CONTRAST PRESERVATION IN PHONOLOGICAL MAPPINGS

A Dissertation Presented

by

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ABSTRACT

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The present study investigates how information about contrasts is employed in the grammar. It is proposed that contrast preservation exists as an independent principle, which, within the framework of Optimality Theory (Prince and Smolensky 1993), is formalized as a family of rankable and violable constraints on preserving contrasts. Those constraints interact with one another and with conflicting markedness constraints resulting in preservation or neutralization of underlying distinctions in surface forms (cf. Trubetzkoy 1971, Martinet 1967, Kiparsky 1973).

This work contributes to the growing body of research on the status of contrast in phonology (cf. Flemming 1995, Padgett 1997, 2000). In standard OT (Prince and Smolensky 1993) and derivational approaches to phonology (Chomsky and Halle 1968), contrast preservation follows from other components of the grammar and is not stated as an independent principle. By re-examining the role of contrast, this study makes a significant contribution to our understanding of a phonological system and the nature of a phonological mapping (cf. Kaye 1974, 1975, Kisseberth 1976).

The proposal to treat contrast preservation as an independent principle has far-reaching consequences: (i) it provides new insights into possible interactions between phonological mappings, and in so doing gives a more accurate typology of chain shifts

(see chapter 4); (ii) it provides a uniform analysis of opaque and transparent phonological processes (chapters 2, 3 and 5); (iii) it eliminates the need for constraint conjunctions and other mechanisms needed to account for opacity (chapter 4); and finally, (iv) it sheds new light on the role of faithfulness and markedness in the grammar (chapter 1).

This dissertation is organized as follows. Chapter 1 presents the proposal. Chapter 2 examines typological implications of the proposal. Chapter 3 provides empirical support based on the example of Finnish chain shifts. Chapter 4 examines the predictions of the proposal and compares them to previous approaches. Finally, chapter 5 applies the proposal to the study of stress-epenthesis interaction in dialects of Arabic.

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I then spent a year at Rutgers where I worked with Alan Prince. Alan's insight, enthusiasm and unwavering search for the unknown taught me much. Thanks also to Roger Schwarzschild for a great semantics class!

I then ventured to UMass, where John McCarthy has been my advisor throughout most of my graduate career. John is very generous in sharing his time with students. I learned a lot from him, both how to conduct research and how to teach. I am very grateful for that. I would also like to thank Barbara Partee for showing me that there is a great deal of joy and satisfaction in doing linguistics and that one should never be afraid to ask questions and explore. Similarly, I would like to thank Angelika Kratzer and Hagit Borer for giving me a solid foundation and an appreciation for precision. I would also like to thank Joe Pater for good phonology talks.

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PROLOGUE

Opacity (Kiparsky 1968, 1973) occurs when an otherwise regular phonological process fails to apply in some forms of the language (counter-feeding opacity) or a phonological process applies unexpectedly (counter-bleeding opacity). Recent approaches to opacity include Goldrick and Smolensky (1999), Inkelas (1999), Kiparsky (2000ab), Kirchner (1996), Łubowicz (2001), McCarthy (1999). This dissertation argues that counter-feeding opacity can be understood in terms of a theory of contrast (cf. Kisseberth 1976, Kaye 1974, 1975). The main observation is that in chain shifts and other opaque mappings, a given underlying contrast is preserved on the surface but manifested as a different surface contrast, called contrast transformation. To account for contrast transformation, this dissertation proposes a modification of Optimality Theory (Prince and Smolensky 1993), called **Contrast Preservation Theory**.

Contrast Preservation Theory, like any theory of contrast, must assume that candidates are sets of mappings, called scenarios. Scenarios are evaluated by a family of constraints on preserving contrasts, PC(P) constraints, interacting with each other and with conflicting markedness constraints. This results in preservation or neutralization of underlying oppositions in surface forms. Languages differ in constraint interaction and thus differ in the interplay of contrasts. The predictions of this proposal regarding phonological mappings will be explored and argued to be superior to previous approaches in several respects.

CHAPTER 1

CHAIN SHIFTS AS CONTRAST TRANSFORMATION

1.1 Statement of the Problem

This dissertation provides an account of chain shift mappings in terms of preserving contrasts (cf. Kirchner 1996, Kisseberth 1976). In a phonological chain shift underlying /A/ maps onto surface [B] and underlying /B/ maps onto surface [C]. Thus, there is a chain shift effect of the form A→B→C. Finnish vowel shift (Anttila 1995, Harrikari 1999, 2000, Lehtinen 1967, McCawley 1964) provides an example.

In Finnish, before the plural suffix -i (similarly before the past tense marker -i), long low vowels shorten (/aa/→[a]), short low vowels undergo rounding (and raising) (/a/→[o]), and short round vowels surface unchanged (/o/→[o]). Thus, we have the following chain shift effect:

(1) Finnish chain shift

aa → a → o ↻

Some examples are given in (2).

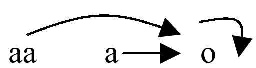
(2)

	singular nominative		plural essive
/aa/→[a]	katt**aa**	'roof'	katt**a**-i-na
	m**aa**	'earth'	m**a**-i-na
/a/→[o]	kiss**a**	'cat'	kiss**o**-i-na
	vap**a**	'fishing rod'	vap**o**-i-na
/o/→[o]	tal**o**	'house'	tal**o**-i-na
	pelk**o**	'fear'	pelk**o**-i-na

The key issue is that in Finnish forms with underlying long low vowels shorten but do not round (/aa/→[a],*[o]), but forms with underlying short low vowels undergo rounding in the same context (/a/→[o]).

Chain shifts present a challenge to Optimality Theory in its original form. OT is *output-oriented*: phonological processes like /aai/→[ai] and /ai/→[oi] bring output forms into conformity with high-ranking markedness constraints. The existence of these processes in Finnish indicates that two markedness constraints, informally *aai and *ai, dominate antagonistic faithfulness constraints. But with both markedness constraints high-ranked, we expect underlying /aai/ to go all the way to [oi], thereby satisfying both markedness constraints. The expected but incorrect mapping is illustrated in (3).

(3) Expected mapping (cf. (1))



Even though chain shifts are problematic for classic Optimality Theory, they are part of a synchronic mechanism of the grammar and we need to be able to account for them formally. Some examples of vowel height chain shifts come from Bassá (Bantu; Schmidt 1996), Gbanu (Niger-Congo; Bradshaw 1996), Kikuria (Bantu; Chacha and Odden 1994), Lena Spanish (Hualde 1989), Nzɛbi (Clements 1991), Servigliano Italian (Kaze 1991). These are mostly raising mappings (Parkinson 1996). Some examples of consonantal chain shifts come from Southern Paiute (Sapir 1930, McLaughlin 1984), Toba Batak (Hayes 1986), Estonian (Ultan 1970), Finnish (Ultan 1970), Irish (Ní Chiosá in 1991). These are mostly lenition mappings on either voicing or consonantal stricture scale (Gnanadesikan 1997). See (4) and (5), respectively.

