high]
b. [αATR] → [$-\alpha$ back]

The same relation may hold for consonants. Palatalized consonants (traditionally described as [−back, +high]) might be referred to simply in terms of [+ATR]. This claim finds support in phenomena from other languages.

For instance, Stadnik (2002) mentions Evenki and Orok which are languages of Mandshu-Tungusic family.[3] She writes that secondary palatal-

[3] The list of the Mandshu-Tungusic language where there is relation between secondary

ization is described in the literature as conditioned by front vowels (Petrova (1967), Avrorin (1959), Avrorin and Lebedeva (1968), Lebedev (1978), Sunik (1985), Simonov (1988), Novikova and Sem (1997); Sem (1997)). Instead, Stadnik (2002) argues that the generalization should rather be made in terms of the feature [ATR]. First, the front vowels in these languages differ from the back vowels not only in terms of the place of the maximal constriction, but also in the position of the tongue root: front vowels, in contrast to back vowels, are articulated with the advancement of the tongue root. Second, there are cases of secondary palatalization triggered by [e, u], where both of them are [+ATR], but not both of them are front. This is the case of the palatalizing of a sibilant [s] in Orok (Stadnik (2002), after Petrova (1967)). Third, the choice of palatalized allomorphs in the adjacency of [+ATR] vowels in Orok would be parallel to the choice of velar-uvular distinction in the context of [+ATR/−ATR] vowels in related language, Even. For Even, it is claimed that the co-occurring consonant-vowel pairs have to be phonetically compatible: [+ATR] vowels appear in the context of velar consonants, and [−ATR] vowels co-occur with uvular sounds. Since the perceptual distinction between advanced and retracted tongue root vowels is small (and only allophonic), it is also often not reflected in writing (which is using the Cyrillic alphabet with an insufficient number of vocalic symbols anyway), and not even in phonetic transcriptions (Petrova (1967), Lebedev (1978)). Thus, Stadnik concludes, contrary to the previous analysis, that palatalized consonants are possibly bound to the environment of [+ATR] vowels, and not of [−back], and non-palatalized consonants appear in the environment of [−ATR] vowels.

Another interesting argument for the relation of secondary palatalization on consonants to [+ATR] comes from Palestinian Arabic. As Czaykowska-Higgins (1987) reports, high front vowels and palatal consonants such as [š] and [dž][4] block the spreading of emphasis. If emphasis should be expressed by means of tongue root features, the effect of a blocking of the spreading might only result from the fact that front vowels and palatal sounds involve advancement of the tongue root, i. e. they are already [+ATR]. To analyze these facts we have to admit that front vowels and palatal(ized) consonants might be specified as [+ATR], even in the systems where the feature [+ATR] seems to be inactive (underspecified), as is the case in Palestinian Arabic.

palatalization and +ATR is not complete. According to Stadnik (p. c.) other languages of this group exhibit similar phenomena.

[4] The original transcription of Czaykowska-Higgins (1987) has been preserved. She refers to the sounds as to palatal.

5.7 Surface Palatalization

Apart from i-retraction after post-alveolars, and Tensing after prepalatals, other data may be accounted for by assuming ATR harmony. Within the framework of Lexical Phonology, a rule of Surface Palatalization has been proposed by Rubach (1984) that adds secondary palatalization to consonants before surface [i] (cf. the overview in chapter 1). The data covered by the rule of Surface Palatalization, can be accounted for by ATR agreement, as below:

(15) Surface Palatalization

[Pal] s i gma	ATRAgr	Preserve Contrast$_{Pal]V}$	Pal ∨ Uniform
a. [Pal] s i [−ATR][+ATR]	*!		
☞ b. [Pal] s^j i [+ATR]			
c. s ɨ [−ATR]		*!	

Candidate (15a) violates AgrATR. Candidate (15c) realizes a [Pal] vowel with an [ɨ], as if it would be a non-[Pal] vowel, thus, failing to render the contrast. Candidate (15b) is optimal with both members of the sequence realized as [+ATR].

On the other hand, when we have a non-[Pal] vowel morpheme-internally, it will surface as [−ATR] and the consonant will be also [−ATR]:

(16) [−ATR] sequences

s ɨ n Cor Cor	ATRAgr	Preserve Contrast$_{Pal]V}$	Pal ∨ Uniform
a. s i [−ATR][+ATR]	*!		
b. s^j i [+ATR]		*!	
☞ c. s ɨ [−ATR]			

The optimal candidate in (16c) complies with ATR agreement, and does not violate Preserve Contrast, unlike candidate (16b), which renders a non-[Pal] vowel the same way as a [Pal] vowel.

In sequences with a mid front vowel, the underlying vowel is non-[Pal],[5] thus [−ATR], and no adjustment is necessary, see (17).