(4) Vowel shifts (Clements 1991, Labov 1994)
a. New Zealand (Labov 1994): æ → e → i → ɨ
b. Nzɛbi (Bantu: Clements 1991): a → ɛ → e → i , ɔ → o → u

(5) Consonantal shifts (Ultan 1970)
a. Southern Paiute (Uto-Aztecan, Sapir 1930): pp → p → v
b. Toba Batak (Austronesian, Hayes 1986): np → pp → ʔp

According to Gnanadesikan (1997) and Kirchner (1996), the solution to chain shift mappings in OT lies in an enriched theory of faithfulness. Both researchers propose special types of faithfulness constraints that block two-step movements like /aai/→[oi], thereby accounting for the discrepancy in phonological mappings between identical derived and underlying segments. Kirchner uses locally-conjoined faithfulness constraints, whereas Gnanadesikan distinguishes between classical IDENT-type constraints and novel IDENT-ADJACENT-type constraints on some scale of similarity.[1]

In this dissertation, I will explore an alternative explanation for chain shifts that has implications going well beyond this phenomenon. The explanation starts from the observation that chain shifts always preserve one underlying contrast at the expense of neutralizing another underlying contrast. In Finnish, the contrast between underlying /aai/ and /ai/, originally one of length, is preserved, albeit in a different form – as a rounding contrast (underlying /aai/ vs. /ai/ surface [ai] vs. [oi]). The contrast between underlying /ai/ and /oi/, the original rounding contrast, is lost (both become [oi]). Thus:

(6)

Input		Output
length contrast	→	rounding contrast
rounding contrast	→	neutralized

[1] For a discussion of Gnanadesikan's and Kirchner's proposals see chapter 4.

Preservation of one contrast taking precedence over preservation of another contrast will be referred to as *contrast transformation*.

There are numerous examples of contrast transformation across languages. Some are given in (7). These are various ways of preserving the obstruent voicing contrast that cannot be realized as such. The examples are from Polish, Friulian, spoken in northern Italy, and dialects of American English.

(7) Preservation of the obstruent voicing contrast

a. Interaction of final devoicing and vowel raising in Polish (Gussmann 1980)

/ko**z**/ vs. /ko**s**/	→	[k**u**s] vs. [k**o**s] 'goats' vs. 'scythes' (gen.)	*by vowel height*

b. Interaction of final devoicing and vowel lengthening in Friulian (Repetti 1994)

/la**d**/ vs. /la**t**/	→	[l**a:**t] vs. [l**a**t] 'gone' (m.) vs. 'milk'	*by vowel length*

c. Interaction of intervocalic voicing and vowel lengthening in Am. English

/ray**d**er/ vs. /ray**t**er/	→	[r**a:**yDer] vs. [r**ay**Der] 'rider' vs. 'writer'	*by vowel length*

In Polish, see (7a), the underlying obstruent voicing contrast in word-final position is preserved on the surface despite final devoicing and manifested as vowel height contrast. The vowel is high before underlyingly voiced obstruents and mid before their voiceless counterparts. In Friulian, see (7b), the obstruent voicing contrast is manifested as surface contrast in vowel length. In American English (7c), instead of final devoicing there is a process of intervocalic flapping. The obstruent voicing contrast is preserved despite intervocalic flapping and represented by vowel length.

Contrast transformation is common cross-linguistically. The main question in this work is where contrast preservation fits into the grammar, whether it follows from other components of the grammar or exists as a primitive. In generative phonology, contrast preservation is an epiphenomenon of rule application. Whether contrasts are preserved or neutralized follows from what rules there are and how they apply in a given language. In standard Optimality Theory (OT), contrast preservation is also a derivative. It follows from the interaction of markedness and faithfulness constraints that do not themselves refer to contrast. The proposal here is different from both generative phonology and standard Optimality Theory. It is proposed that contrast preservation exists as an independent principle in the grammar, which in the framework of Optimality Theory is formulated as a family of rankable and violable constraints on preserving contrasts. I will refer to this proposal as *Contrast Preservation Theory* (PC theory).

The next section (section 1.2) presents the elements of the proposal. Section 1.3 illustrates the proposal with a simple case of neutralization and the lack of it. Subsequent sections (sections 1.4-1.5) show how the proposal can be applied to analyze Finnish and other chain shifts.

1.2 PC Theory

To account for phonological mappings that involve contrast transformation like chain shifts, I will propose a modification of Optimality Theory (Prince and Smolensky 1993), called *Contrast Preservation Theory* (PC theory). In PC theory contrast preservation is not just a phenomenon but a formal property of the grammar (cf. Flemming 1995, 1996, Padgett 1997, 2000). It is formalized as competing constraints on preserving contrasts.

PC theory also contributes to our understanding of opacity (Kiparsky 1973, 1985, 1993; Kisseberth 1976; McCarthy 1999; Rubach 1984). Opaque processes, of which chain shifts are an example, are problematic for standard OT. In standard OT a process applies when markedness outranks conflicting faithfulness and is blocked with the opposite ranking. This is true for transparent processes. But opaque alternations do not comply with those rankings. Opaque processes apply even though markedness is low-ranked and are blocked despite high-ranked markedness. Standard OT finds those problematic. PC provides an explanation.

A central finding of PC theory is that opaque phonological alternations trade one distinctive opposition for another, preserving contrast but in a different way than in the underlying form. Based on this observation, PC theory proposes that opaque processes can be explained by a high-ranking requirement on preserving contrast.

PC makes a novel prediction as to what can force or block a phonological process. In PC phonological mappings are evaluated together, and thus one mapping can force or block another mapping in the same system for reasons of contrast. This prediction is different from other approaches to phonology, where mappings are evaluated in isolation.[2] In the previous approaches, mappings cannot directly activate or block one another. I will argue that the predictions of PC theory are superior to previous approaches and I will illustrate them using the example of the Finnish chain shift.

By formulating contrast preservation as an imperative in a phonological system, PC theory provides an explanation for opaque processes (e.g., chain shifts) and explains transparent and opaque phonological processes in a uniform manner with no additional

[2] In previous approaches, there are ways to encode morphological relatedness between forms such that forms can influence one another. In standard OT, relatedness between forms is encoded in the form of faithfulness constraints on Output-Output correspondence (Benua 1997, Burzio 1998), Base-Reduplicant Identity (McCarthy & Prince 1995), Paradigm Uniformity (Kenstowicz 1996, Steriade 2000) or morphological Anti-faithfulness (Alderete 1999, Horwood 2001). In derivational OT, relatedness between forms is encoded in underlying representations and by means of rule ordering. Yet in none of the approaches is mapping interaction stated explicitly, as it is in PC theory.

mechanisms required. This is different from previous OT approaches to chain shifts (see chapter 4).

The next section (1.2.1) shows how to form a candidate in PC theory, and the following section (1.2.2) describes the constraints.

1.2.1 A Scenario

The central claim of PC theory is that there exist anti-neutralization PRESERVE CONTRAST constraints. Constraints on contrast preservation can only be formalized under the assumption that no /input/→[output] mapping takes place in isolation; all such mappings are part of a system (cf. Flemming 1995, Padgett 1997). Formally, in the OT framework this must mean that candidates are sets of mappings, which I will call *scenarios*. The main idea is that mappings influence one another. A mapping can block or force another mapping in a system. The claim is that chain shifts can be understood as part of a system of mappings (a scenario).

1.2.1.1 The Logic

A scenario represents interaction between mappings. Let us first look at a scenario in Finnish. In Finnish, the logic behind a scenario is as follows. Underlying /aa/ undergoes shortening before –i and maps onto [a]. This forces underlying /a/ in the same context to move away - it undergoes rounding and maps onto [o]. By rounding, the low vowels distinct in length, /aa/ and /a/, do not neutralize on the surface. They map onto distinct outputs. This has consequences for the system of mappings. The length merger is avoided, but there is another merger that takes place as a consequence. Due to rounding, there is a merger between underlying /a/ and /o/. They both map onto [o].[3]

[3] It is important that the mappings all take place in the same context.

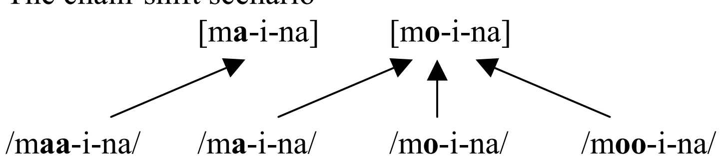
There is another mapping in Finnish that also maps onto [o] and thus is part of the interacting mappings. This is the mapping for underlying /oo/. In Finnish, underlying /oo/ before /i/ shortens with no change in height (/oo/→[o]) and thus merges with the short vowels /a/ and /o/. Some examples of the mapping for underlying /oo/ are given below.

(8) Shortening of /oo/

eht**oo**	'evening'	eht**o**-i-na
tien**oo**	'area'	tien**o**-i-na

Altogether, the four mappings constitute part of the chain-shift scenario in Finnish: /aai/→[ai], /ai/→[oi], /oi/→[oi], and /ooi/→[oi]. This is shown below.

(9) The chain-shift scenario



The actual chain-shift scenario competes with other scenarios in the same candidate set. In PC theory, each scenario is a candidate, and rankable constraints determine which scenario is optimal. Some examples of scenarios in a candidate set are given below. Scenarios represent languages with various mapping coexistence patterns.

(10) Some scenarios in a candidate set

A. Identity scenario (Identity map)	B. Transparent scenario (Shortening)	C. Chain-shift scenario (Shortening & rounding)
[aai] [ai] [ooi] [oi] ↑ ↑ ↑ ↑ /aai/ /ai/ /ooi/ /oi/	[ai] [oi] /aai/ /ai/ /ooi/ /oi/	[ai] [oi] /aai/ /ai/ /ooi/ /oi/

In the identity scenario, each input maps onto an identical output. In the transparent scenario, there is shortening but no rounding. In the actual scenario, there is both shortening and rounding, but rounding targets only underlying short vowels. (In (10), I show interacting processes only. As will be explained below, each scenario contains a whole space of mappings.)

1.2.1.2 Formalization

In rest of this section I describe how to formally determine the set of inputs and outputs of a scenario.

The Input. "Scenario-inputs" are returned by the function (the operator) *Gen* (cf. Prince and Smolensky 1993). The construction of scenario inputs is analogous to the role of *Gen* in correspondence theory (McCarthy & Prince 1995). Formally, for a given underlying form Gen returns "scenario-inputs." Those are the inputs of each scenario in a candidate set. This is defined below.

(11) The role of Gen in PC
Gen (underlying form_i) $\rightarrow$ scenario-inputs_i

Gen takes an underlying form as its argument and returns a set of inputs as its value. The set of inputs returned by Gen (scenario-inputs) contains forms (string of segments) that can potentially interact. For an underlying form of length n, scenario-inputs contain all strings of length 0…2n+1. I will now discuss the function Gen in more detail.

The input to Gen is a string of segments (a word) and the outputs are strings that are different from the input in P (phonological) properties. The P properties are distinctive phonological properties, such as *voicing, place, manner, length* etc. Let us put aside length differences for the moment and consider distinctive features other than segmental deletion and insertion. With that in mind, the set of scenario-inputs returned by

Gen for a given underlying form contains strings that consist of any sounds (bundles of P properties) and sound combinations that are logically possible.

(12) The role of Gen
Gen (underlying form$_i$) $\rightarrow$ $\forall$P(honological) properties, $\forall$linear combinations of P, $\exists$y such that y$\in$scenario-inputs$_i$

For example, the set of scenario-inputs for a three-segment underlying form *bad* contains *bad, bat, pat, ugh, k̥lo* etc. This is illustrated below:

(13) Inputs by feature changes
Gen (bad) $\rightarrow$ {bad, bat, pat, ugh, k̥lo etc.}

In addition to featural differences, the input set also contains forms that differ from the underlying form in the number of segments. Those are forms that contain fewer segments than the underlying form (by deletion), including a null set, and forms that contain more segments (by epenthesis). Some examples for *bad* are *ba, a, bada* etc.

(14) Inputs by deletion and insertion
Gen (bad) $\rightarrow$ {ba, a, bada etc.}

The way in which scenarios are evaluated, as will be discussed in the next section, demands that scenarios be finite. Therefore, epenthesis needs to be limited to only a certain number of segments. If epenthesis were not bounded, the input set would be infinite since we can add segments ad infinitum. To prevent unbounded insertion of segments, I must assume that there is a limit on the number of segments that can be added to the underlying form. There can be only as many segments added to the underlying form as there are segments in it plus 1. Formally, epenthesis takes place such that there is only one spot adjacent to each segment in a string of segments available for an epenthetic filler.

(15) No unbounded epenthesis
Gen (bad) → _b_a_d_, where _ represents possible sites of epenthesis.

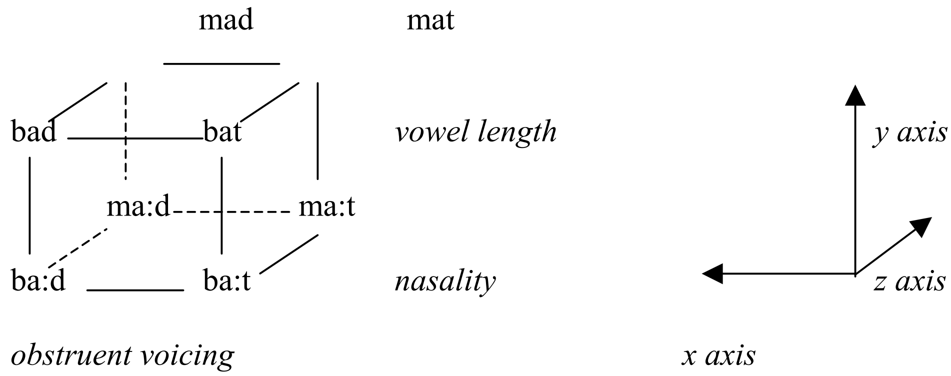
In addition to forms with featural changes (see (13)) and deletion or insertion of segments (see (14)), there are forms where Gen changes more than one P property in one and the same form. For example, it combines a change in a P property, such as place or manner, with deletion or insertion of segments. Thus, altogether, the set of scenario-inputs returned by Gen for a three-segment underlying form *bad* contains, among other, forms *ba, a, ugh, ug* etc.

(16) Altogether
Gen (bad) → {ba, a, bada, ugh, ug, pata etc}

As a final comment on Gen, I would like to point out that Gen is a universal function, the same for all underlying forms, but scenario-inputs generated by Gen are not universal. The same scenario-inputs are generated for all underlying forms of a given length, length n, but different for underlying forms of different length. Given an underlying form of length, n, scenario-inputs generated by Gen are any strings 0…2n+1. The idea is that Gen generates all inputs that could possibly interact. Thus, the same scenario-inputs will be generated for *bad* as for *pat* or *ugh*. This set is different from the one for *pata*, a four-segment underlying form, though there is an overlap between the two scenario-inputs due to deletion and insertion of segments.