(17) No Surface Palatalization of coronals before mid vowel

s ɛ Cor Cor [+ant] [−ant]	ATRAgr	Preserve Contrast$_{Pal]Vowel}$	Pal ∨ Uniform	∗Cor [−ant, +ant]
a. s e [+ant] [−ant] [−ATR][+ATR]	∗!			
b. sʲ e [+ant] [−ant] [+ATR]				∗!
☞ c. s ɛ [+ant] [−ant] [−ATR]				

Candidate (17b) does not violate Preserve Contrast(Pal)]$_{Vowel}$ because most probably in this position there is no contrast between palatalizing and non-palatalizing vowel. The deciding factor is the articulatory constraint against secondarily palatalized consonants.

5.8 Sequences of Coronal/Labial Consonants with Front Vowels

Adopting an ATR solution for i-retraction and for the e/ɛ alternation opens new perspectives for the interpretation of other – so far unrelated – facts of Polish. In a similar vein, co-occurrence constraints on the sequences of consonants with [i] and [ɨ], and with [e] and [ɛ] may be explained in general. The gist of the analysis of i-retraction and e-tensing data in (1) and (2) was the observation that the surface sequences involving a consonant + front vowel ([i] or [ɨ], [e] or [ɛ]) have to agree in the position of the tongue root. Generalizations as in (18) may be proposed with respect to the sequences of post-anterior coronals followed by front vowels:

[5] Cf. the discussion on the morpheme-internal mid-vowel in the following section.

(18) Co-occurrence constraints on the sequences involving non-anterior consonants and front vowels
∗ɕɨ √ɕi
∗ɕɛ √ɕe
∗ši √šɨ
∗še √šɛ
for ɕ= any prepalatal, š = any post-alveolar

Surface sequences in (18) differ from non-occurring sequences in that they agree in the position of the tongue root. Let us now observe that ATR agreement cannot be violated in sequences involving post-anterior, anterior coronal sounds, as well as labials:

(19) Co-occurrence constraints on the sequences involving coronals/labials and front high vowels
For tš = any post-alveolar, t = any dental, p = any labial, C^j = relevant secondarily palatalized sound:

a. ∗tši √tšɨ
[tšɨ]sto 'clean', adv., mę[tš+ɨ] 'makes tired', 3rd sg.

b. ∗$tš^j$ɨ √$tš^j$i
ma[$tš^j$i]smo 'machismo', [$tš^j$i]bo 'Chibo' brand name

c. ∗ti √tɨ
[tɨ]lko 'only', [tɨ] 'you', matema[t+ɨ]ka 'mathematics'

d. ∗t^jɨ √t^ji
[ma$t^j$is] 'Matisse', [t^jinktura] 'tincture'

e. ∗pi √pɨ
[pɨ]tanie 'question', ma[p+ɨ] 'maps'

f. ∗p^jɨ √p^ji
[p^ji]sk 'squeak', [p^ji]ramida 'pyramid', głu[p^j+i] 'stupid'

Up till very recently, there were no surface sequences with a dental consonant followed by [i] in Polish. Possible sequences were only [tɕi] and [tɨ], due to the higher ranking of general PAL (not disjoint with Uniform), which forbade secondary palatalized segments in general. In modern Polish, [tɕ] is an independent phoneme, and the constraint inducing palatalization is conjoined with Uniform, and therefore, it applies only in Alternating Environment. Morpheme-internal sequences cannot be recovered as underlying /ti/. A gap in the pattern appeared, and for a while there were no underlying /ti/ sequences morpheme-internally, cf. (20)–(21). This gap was soon filled with new borrowings, which are realized with secondary palatalization on the consonant:

(20) Original mappings
/ti/ → [tɕi]
/tɨ/ → [tɨ]
[∗tʲi]

(21) Modern Polish mappings (morpheme-internally)
/ti/ →[tʲi]
/tɨ/ →[tɨ]
/tɕi/ →[tɕi]

Previously, borrowings containing in the original language sequences coronal + i were realized in Polish with surface [ɨ] or [i] and deep palatalization of the consonant. Nowadays, the recent borrowings realize the sequences with [i] faithfully with respect to the vowel, and with a preceding consonant secondary palatalized. Secondarily palatalized segments are banned only in the contexts where [Pal] needs to be marked by two perceptual features. The borrowings with front-mid vowel are regularly analyzed as containing non-palatalizing [ɛ],[6] and non-palatalizing front vowel will be assigned by default [−ATR] vowel. Thus, no amendments of the consonants are necessary.

ATR agreement holds without exception also for the sequences across-morpheme-boundary (cf. (19)), as well as for sequences with a mid vowel, both morpheme-internal and across the morpheme boundary, see (22):

(22) Co-occurrence constraints on coronals/labials + mid front vowels
a. ∗pe √pɛ
[pɛ]stka '(of a fruit) stone', ła[p+ɛ]k 'paws', dim. gen. sg.
b. ∗te √tɛ
[tɛ]raz 'now', ma[t+ɛ]k 'mothers', gen. pl.

To sum up this section, it has been demonstrated that all sequences with labial and coronal consonants followed by any front vowel necessarily obey the ATR agreement.