It is helpful to think of inputs as distributed in a multi-dimensional space. Inputs generated by Gen form a network, the dimensions of which are determined by the P properties. Here is a subset of the input network defined by three distinct P properties: (i) obstruent voicing in word-final position (x axis), (ii) vowel length (y axis), and (iii) nasality in word-initial position (z axis).

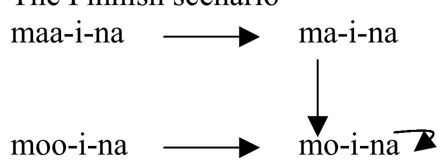
(17) The input network



The various P properties define the space of inputs in a scenario. Since a scenario contains a set of input-output mappings, it is also necessary to define what outputs are included in the scenario.

The Output. I propose that a scenario is a mapping of the input set into itself. Thus, outputs in a scenario are a subset (possibly improper) of the input. There is nothing in the output of a scenario that is not also in the input. This limits the space of mappings that is evaluated. We do not go outside the set of forms that constitute scenario-inputs. Consider part of the Finnish scenario that consists of inputs minimally distinct in vowel length and vowel rounding. In the diagram below, arrows indicate input-output mappings. As shown here, outputs are drawn from the set of inputs.

(18) The Finnish scenario



Scenarios represent alternatives that compete for the status of the optimal scenario. Let us look at what scenarios compete with one another (what scenarios there are in a candidate set).

Scenarios as Candidates. Scenarios in a candidate set represent all mappings of the input set into itself. Thus, scenarios in a candidate set have the same inputs but differ in the set of outputs and/or input-output relations even if outputs are the same. As shown in (10), the identity scenario has a different set of outputs from the transparent and actual scenarios. The transparent and actual scenarios have the same outputs but differ on the input-output relations. Thus, there are two ways in which scenarios in a candidate set differ from each other: the set of outputs and/or input-output mappings.

The Size. Since each scenario represents one of the ways of mapping all the inputs contrasting in some feature(s) onto some output subset, the size of a scenario is determined by the input. Scenarios in a candidate set are of the same size. They contain the same number of inputs and thus the same number of input-output mappings. Since there is a finite number of oppositions and there is a limit on the length of words in a scenario, a scenario is finite. This is a crucial point, if contrast is to be evaluated.

A final note on scenario-inputs: The input set, as defined above, is finite since forms contrast with one another on some finite number of dimensions and insertion is bounded, but it is a big set. However, not all dimensions of contrast are equally informative. Some of the contrasts are always preserved. Similarly, some input pairs represent contrasts that are always lost (the latter type are inputs supplied by Richness of the Base). There are also contrasts that are preserved in some position but lost elsewhere.

In a tableau, not all of the relevant inputs will be shown. The inputs that will be shown in a tableau will consist of minimally distinct words (words that are distinct on a single P property in one and the same location), i.e., *ba**d*** vs. *ba**t*** are minimally distinct but not ***bad*** vs. ***sat***. However, ***bad*** vs. ***sat*** will be included into the scenario in a tableau if their minimally distinct counterparts, ***bat*** and ***sad***, are also included. That is, for any form included in a tableau, there must be a form that is minimally contrastive on some property. Contrasts cross-classify. Given the way the set of inputs is generated, not all of those forms will be actual words of the language. This is what distinguishes my proposal from accounts where contrast preservation is strictly limited to avoidance of homophony, such as Crosswhite (1997), Steriade (1996). It is similar to Flemming (1995).[4]

This raises the question of how the process of learning takes place since the forms included into the scenario are possible words but not necessarily existing words of the language. The current hypothesis is that in the process of learning, the learner uses the actual words to establish a language particular constraint ranking and only then generalizes them to hypothetical forms (see *Predictions of the Theory,* chapter 4 for discussion).

The optimal scenario is chosen by the interaction among rankable and violable constraints. These are presented in the next section.

1.2.2 The Constraints

As defined in the previous section, a scenario is a space of mappings, with its dimensionality given by contrasting features. Outputs in the scenario are a subset of its inputs. Thus mappings are from the set of inputs onto its subset. (Mappings are output $\subseteq$ input.) Scenarios in a candidate set compete for the status of the optimum. There are three aspects of scenario evaluation: contrast preservation (1.2.2.1), output well-formedness (1.2.2.2), and the degree of input-output disparity in a scenario (1.2.2.3).

[4] The proposals of Padgett and Flemming will be discussed in *Predictions of the Theory,* chapter 4.

Contrast preservation compares scenarios for what types of contrasts are preserved or neutralized in surface forms, and at what cost. There are three aspects of contrast preservation that are evaluated: (i) the number of inputs involved in neutralizations, (ii) the number of outputs that are ambiguous as a result of neutralization, and (iii) the correspondence between input contrasts and output contrasts. Different aspects of contrast preservation take precedence in different languages, and thus different scenarios are optimal in those languages. (Section 1.2.2.1.)

In addition to contrast preservation, scenarios are compared for output well-formedness. Different scenarios may contain different outputs. In addition, since mappings are evaluated together, the same outputs may correspond to a different number of inputs in different scenarios. That is, scenarios differ not only in the types of outputs but also in the number of particular output forms. Both aspects of output well-formedness are evaluated. (Section 1.2.2.2.)

Finally, different scenarios may fare the same on contrast preservation and output well-formedness but they may differ in the degree of input-output disparity. The same interplay of contrasts and the same output forms can be achieved at various cost. The scenario with the smallest degree of disparity wins. Disparity is evaluated separately for different types of outputs in a scenario. (Section 1.2.2.3.)

The natural set of conditions on mappings is summarized below. Recall that these are conditions on contrast preservation, output well-formedness and input-output disparity, respectively. The condition on contrast preservation has three aspects to it, as mentioned above.

(19) Conditions on mappings
 i. Contrasts are preserved.
 a. Inputs do not merge.
 b. Outputs are not ambiguous.
 c. Output contrasts correspond to identical input contrasts.
 ii. Outputs are well-formed.
 iii. Outputs and corresponding inputs are expressed in the same way.

As will become clear from the following discussion (see chapter 2 in particular), each of these conditions is indispensable for an effective comparison between scenarios in a candidate set.

In PC theory, each condition is formalized as a family of violable and rankable constraints. These are Preserve Contrast (PC constraints), tokenized markedness and generalized faithfulness. The latter is such that it does not distinguish between different types of identity. The following is a summary of the constraints.

(20) Constraints in PC (cf (19))
 i. Preserve Contrast (PC)
 a. Input-oriented PC
 b. Output-oriented PC
 c. Relational PC
 ii. Tokenized Markedness
 iii. Generalized Faithfulness

Constraints in PC theory belong to two stages of Eval(uation). *Eval* is the evaluator function H that consists of the language-particular constraint hierarchy. In standard OT, Eval is a one-stage constraint ranking. In PC, it is proposed that there are two stages of Eval. PC and markedness constraints belong to stage 1 (H-$eval_1$), and generalized faithfulness to stage 2 (H-$eval_2$). This is to avoid redundancy between PC and generalized faithfulness. For example, both PC and generalized faithfulness can block a phonological process. Since Eval is subdivided into two stages, this means that generalized faithfulness constraints can apply only after PC and markedness get a chance to apply. As a result, generalized faithfulness constraints deal with differences between scenarios that have not been determined in H-eval$_1$ by PC or markedness. The two stages of Eval are illustrated below.