5.9 ATR Harmony in Sequences with Velar Stops

More constraints can be observed on co-occurrence of velar consonants in sequences with front vowels. Let us start with sequences involving high front vowels, cf. (23):

[6] There are few exceptions, where the loan word in the original spelling or pronunciation contains [j], as in [sjesta].

(23) Sequences involving velar sounds with stops + high vowel: morpheme-internally and with morpheme boundary

a. ∗ki ∗k+i
b. ∗kɨ ∗k+ɨ
c. ∗cɨ ∗c+ɨ
versus
d. √ci √c+i

It is obviously not only the position of the tongue root that matters ((23b) should then be acceptable) but also another factor should be taken into account. I propose that the place of the constriction needs to be harmonic for velar stops, cf. (24):

(24) Velar stop + front high vowel sequences with respect to constraints on place and ATR agreement

				Pl Agr	ATR Agr
ki	Vel. −ATR	Cor +ATR	∗!	∗	∗
ci	Vel/Cor +ATR	Cor +ATR	OK		
kɨ	Vel. −ATR	Cor −ATR	∗!	∗	
cɨ	Vel/Cor +ATR	Cor −ATR	∗!		∗

It is proposed then that for velars, unlike for labials, a constraint Agr Place holds:

(25) Agr Pl(Dor C)
Coronal specification of the vowel is docked also on the preceding velar consonant.

It seems also that (25) is vacuously satisfied for the sequences with any back vowel as well, because back vowels are all Dorsal, though we do not observe any effect on the surface. One could wonder why agreement in place is limited to velar stops. It might be motivated articulatorily. While the movements of the lips are completely independent from the movements of the tongue, the movements of the dorsum and the middle part of the tongue influence each other. Thus, it is in general articulatorily more difficult to produce a sequence velar + coronal than labial + coronal. Hence, it is more important to modify a velar consonant, so that it does not hinder the production of the consecutive front vowel, than to modify a labial consonant before a coronal vowel, see (26).

(26) Agr Place(Dor C, V) >> Agr Place (Cor C, V) >> Agr Place (Lab C, V)

Let us now compare the sequences with mid vowels:

(27) Sequences of velar stops and mid vowels

a. ∗ke ∗k+e

b. √kɛ ∗k+ɛ e. g. [kɛ]lner 'waiter', [kɛ]ks 'cake'

c. ∗cɛ ∗c+ɛ

d. √ce √c+e [ce]dy 'when', ma[c+e]m 'poppy flower', instr. sg.

In the sequences with mid vowels, ATR agreement is still observed. However, unlike for sequences with high vowels, a sequence that does not agree in Place (kɛ) is allowed in mid vowels morpheme-internally (but not at the morpheme boundary). This can be accounted for by proposing that more specific constraints requiring place agreement for high vowels, and on the other hand, a more specific constraint requiring place agreement in an alternating environment, are higher ranked than the general constraint on Place Agreement, as in (28):

(28) Relative ranking of Place Agreement constraints

a. PlAgr(C, Open3) >> Pl Agr

b. Pl Agr ∨ Uniform >> Pl Agr

The motivation for the ranking in (28a) is again articulatory. In the articulation of high vowels, the movements of the tongue must be more controlled than for lower vowels, producing an opening which is bigger than for approximants but still maximally small as for vowels, and, thus, it is important that already the preceding consonant is articulated in such a way as not to hinder the production of the vowel. (28b) is motivated by learning strategies of the speaker of a language, as argued in chapter 2 (Anderson, 1981). In an environment without alternation, there is also no positive evidence for the existence of some constraint, and learners may draw a surface-true generalization that a constraint holds only in the environment where there is such positive evidence, that is in an alternating environment.

Now let us compare the behavior of velar fricatives in the context of front vowels:

(29) Sequences of a velar fricative and a front vowel

a. ∗xi ∗x+i (violation of ATR, and Pl Agr)

b. √xɨ √x+ɨ (violation of Place Agr)

c. ∗çɨ ∗ç+ɨ (violation of ATR Agr)

d. √çi ∗ç+i no violation

In contrast to plosives, the constraints on fricative sequences are less restrictive: AgrPl does not have to be satisfied (29b), only AgrATR is exceptionless (29a & c). It is proposed that a specific constraint on the place agreement in sequences with stops is higher-ranked than a general Place agreement:

(30) Agr Place([Open0]C, V) >> Agr Place (C, V)

Whereas fricatives last longer and give the speaker enough time for the modification of the position of the articulators in anticipation of the following sound, stops last shorter, and require a maximal displacement of the articulator, but still have to be articulated with the configuration of articulators which would not hinder the articulation of the consequent segment.

It is interesting in (30) that completely harmonic sequences fricative + front high vowel are not found at the morpheme boundary (case d.). The reason might be the following: In the context of the palatalizing front vowel, the velar consonant surfaces as [š]. With a non-palatalizing vowel, consonant+vowel sequence will surface as [x ɨ] with a regular default mapping of non-[Pal] as [−ATR]. Lack of ∗ç+i as in (30d) is a gap resulting from the limited number of underlying contrasts.

For sequences of velar fricatives with mid front vowels, an analogous picture emerges as in sequences with high vowels:

(31) Sequences of velar fricatives followed by front mid vowels
∗xe ∗x+e
√xɛ √x+ɛ [xɛ]mia 'chemistry', brzu[x+ɛ]m 'stomach', instr. sg.
∗çɛ ∗ç+ɛ
√çe ∗ç+e [çe]na 'hyena', [çe]ronim 'Hieronim', name, masc.

No further constraints need to be proposed for sequences with mid vowels.

It seems that a constraint referring to the level of opening of the consonant and of the vowel is in a way cumulative. If the opening is minimal for the consonant, and minimal for the vowel, Place agreement must be observed. If the opening is bigger than minimal either for consonant or for the vowel, Place agreement does not have to be obeyed, except in the morpheme boundary environment for plosives. Thus, I propose a cover constraint:

(32) AgrPl(CDor, V; Open<4)
For the sequence Dorsal consonant + vowel, a place agreement must hold if the sum of the grades of jaw opening for the consonant and the vowel is less than 4.

Concluding this section, we observe that ATR agreement holds without exception for the sequences with velar consonants as well. Velar stops need to obey additionally Agr Pl, however, this requirement holds only for high vowels and for mid vowels only across the morpheme boundary. It has been postulated that place agreement effects can be accounted for if we assume that

1. Agr Pl targeting specifically velars is higher-ranked than general Agr Pl,

2. Agr Pl targeting plosives is higher ranked than general AgrPl,

3. AgrPl targeting sequences with high vowels is higher ranked than the general constraint, (6)

4. AgrPl conjoined with Uniform is higher ranked than AgrPl.

Assumptions 2. and 3. refer clearly to the degree of jaw opening in the production of the sound sequence: those with less opening are more exposed to the restrictions on articulatory incompatibility, and the opening for the sequence should be treated cumulatively.

5.10 Velar Fronting

This section approaches the generalizations discussed in the previous section from a slightly different perspective. We will show that the generalizations proposed in the previous section cover another set of data from the literature, i. e. Velar Fronting (Rubach, 1984). Section 5.10.1 recapitulates the data, section 5.10.2 offers an analysis in terms of ATR and place agreement.

5.10.1 The Facts

It has been observed that when it comes to the concatenation of morphemes, the environment of velar plosives triggers fronting of the underlying non-palatalizing front high vowel, as in (33).

(33) Velar fronting

ma[k] 'poppy flower'	ma[c]+[i] pl.
	ochłap+[ɨ] 'rest-overs'
	skrót+[ɨ] 'short-cuts'
dro[g]+a 'way'	dro[ɟ]+[i] pl.
	grob+[ɨ] 'graves'
	płot+[ɨ] 'fences'
głębok+o 'deep', adv.	głębo[c]+[ix] 'deep', adj.
	grub+[ɨx] 'thick', gen. pl.
	smutn+[ɨx] 'sad', adj. gen. pl.
drug+a 'second', fem.	dru[ɟ]+[im] 'second', dat. pl.
	grub+[ɨm] 'thick', dat. pl.
	smutn+[ɨm] 'sad', nom. sg.

Fronting does not apply after velar fricative [x], which is in accordance with the generalization in (31). Consider the examples below:

(34) No Velar Fronting after [x]

mu[x]+a 'fly', nom. sg.	mu[x]+[ɨ] 'flies', nom. pl.
głu[x]+a 'deaf', adj. nom. sg. fem.	głu[x]+[ɨx] 'deaf', adj. gen. pl.
	głu[x]+[ɨm] 'deaf', adj. dat. pl.

The surface [i] is in suffixes in (33) and (34) underlyingly non-[Pal]. It does not trigger palatalization of coronals or labials. Per default, it should surface as [ɨ], like in the context of labials and coronals, as in (34).

5.10.2 The Analysis of Velar Fronting

The facts of Velar Fronting follow from the constraints proposed in the previous section, repeated here as (35)–(38):

(35) Agr ATR (C, V)
For consonant C and vowel V, C and the directly following V agree in value for [ATR].

(36) Agr Pl(Dor C, V)
Place specification of the vowel agrees with Place of the preceding velar consonant.

(37) AgrPlace ([Dor,Open0] C, V)
A velar stop shares the place specification with the following vowel.

(38) AgrPl(Dor C, V;Open<4)
A velar consonant+ vowel sequence has to obey Place agreement if

the sum of the degrees of the jaw opening for the vowel and for the consonant is less than 4.

If we evaluate the possible sequences of velar stops followed by high front vowels with respect to place and ATR agreement, it will turn out that the only sequence which does not violate the two constraints is [ci] (and, by the same token [ɟi]), that is, a sequence in which the consonant is secondarily palatalized and the vowel is [ATR].

The data of Velar Fronting may be explained by the interaction of 1. ATR and specific Place agreement, 2. the need to preserve the contrast between the underlying [Pal], and non-[Pal] vowels, see (39).