(21) Structure of PC grammar

a. Gen (In_k) → {$Scen_1$, $Scen_2$, … $Scen_n$}

b. H-eval$_2$ (H-eval$_1$ ($Scen_i$, $1 \leq i < \infty$)) → $Scen_{real}$

Where:

H-eval$_1$	=	PC and Markedness
H-eval$_2$	=	Generalized Faithfulness

Scenarios are first evaluated by PC and markedness in H-eval$_1$. The output of this evaluation process becomes an argument of H-eval$_2$ that consists of a language particular ranking of generalized faithfulness constraints.

In the following sections I discuss each constraint family in turn. I start out with PC constraints, followed by tokenized markedness, and generalized faithfulness. I then show how the constraints can be used to analyze Finnish and other chain shifts.

1.2.2.1 PC Constraints

PC constraints evaluate contrast. There exist three families of PRESERVECONTRAST constraints: input-oriented PC, output-oriented PC, and relational PC. Those constraints evaluate scenarios for whether and how they preserve underlying contrasts in surface forms. We need all of them because there are distinct forms of complexity that can inhere in different sets of mappings. The following sections describe the PC constraints in more detail. When introducing the constraints, I always compare two scenarios, one of which is the actual scenario from Finnish, while the other is a competing scenario from the same candidate set. Let us start out with input-oriented PC.

1.2.2.1.1 Input-oriented PC

Input-oriented PRESERVECONTRAST constraints, $PC_{IN}(P)$ for short, demand that pairs of words that contrast underlyingly in a given phonological property P contrast on the surface (not necessarily in P). Such constraints are defined in (22).

(22) $PC_{IN}(P)$
For each pair of inputs contrasting in P that map onto the same output in a scenario, assign a violation mark. Formally, assign one mark for every pair of inputs, in_a and in_b, if in_a has P and in_b lacks P, $in_a \rightarrow out_k$, and $in_b \rightarrow out_k$.
"If inputs are distinct in P, they need to remain distinct."

What it means to contrast in P is defined as follows.

(23) Def. of Contrast in P
A pair of inputs, in_a and in_b, contrast in P, when corresponding segments in those inputs, seg_a and seg_b, are such that seg_a has P and seg_b lacks P.

P is a potentially contrastive phonological property, such as a distinctive feature, length, stress, presence vs. absence of a segment. The properties P, then, are essentially the same as the properties governed by faithfulness constraints in standard OT. Indeed, PC(P) constraints are like faithfulness constraints in that they look at two levels of representation. But they are novel in that they evaluate contrasts for pairs of underlying words and corresponding output words instead of evaluating individual input-output mappings.

Input-oriented PC constraints, unlike standard faithfulness, admit contrast transformation. Since contrasts can be expressed by various properties, $PC_{IN}(P)$ constraints are satisfied even when contrasts are expressed on the surface in a different way than in the underlying form. In Finnish, for example, even though words that contrast underlyingly in length contrast on the surface in rounding, the PC_{IN}(long) constraint is satisfied. As will be discussed below, $PC_{IN}(P)$ constraints by themselves do not determine how to preserve particular contrasts. The way in which a given underlying contrast is expressed on the surface is determined by the interaction of input-oriented PC constraints with each other and with other constraints in the theory.

Another role of input-oriented PC constraints is to minimize the number of mergers in a scenario. Given two scenarios that merge the same types of contrast, they prefer a scenario where fewer input pairs are involved in the same type of merger. Compare the chain-shift scenario to a competing total merger scenario. Both merge length and rounding but the total merger scenario merges those properties for more input pairs and thus is non-optimal on input-oriented PC.

(24) a. Chain-shift scenario b. Total merger scenario

As far as length mergers are concerned, the chain-shift scenario merges two input pairs, {/oi/, /ooi/}, {/ai/, /ooi/}. The corresponding total merger scenario, on the other hand, merges four input pairs distinct in length, {/oi/, /ooi/}, {/ai/, /ooi/}, {/ai/, /aai/}, {/oi/, /aai/}. The same goes for rounding. In the chain-shift scenario, there are two input pairs that merge rounding, {/ai/,/oi/}, {/ai/,/ooi/}. In the total merger scenario, rounding is neutralized for four input pairs, {/ai/,/oi/}, {/ai/,/ooi/}, {/aai/,/oi/},{/aai/,/ooi/}. Thus, the total merger scenario would never win on input-oriented PC constraints over the chain-shift scenario since it incurs more mergers of each type. But the total merger scenario contains only one output and thus output well-formedness would select it over the competing chain-shift scenario (see chapter 2 for discussion).

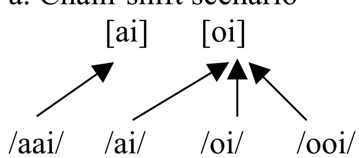
1.2.2.1.2 Output-oriented PC

In addition to input mergers, scenarios are evaluated for the ambiguity of their outputs. A scenario with fewer ambiguous outputs is preferred, all else being equal. This is the role of output-oriented PC, $PC_{OUT}(P)$, as defined below.

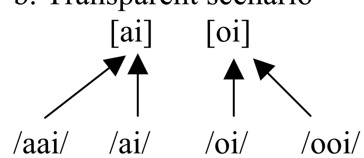
(25) $PC_{OUT}(P)$
For each output that corresponds to two or more inputs contrasting in P assign a violation mark. Formally, assign one mark for every output, out_k, if $in_a \rightarrow out_k$, $in_b \rightarrow out_k$, in_a has P, and in_b lacks P.
"Avoid outputs ambiguous in P property."

The primary role of output-oriented PC is to ensure that if mergers take place in a scenario they are accumulated in one location rather than distributed among outputs. This often forces a merger along some additional dimension of contrast. Compare the chain-shift scenario to a transparent scenario.

(26) a. Chain-shift scenario



b. Transparent scenario



The two scenarios differ in the distribution of length neutralizations among outputs. The chain-shift scenario contains one output ambiguous in length, the [oi] output. The transparent scenario contains two such outputs, [ai] and [oi]. Thus, in the chain-shift scenario there are fewer outputs that correspond to inputs distinct in length. This is at the cost of merging rounding. There are no rounding neutralizations in the transparent scenario but there are some in the chain-shift scenario. In the chain-shift scenario two pairs of inputs merge in rounding: {/ai/,/oi/} and {/ai/,/ooi/}.

In Finnish, PC_{OUT}(long) ranked above $PC_{IN/OUT}$(round) selects the chain-shift scenario over the transparent scenario since the chain-shift scenario contains fewer outputs ambiguous in length. When ranked higher than PC constraints against rounding mergers, this constraint forces a merger in rounding. As a result, length neutralizations are accumulated in one location in this scenario rather than distributed among outputs.

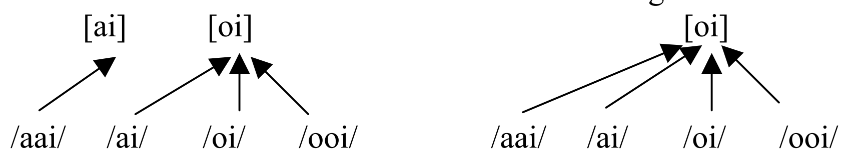
When neutralizations cluster, there are fewer outputs in a scenario that are ambiguous in some property P. If the number of ambiguous outputs is taken to be an indication of the recoverability of a scenario, output-oriented PC constraints increase recoverability. See section 1.4 for discussion. For previous work on recoverability see Gussmann (1976), Kaye (1974), (1975), Kisseberth (1976). See also evidence for clustering of faithfulness violations in the work of Burzio (1996), (1998). Predecessors of output-oriented PC constraints include output-oriented IDENT-type constraints (see Keer 2000, Struijke 2001).