(39) Velar Fronting

k+ɨ	Agr ATR AgrPl(DorOpen<4)	Preserve ContrastPal]V	PAL ∨ Uniform
a. k ɨ	∗!		
b. k i	∗! ∗		
c. tš ɨ		∗!	
☞ d. c i			

Candidates (39a) and (39b) are eliminated by articulatory constraints on ATR agreement (35) and Place agreement (38). Candidate (39c) would be surface identical with the output of input /k+i/ sequence, which undergoes palatalization to [tš]. The optimal candidate is (39d).

On the other hand, Velar Fronting does not occur to the sequences with a fricative due to the lower ranking of the general Place Agreement:

(40) No Velar fronting after fricatives

x+ɨ	AgrATR AgrPl(DorOpen<4)	Preserve Contrast (Pal)V	Pal ∨ Uniform	∗C^j	AgrPl
☞ a. xɨ					∗
b. çɨ	∗!				
c. xi	∗!				∗
d. šɨ		∗!			
e. çi				∗!	

Candidate (40b) and (40c) violate inviolable AgrATR. (40d) is surface identical with the correspondents of the underlying sequence with the non-palatalizing vowel. (40e) violates the general ban against palatalized consonants. (40a) does not violate the particular place agreement constraint, because [x] is [Open1], and is this way the optimal output. Notice that low-ranked ∗C^j must be higher ranked than the AgrPl, otherwise we would expect that the winner be candidate (40e).

5.11 Surface Velar Palatalization

Yet another set of data can be accounted for without any additional assumptions. Consider the data of Surface Velar Palatalization (cf. Rubach (1984), Szpyra (1995)):

(41) Surface Velar Palatalization

ro[c]+em	'year', instr. sg.
dro[ɟ]+ego	'expensive', gen. sg. masc. & neut.
versus	
chło[p]+em	'peasant', instr. sg.
bu[t]+em	'shoe', instr. sg.
gru[b]+ego	'thick', gen. sg. masc. & neut.
twar[d]+ego	'hard', gen. sg. masc. & neut.

Surface Velar Palatalization (palatalizing velar consonants before surface [e]) was usually analyzed independently from the data of Velar Fronting. However, assuming constraints on ATR agreement and place agreement for sequences with velars, the facts of Velar Fronting are intrinsically connected to Surface Velar Palatalization.

For sequences with mid vowels, we can propose a parallel analysis to (39), cf. (42). /kɛ/ may surface morpheme internally:

(42) Articulatory agreement effects for mid vowels (without morpheme boundary)

kɛ	ATR Agr AgrPl(DorOpen<4)	Preserve Contrast(Pal)V	$*C^j$	PlAgr
☞ a. kɛ				*
b. cɛ	*!			
c. ke	*!	*		
d. ce			*!	

The requirements on place agreement across the morpheme boundary are higher than in the general case. AgrPl([Dor,Open0],V) disjoined with Uniform guarantees that the place agreement is also observed in sequences k+mid vowel, as in (43).

(43) Articulatory agreement effects for mid vowels (with morpheme boundary)

k+ɛ			AgrPl([Dor, Open0],V) ∨ Uniform	AgrATR AgrPl (DorOpen<4)	Preserve Contrast	PAL ∨ Uniform	$*C^j$	AgrPl
	a.	kɛ	∗!					∗
	b.	cɛ		∗!				
	c.	ke		∗!				
	d.	tšɛ			∗!			
☞	e.	ce					∗	

5.12 In Support of the Alternating Environment Solution

Rubach (1984, 176-177) notes that there is a "systematic relationship" between palatalized velars and underlying yers. Underlying yers, if they surface, trigger secondary palatalization (Surface Velar Palatalization) on the velar stops, as in (44):

(44) yer-zero alternation; yer triggers Surface Velar (quoted from Rubach (1984, 177))

[ɟez] 'gadfly'	[gz+ɨ] nom. pl.
szczy[ɟew] 'bird art'	szczy[gw]+a gen. sg.
szwa[ɟer] 'brother-in-law'	szwa[gr]+a gen. sg.
is[cer] 'spark', gen. pl.	is[kr]+a nom. sg.
cu[cer] 'sugar'	cu[kr]+u gen. sg.
cer[cev] 'orthodox church'	cer[kv]+i gen. sg.

Notice that we observed that for sequences of velar stops with front mid vowels, the Place Agreement with respect to velar stops holds at the morpheme boundary but usually it does not morpheme-internally, and to account for that we proposed a disjunction of AgrPl([Dor, Open0], V) and Uniform. In (44) the morpheme-internal sequences are treated like the sequences at the morpheme boundary. This is predicted by the definition of the alternating environment that I proposed in chapter 2. Throughout the paradigm, we observe alternations with respect to the sequences in question between the presence versus absence of a surface vowel. Consequently, the examples in (44) may be analyzed in the same way as sequences at the morpheme boundary:

(45) Articulatory agreement effects for morpheme internal yers

tsuk Cor r		AgrPl([Dor, Open0],V) ∨ Uniform AgrATR AgrPl (DorOpen<4)	Preserve Contrast (Pal)]V	PAL ∨ Uniform	$*C^j$	AgrPl
	a. kɛ	*!				*
	b. cɛ	*!				
	c. ke	*!				
	d. tšɛ		*!			
☞	e. ce				*	

Since it is an Alternating Environment, the prediction is that surface agreement in place will have to be obeyed as in the case of the morpheme boundary context. The prediction is borne out.