1.2.2.1.3 Input- and Output-oriented PC

In many cases, input- and output-oriented PC constraints play the same role. They both prohibit neutralizations of particular contrasts. Thus, they are partially overlapping. The difference between the two lies in whether they count neutralizations from the input or the output. This is an important difference when comparing scenarios.

Consider two scenarios with length and rounding mergers, the same number of ambiguous outputs, but a different number of input mergers.

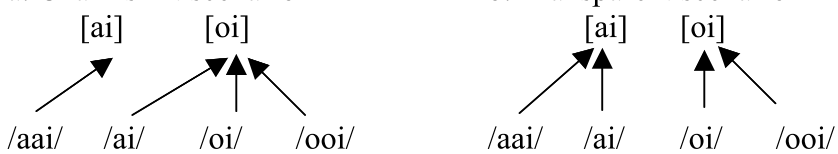
(27) a. Chain-shift scenario b. Total merger scenario



To compare the two scenarios, we need input-oriented PC. Output-oriented PC does not see the difference since it does not count the number of inputs involved in neutralizations. For output-oriented PC, the two scenarios are the same.

Conversely, output-oriented PC is needed to see the virtues of the chain-shift scenario over a transparent scenario.

(28) a. Chain-shift scenario b. Transparent scenario



Input-oriented PC would always prefer the transparent scenario since it avoids merging along one additional dimension of contrast. In the transparent scenario, there are only length mergers. In the opaque scenario, there are both length and rounding mergers. In terms of constraints, PC_{IN}(long) constraint is violated twice in both scenarios. PC_{IN}(round) constraint is violated only in the opaque scenario. Thus, the opaque scenario is harmonically-bounded by the transparent scenario on input-oriented PC constraints. To ensure that the opaque scenario has a chance to win, we need output-oriented PC constraints. PC_{OUT}(long) prefers the opaque scenario since it reduces the number of outputs ambiguous in length.

The output-oriented PC constraint redistributes neutralizations in a scenario onto one output. As a result, there are fewer outputs ambiguous in some property P.

1.2.2.1.4 Relational PC

In PC theory, there are also relational PC constraints. The logic behind relational PC is as follows: even though in chain shifts (and other opaque processes) some contrast is preserved at the cost of neutralizing some other contrast - in Finnish length is preserved at the cost of neutralizing rounding - there are limits on how many instances of the rounding contrast are neutralized. Too much neutralization may result in an output contrast that does not reflect any minimal instances of an identical input contrast. In Finnish, for example, transforming too many instances of the length contrast into the rounding contrast may result in an output rounding contrast that does not correspond to any instances of the minimal rounding contrast from the input. We can go even further and say that when this happens, the identity of the output contrast is non-recoverable. The output contrast bears no relation to its source. Relational PC militates against it.

Relational PC is related to Kiparsky's Alternation Condition, which prohibits absolute neutralizations. The Alternation Condition bans positing underlying oppositions that are always neutralized on the surface. The following formulation is given by Kenstowicz and Kisseberth (1979, p. 215).

(29) Alternation Condition (Kiparsky 1971)
Each language has an inventory of segments appearing in underlying representations. Call these segments phonemes. The U(nderlying) R(epresentation) of a morpheme may not contain a phoneme /x/ that is always realized phonetically as identical to the realization of some other phoneme /y/.

In short, the Alternation Condition prohibits positing an opposition /x/ vs. /y/ that is always neutralized on the surface.

Similar to the Alternation Condition, relational PC guards identity between output contrasts and their input correspondents. It demands that a given output contrast correspond to at least one instance of an identical minimal input contrast. Relational PC is defined below:

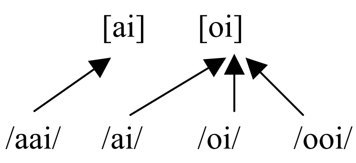
(30) $PC_{REL}(P)$

For a pair of outputs minimally contrasting in P that does not correspond to a pair of inputs minimally contrasting in P, assign a violation mark. Formally, assign one mark for every pair of outputs, out_a and out_b, $|out_a - out_b| = P$, if there in no pair of inputs, in_i and in_j, $\{in_i, in_j\} \rightarrow \{out_a, out_b\}$, and $|in_i - in_j| = P$.

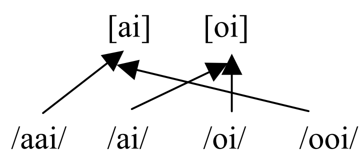
Too much transformation violates relational PC, and thus a conflict results between relational PC and contrast transformation. Given two scenarios that transform contrasts, a scenario in which contrast relation is not preserved loses on relational PC. (See chapter 2.)[5]

Compare the chain-shift scenario as in (31) to a competing bi-directional scenario (bi-directional since it contains movement going in opposite directions). In both, the length contrast is preserved at the cost of neutralizing rounding. In the chain-shift scenario, the length contrast is preserved for two pairs of inputs and realized as a surface contrast in rounding, both /aai/ vs. /ai/ and /aai/ vs. /oi/ map onto [ai] vs. [oi]. The two other input-length contrasts in this scenario, /ooi/ vs. /oi/ and /ooi/ vs. /ai/, are neutralized. In the bi-directional scenario, on the other hand, length is preserved for every pair of inputs and realized as a surface contrast in rounding, both /aai/ vs. /ai/, /ooi/ vs. /oi/, /aai/ vs. /oi/, and /ooi/ vs. /ai/ are realized as [ai] vs. [oi].

(31) a. Chain-shift scenario



b. Bi-directional scenario

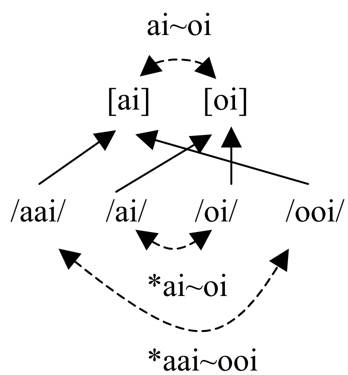


5 Relational PC reverses the Alternation Condition. In the Alternation Condition, if /x/ is not equal to /y/ on P, then somewhere [x] is not equal to [y] on P. But in (30), if [x] is not equal to [y] on P, then /x/ is not equal to /y/ on P.

Given the high-preference for preserving length contrasts in Finnish, the bi-directional scenario is expected to come out optimal. It preserves every length contrast from the input.

However, as a result of preserving length for each pair of inputs, in the bi-directional scenario each minimal rounding contrast from the input is neutralized: /aai/ vs. /ooi/ and /ai/ vs. /oi/ map onto [ai] and [oi], respectively. As a result, in the bi-directional scenario, the output rounding contrast does not correspond to any of the minimal instances of the rounding contrast from the input. As already mentioned, when this happens, the identity of the output contrast is non-recoverable. This is illustrated in the following diagram. The diagram indicates minimal rounding contrasts from the input. Contrasts that are neutralized are indicated with an asterisk.

(32) Bi-directional scenario



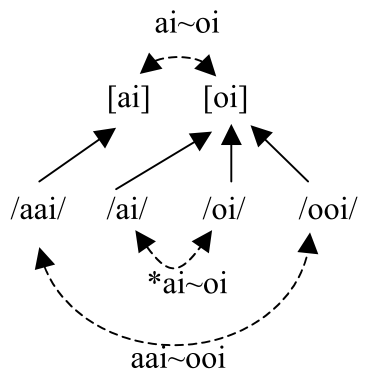
Non-recoverable identity

In the bi-directional scenario, the identity of the output rounding contrast is non-recoverable since neither /aai/ vs. /ooi/ nor /ai/ vs. /oi/ are preserved. Graphically, both contrasts get an asterisk.

In the chain-shift scenario, on the other hand, the output rounding contrast corresponds to one minimal instance of the rounding contrast from the input. While one of the minimal rounding pairs neutralizes - /ai/ vs. /oi/ both map onto [oi] - the other pair,

/aai/ vs. /ooi/, maps onto distinct outputs, [ai] vs. [oi]. Thus, in the chain-shift scenario, unlike in the bi-directional scenario, the identity of the output rounding contrast is recoverable. A minimal rounding contrast from the input, /aai/ vs. /ooi/, is preserved.

(33) Chain-shift scenario



Recoverable identity

Graphically, only one contrast, /ai/ vs. /oi/, gets an asterisk.

In Finnish, the high-ranking PC_{REL}(round) constraint chooses the chain-shift scenario over the bi-directional scenario, since the chain-shift scenario retains some identity between its output and input rounding contrasts. The choice is made in favor of the chain-shift scenario, even though it is the bi-directional scenario that avoids length mergers altogether. Thus, in Finnish, relational PC is in conflict with PC constraints against length mergers. The choice is made in favor of relational PC.[6]

1.2.2.2 Tokenized Markedness

In addition to PC constraints, there are also markedness constraints in the theory. Markedness constraints are indispensable to ignite a shift. As will become apparent, without high-ranking markedness, there would be no movement in a scenario since PC constraints themselves cannot initiate movement (see chapter 4 for discussion). By movement, I mean any unfaithful mapping in a scenario.

In standard OT, markedness constraints evaluate output well-formedness. The same role of markedness is retained in PC theory. In Finnish, for example, high-ranking markedness against tri-moraic syllables accounts for shortening. It is more important to avoid tri-moraic syllables than to preserve length contrasts. But in PC the concept of markedness is taken a step further. Scenarios are different not only on output types but also on how many outputs of a particular type there are in a scenario. (The number of outputs equals the number of inputs that map onto them.) Since markedness in PC counts the number of output types, it is called tokenized markedness.

(34) TOKENIZED MARKEDNESS
Assign a violation mark for every instance of output, out_x, where the number of outputs equals the number of inputs that map onto out_x.
"Assign a violation mark for every token of a marked output in a scenario, where the number of tokens equals the number of inputs that map onto this output."

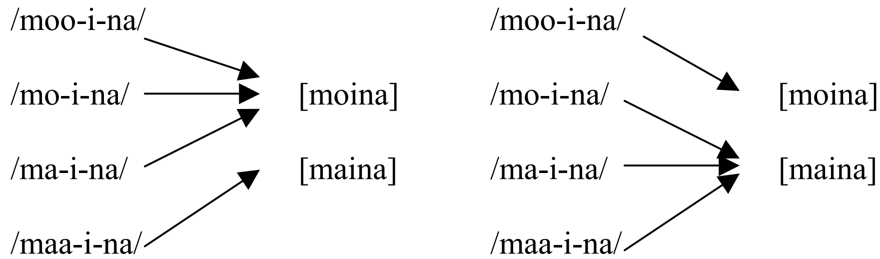
When there is no output x in a scenario, tokenized markedness is satisfied. When there is an output x, tokenized markedness is violated and it distinguishes between scenarios with different number of inputs that map onto x. Since there are markedness constraints against various types of outputs and they are ranked with respect to one another, tokenized markedness constraints decide which output in a scenario is a preferred site for neutralization. The less marked output is the one that is preferred according to markedness. It is better to have more instances of a less marked output in a scenario than of its more marked competitor.

Consider two competing chain-shift scenarios. The two scenarios have the same set of outputs but differ on which output is the site of neutralization. In the chain-shift scenario (35a), the output with the [oi] diphthong is the site of neutralization, [moina]. In

[6] As will be shown in chapter 2, bi-directional contrasts do actually arise.

the mirror-image scenario (35b), it is the output with the [ai] diphthong, [maina]. The scenarios are represented vertically to better illustrate the difference.

(35) a. Chain-shift scenario b. Its mirror image



Tokenized markedness makes the choice between the two scenarios. The scenario with neutralization onto [moina], the chain-shift scenario, creates more outputs of type [oi]. The scenario with neutralization onto [maina], the mirror-image scenario, contains more tokens of type [ai]. Depending on the relative ranking of tokenized markedness constraints, *ai versus *oi, one or the other scenario is more harmonic. If [maina] is a better output than [moina], then the chain-shift scenario is more harmonic. With the opposite ranking, its mirror image wins.

The two scenarios in (35) differ in directionality of movement. The chain-shift scenario contains rounding, the competing mirror-image scenario contains lowering. Tokenized markedness makes the choice between the two.[7]

To conclude, tokenized markedness constraints have two roles in the theory: (i) they force movement in a scenario by evaluating output well-formedness, and (ii) they evaluate directionality of movement by counting the number of marked tokens in a scenario. Thus, tokenized markedness constraints combine the notions of standard

[7] Even though tokenized markedness makes a choice between the two types of scenarios, I will argue that in Finnish the *ai markedness constraint is ranked below conflicting PC(round), since it does not force rounding in Finnish. In Finnish, rounding only takes place where shortening occurs. Thus, I will argue that it is due to a high-ranking PC_{OUT}(long) constraint and not *ai markedness.

markedness and faithfulness. They are like standard markedness since they evaluate output well-formedness. But they are also like standard faithfulness since they have access to the input as well as to the output. Consequently, like standard markedness, they can force a phonological process and like standard faithfulness, they can determine directionality of movement in a scenario.[8]

1.2.2.3 Generalized Faithfulness

Markedness and PC constraints constitute the core of PC theory. They belong to stage 1 of Eval and perform the initial screening of scenarios in a candidate set. However, they do not make all necessary distinctions between scenarios. Therefore, once markedness and PC get a chance to trim down the candidate set, faithfulness comes into play. In PC faithfulness constraints belong to stage 2 of Eval. Their role is solely to resolve ties from stage 1. As will become apparent, this is a much more reduced version of faithfulness than the one in standard OT. The reduction of faithfulness is expected in the light of the transfer of much of its responsibility to PC constraints and tokenized markedness.

In PC theory faithfulness has two goals: (i) it rules out scenarios that involve unnecessary movement (movement that is not motivated by either PC or markedness), and (ii) it determines the directionality of movement in a scenario. Movement in PC theory is understood as any type of input-output disparity for each mapping in a scenario. In the following discussion, I will first describe how faithfulness rules out unnecessary movement and then show how it determines the directionality of movement in a scenario.

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[8] Tokenized markedness makes the choice in directionality of movement for most scenarios, except the ones that contain the same number of outputs of each type; in this case generalized faithfulness makes the choice. Bi-directional scenarios are an example. See next section and chapter 2.