Notice that in the discussed case, the solution to the Derived Environment problem offered by Łubowicz (1998) makes wrong predictions. Łubowicz argues that palatalization occurs on the consonant c_1, if this consonant c_1 is stem final but not syllable final, which is formally expressed by a disjunction, repeated here as (46).

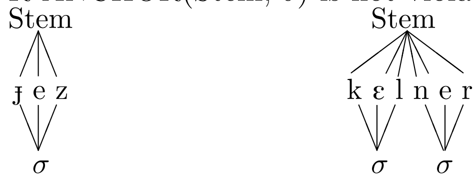
(46) R-ANCHOR(Stem; δ)
The rightmost segment of a stem in the input has a correspondent at the right edge of a syllable in the output.

(47) Pal (not defined by Łubowicz (1998))
Denotes adjoining of the feature Coronal to the preceding consonant.

(48) R-ANCHOR(Stem; δ) & Pal (not defined in Łubowicz (1998))
Understood as “palatalize when R-ANCHOR(Stem; δ) is violated.”

In a similar way, if Place Agreement holds for velar stops in conjunction with R-Anchor(Stem, δ), then the prediction would be that yer-vowel may not trigger Place Agreement. In [ɟez] giez ‘gadfly’, the harmonic consonant is not stem-final and not syllable-final, thus, the proposed R-ANCHOR(Stem; δ) is not violated. Consequently, Local Conjunction (an inclusive disjunction in our terms) should not induce Place Agreement, exactly like in the word [kɛlner] which contains morpheme-internally a “normal” mid vowel, and where the environment is uniform:

(49) R-ANCHOR(Stem; δ) is not violated



The predictions of Łubowicz's proposal are not borne out in this case.

5.13 Summary of Constraint Ranking

In the discussion of ATR agreement effects, we came up with a number of detailed constraint rankings. It has been postulated that place agreement referring to C-V sequences containing a velar consonant will be higher ranked than those referring to coronal consonants, and these in turn would be higher-ranked than those with respect to labial consonants, cf. (50). These effects would be caused by the relative independence of the places of articulation in question.

(50) AgrPl(C:Vel) >> PlAgr (C:Cor) >> PlAgr (C:Lab)

Further, place agreement constraints may be ranked depending on the degree of opening in the vowel: the less open the vowel, the less time is available for the articulatory adjustments and the more the articulation has to be "harmonic" in advance, thus:

(51) AgrPl (V:Open3) >> AgrPl (V:Open4) >> AgrPl(V:Open5)

The same kind of reasoning is valid for consonants: the more radical the closure, the more important it is to 'harmonize' the articulation in advance and allow for place agreement, thus (52) has been postulated:

(52) AgrPl (C:Open0) >> AgrPl (C:Open1)

In Polish, it seems that it is rather that the particular articulatory constraints referring to the degree of jaw opening may accumulate the effects and a constraint has been proposed AgrPl(C Dor,V;Open<4), where 4 is the sum of the levels of jaw opening in the vowel and in the preceding consonant.

We observed also that AgrPl(C: Vel, Open0) is effective only in the alternating environment, thus, it is disjoined with Uniform.

(53) AgrPl(C: Vel, Open0) $\vee$ Uniform >> AgrPl(C: Vel, Open0)

The ranking of the constraints emerging from our discussion in this chapter is following:

(54) Ranking of constraints in Polish
AgrATR, AgrPl(C: Vel, Open0) ∨ Uniform, AgrPl(C Dor, V;Open¡4)
>>
>> PreserveContrast(Cor-Vel), PreserveContrast(Pal,V)
>> PAL ∨ Uniform >>
>> $*C^j$ >>
>> PlAgr(C: Vel)

5.14 Summary of ATR Analysis

With the assumption that prepalatals are [+ATR], like surface high front vowel [i], a new account of the retraction of front vowel [i] to front vowel [ɨ] in the context of post-alveolars may be offered. In short, the consonant resulting from palatalization of velars surfaces as [−ATR], and the vowel has to be compatible in this respect: the output must in any case fulfill the requirement according to which the vowel and the preceding consonant agree in terms of the position of the tongue root. The ATR analysis, drawing on the relation between the position of the tongue root and secondary palatalization, is supported by, first, studies of phonetic properties of the Polish sounds, second, cross-linguistic phonetic observations, third, cross-linguistic phonological data, and, fourth, a number of other effects in Polish phonology.

As to the other data in Polish phonology, for instance co-occurrence constraints on sequences of consonants followed by front vowels have been discussed. The proposal is that in Polish an agreement in terms of the tongue root position holds without exception for sequences with front vowels. Sequences with back vowels are not discussed. Non-occurrence of some sequences satisfying ATR agreement results from two sources. The first source is the lack of the underlying contrast and the tendency to simplify the pronunciation on the surface. The second source of non-occurrence of certain specific sequences with velar consonants goes back to the violation of the agreement in terms of place of articulation. We observed that place agreement does not hold in absolute terms, but rather specific place agreement constraints referring to specific classes of sounds, or a specific environment, are higher-ranked. The higher ranking of these specific constraints in comparison to the general constraints is motivated articulatorily or psychologically. For instance, it is more important to fulfill the requirement of place agreement for the sequences with accumulative smaller jaw opening.

It has been demonstrated that a number of processes discussed in literature, and attributed to various independent formal devices, i. e. Secondary Palatalization, Velar Fronting, Surface Velar Palatalization, e-tensing, and

Retraction, result from the general co-occurrence constraints discussed in sections 5.8 and 5.9. In this chapter, we have accounted for the above mentioned processes in terms of the requirement for the ATR harmony and the tendency towards place agreement.

Finally, the discussion of the co-occurrence constraints on sequences with velar stops offered us an argument for the description of the Derived Environment in terms of paradigm alternation rather than using the solution offered by Łubowicz (1998) in terms of stem-syllable edge alignment. It has been demonstrated that a constraint on place agreement holds in the words containing a yer, as predicted by the Alternating Environment solution, proposed in chapter 2, and not as predicted by the Alignment solution of Łubowicz (1998).

Chapter 6

SUMMARY AND CONCLUSIONS

The present dissertation is a study of palatalization from a new perspective, regarding palatalization as driven by a set of articulatory and auditory factors. A functional approach has been adopted with its basic claims that the shape of a language is determined by two tendencies: first, to minimize the effort of the speaker, that is, to simplify the articulation, and second, to minimize the effort of the listener, i. e. to maximize the distinctiveness of the units of language, cf. Passy (1891); Martinet (1955), Lindblom (1986), Flemming (1995), Boersma (1998). From this perspective, the presence of palatalization has more advantages from the point of view of the users of the language than its absence. The attempt was to identify different articulatory and auditory factors in palatalization processes within the system of one language, that is, Polish, and to offer an explanatory account of the processes in Polish. The other goal was to offer adequate formal means for such an analysis.

Great care has been taken to offer a holistic picture: the analysis covers all palatalization processes in Polish that cannot be claimed to be fully of morphological nature, the data is not out of context, and the proposed feature specifications have their justification in phonetic studies.

The goal of chapter 1 was to generally motivate the reference to perception in the phonological analysis and in the analysis of palatalization in particular. We reviewed previous approaches to Polish palatalization data, focusing explicitly on the questions that are left unanswered. A hypothesis has been put forward that these questions may find a solution if we assume that perceptual factors may play a role in palatalization. A number of phonetic studies have been quoted to indicate that it might be indeed so, and a number of phonological issues from various areas of phonology have been listed to support the view that perception plays a role in phonology in general.

In chapter 2, I attempt to develop a model of the interaction of articulatory and auditory factors in phonology, to provide means for the analysis of

Polish. The constraints and (especially perceptual) features applied in the further analysis are defined. In this chapter, another important issue is discussed, namely that of the Derived Environment. In Optimality Theory the old definition of the Derived Environment could not be directly taken over, as it refers to the notion of derivation, which is absent from the classical main-stream OT. To express the fact that the application of certain phonological rules is restricted to the environment of a morphological boundary or has to co-occur with another process, some solutions have been proposed in the literature. One solution, in terms of a particular faithfulness constraint referring to stems ranked higher than the general faithfulness (cf. McCarthy and Prince (1995), Kager (1999), Pater (1999)), cannot be applied to Polish data because the distinction is made between the stem consonants and suffix consonants, and not between the stem-internal and stem-final consonants, as in Polish examples. The other OT-solution proposed in the literature defines the morpheme boundary environment in terms of local conjunction of a constraint inducing palatalization with an alignment constraint requiring that the right edge of the stem corresponds to the right edge of the syllable (Łubowicz, 1998). In chapter 2, I propose yet another approach, referring to the relationships between surface representations exclusively, and without the mention of the underlying representation, in terms of paradigmatically Alternating versus Uniform Environment. It is argued that the environment for the application of palatalization in Polish is the paradigmatically Alternating Environment, that is, alternating among surface forms within the whole paradigm. This approach is more functional in the sense that it seeks explanation in external factors, namely in general learning strategies. The proposed solution is devoid of the problems connected with previous accounts, and, as shown in chapter 5, covers also the set of data which – adopting Łubowicz's solution – would have to be analyzed independently.

Chapter 3 gives the factual background for the further discussion: Polish alternations referred to as palatalization are listed. The phonetics of Polish sounds involved in palatalization processes is discussed from the articulatory perspective, based on the earlier research of Koneczna and Zawadowski, Wierzchowska, Biedrzycki, and others, as well as from the acoustic perspective. The acoustic part is based partly on earlier studies, partly on the results of my own measurements carried out with the help of Praat, version 3.9.36, written by and used with the permission of the author, Paul Boersma. On the basis of the phonetic description, I argue for the particular underlying inventory of sounds of Polish, and specify the featural make-up of sounds of Polish. In particular, the phonetic measurements serve the purpose of justifying the specification of segments with respect to perceptual features, which for Polish have never been discussed before. Also, some claims about the articulatory specifications are made which are contrary to earlier assumptions as e. g. in Rubach (1984). For instance, it is argued that the Polish vowel transcribed usually as [ɨ] is front (Coronal[non-anterior]) – in accordance with the phonetic description and against the earlier assumption that it is back. In the articulatory description of Polish sounds, special attention has been drawn to a criterion so far completely disregarded, namely, the position of the tongue root. The specification of sounds with respect to the tongue root position allows later for, first, distinguishing two groups of palatalization processes (one involving perceptual factors, and the other primarily involving ATR feature) which so far have always been treated together, and second, finding a common analysis for several so far unrelated processes in terms of ATR-agreement, as argued in chapter 5.

In the present study we see all effects of palatalization as resulting from two major processes. In chapter 4, palatalization resulting from the prolongation of perceptual feature [Pal] is discussed. This group of palatalization processes occurs at the morpheme boundary, and in the context of the same morphemes irrespective of the place of articulation of the target. In this group of palatalization processes (traditional: Coronal Palatalization, 1st Velar Palatalization and Labial Palatalization) drastic changes in the place of articulation for coronals and velars, or, in the standard Polish, [j] insertion after labials occur. The claim is that the clue of the process is the spreading of the perceptual feature [Pal], which has the positive effect of making the distinction in palatality more salient. The distinction in palatality may be enhanced both by an insertion of friction (as in Coronal and Velar Palatalization), but also by an insertion of the palatal glide [j] after labials. The lack of palatalization of labials in certain contexts is, according to the proposed analysis, due to constraints referring to perceptibility of cues for palatalization. Thus, there is neither [j] insertion nor secondary palatalization of labials before a pause or before another consonant, because [j] cannot be inserted (due to SSG), and otherwise palatalization cues would not be sufficiently salient. Also, [j] insertion occurs only before [e] but not before [i], because [j] before [i] is not sufficiently distinctive, and hence, does not serve the purpose of enhancing the palatalization contrast on the consonant.

The process is constrained in several ways by different articulatory and auditory factors, which might be summarized as follows:

1. The output of palatalization has to be faithful with respect to its perceptual features to the input representation.

2. The perceptual changes may not violate articulatory constraints (here: perceptual palatalization has to observe ATR agreement).

3. The underlying contrasts must be preserved on the surface. This factor prohibits merging of effects of palatalization of labials, coronals and velars in Polish.

The other group of processes, including surface secondary palatalization of consonants and the modification of vowels following the palatalized sounds, is discussed in chapter 5. In these palatalization processes, a slight modification of the underlying articulation is involved. Most of the time, the modification is also insignificant perceptually (not sufficiently salient). The articulatory effects may be attributed to the articulatory requirements of [ATR] agreement and – in the case of velar consonants – by the agreement in terms of the place of articulation in addition. Due to the division of palatalization into two groups (perceptually driven palatalization, and primarily ATR-driven palatalization) a number of previously unrelated processes find an explanation in terms of general co-occurrence constraints resulting from constraints inducing ATR harmony.

Whereas ATR agreement is argued to hold absolutely, the active effect of the constraint on place agreement is limited to velar plosives and alternating environment. It is argued that specific place agreement constraints targeting sequences with a smaller degree of jaw opening are higher ranked than the general place agreement constraint, which produces a network of effects described and analyzed in chapter 5. The ranking of more specific constraints in relation to more general constraints is externally motivated by the relative difficulty of articulation and the relative salience of a perceived speech string.

When comparing the offered analysis with previous approaches, one issue is that none of the previous accounts referred to perceptual factors, and thus, I claim, could not be fully explanatory. Previous approaches could not explain which articulatory assimilations are possible and which are not. In our analysis, this is determined by perceptual similarity between the output and the input. Previous accounts made reference to affrication in a vague and informal way, if at all. In the analysis presented in this study, affrication is a means of enhancing the palatality distinctiveness. Further, it is not clear in previous accounts why there should be three different sets of outputs, distinct for labials, coronals, and velars in the context of one type of front vowels. If only articulatory factors were involved, one would expect that the optimal output should always be maximally similar to the trigger. In the present study this question is answered in terms of contrast preservation: the underlying contrast between coronals, labials, and velars must be somehow rendered on the surface. Finally, earlier accounts do not explain why and when prepalatals and post-alveolars may emerge. In this dissertation, an answer is offered by referring to the concept of optimal surface contrast.

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