Faithfulness constraints in PC theory are not the same as faithfulness constraints in standard OT. Faithfulness constraints in PC sum up violations of identity for all mappings in a scenario and they treat any change - rounding, nasalization, deletion or insertion the same way. Since they do not distinguish between different types of non-identity, they are called *generalized* faithfulness constraints. This is the main difference between generalized faithfulness and standard faithfulness.

Standard faithfulness distinguishes between different types of non-identity. There are distinct standard faithfulness constraints that militate against a change in rounding, IDENT(round), and different faithfulness constraints that militate against a change in nasality, IDENT(nasal). In PC theory, these are expressed under one and the same constraint. The role of generalized faithfulness, therefore, is to evaluate the cost of achieving a certain interplay of contrasts and markedness in the system. Given a choice between scenarios that fare equally on markedness and PC, generalized faithfulness constraints choose a scenario where inputs and outputs are most similar to each other.

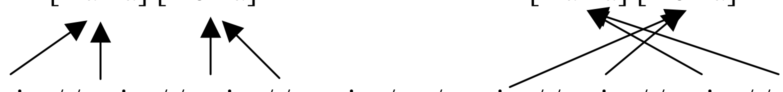
Below I give a preliminary definition of generalized faithfulness. This definition will be modified once the other goal of faithfulness, directionality of movement, is discussed.

(36) GENERALIZED FAITHFULNESS (first pass)
An output is identical to its input correspondent in every property. Assign a violation mark for any type of disparity (i.e., featural change, deletion, insertion).

Consider two scenarios which are alike except for the degree of input-output disparity. The two scenarios are the transparent scenario with shortening (37a) and multi-directional scenario with shortening, lowering and rounding (37b).

(37) a. Transparent scenario b. Multi-directional scenario

[maina] [moina] [maina] [moina]



/maaina/ /maina/ /moina/ /mooina/ /maaina/ /maina/ /moina/ /mooina/

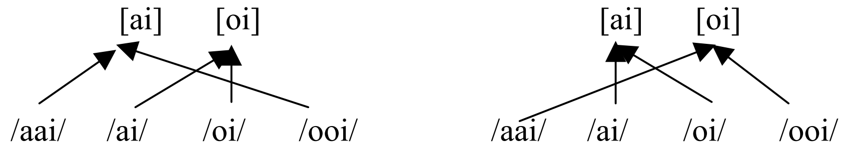
The two scenarios fare the same on markedness and PC. They contain the same outputs and the same number of them (tokenized markedness). They merge the same type and number of input pairs (input-oriented PC). They also both contain the same two ambiguous outputs (output-oriented PC). But the two scenarios are different and the theory should be able to express this formally. This is where generalized faithfulness comes into play.

The two scenarios differ in the degree of disparity between inputs and their corresponding outputs. In the multi-directional scenario, outputs and corresponding inputs are more distant than in the competing transparent scenario. The choice between the two scenarios is left to faithfulness. Faithfulness rules in favor of the transparent scenario since it contains less movement.

To distinguish between the transparent and multi-directional scenarios, it would be enough for faithfulness to be formulated as a general constraint against input-output disparity. This constraint would then sum up violations of disparity for each mapping in a scenario. However, as the following example shows, a more detailed formulation of the constraint is needed.

Consider two bi-directional scenarios. They are called bi-directional since they contain both rounding (raising) and lowering.

(38) a. Bi-directional scenario b. Its mirror image



The two scenarios tie on PC and markedness. As far as PC constraints are concerned, both scenarios incur the same types of mergers and involve the same number of inputs and outputs in each merger. As far as markedness goes, both scenarios contain the same outputs and the same number of them. The two scenarios also contain the same degree of input-output disparity since they change length and rounding to the same degree. But the two scenarios are clearly distinct. I will propose that it is the role of generalized faithfulness to distinguish between them.

Let us consider how the two scenarios can be distinguished. Both scenarios contain the same phonological processes: rounding, lowering and shortening. Both scenarios have the same outputs and merge the same inputs. They differ however on what the long and short vowels map onto. In (38a), the long vowels map onto the unrounded vowel output. In (38b), the long vowels map onto the rounded vowel output. Since long vowels shorten, the mapping involving long vowels is less faithful than a comparable mapping involving short vowels (/aai/ → [ai] is less faithful than /ai/ → [ai]). Thus, the two scenarios differ in the distribution of unfaithful mappings across outputs. In (38a), it is the unrounded vowel output that is less faithful. In (38b), it is the rounded vowel output.

To capture this observation formally, I propose that in addition to militating against unnecessary input-output disparity, generalized faithfulness constraints evaluate disparity separately for different types of outputs in a scenario (the type of output is determined by the presence/absence of the P property). Since faithfulness is evaluated with respect to the type of output, formally, it takes the output segment as its modifier. One can think of it as partitioning the space of outputs into P sets (divided by the type of output) and then evaluating disparity for each mapping in a set. The constraint is defined below.

(39) [αP]-FAITH (cf. (36))
An [αP] output is identical to its input correspondent in every property. Assign a violation mark for any type of disparity (i.e., featural change, deletion, insertion).

The key idea is that some sets of P properties tend to be more resistant to unfaithful mappings than others, and thus faithfulness, subcategorized to a set, can determine which types of segment(s) can receive a mapping.

Thus, generalized faithfulness that belongs to stage 2 of Eval has two goals: (i) it minimizes input-output disparity, and (ii) determines directionality of movement in cases when the choice is not already made on tokenized markedness. (Tokenized markedness which determines directionality of movement in stage 1 of Eval would not be able to distinguish between the two bi-directional scenarios. Both scenarios fare the same on tokenized markedness: they have the same outputs and the same number of them.)

Let us now evaluate the two bi-directional scenarios with respect to the constraint defined in (39). The two scenarios differ on where long and short vowels map. In (38a), long vowels map onto [ai], the output with the unrounded vowel. In (38b), they map onto [oi], its rounded counterpart. This has consequences for generalized faithfulness. In the scenario where long vowels map onto [ai] (38a), it is the unrounded vowel [ai] that is less faithful, whereas in the other scenario, (38b), it is the rounded counterpart [oi] that fares worse on faithfulness. Depending on the relative ranking of generalized faithfulness constraints, *unrounded*-FAITH versus *rounded*-FAITH, one or the other scenario comes out optimal.

The generalized faithfulness constraint can be seen as a combination of faithfulness and markedness. It is a faithfulness constraint since it evaluates input-output identity but it is also subcategorized to a particular output and in that, resembles standard markedness. The idea behind generalized faithfulness is that in a given language some outputs are more faithful than other outputs.[9]

The next section shows how PC constraints interact with each other, conflicting markedness constraints, and low-ranked faithfulness in choosing the optimal scenario.

1.3 Illustration of the Proposal

Here is an example of how the constraints work on a simple case of neutralization and the lack of it.[10]

1.3.1 Neutralization: Final Devoicing

Consider a language with final devoicing. For final devoicing to take place, markedness against voiced obstruents syllable-finally must outrank conflicting PC. It is more important to avoid voiced obstruents syllable-finally than it is to preserve contrast in voicing. The neutralization ranking is given below.

(40) Neutralization ranking

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[9] One can think of cases where certain phonological alternations take place in the language but some sets of segments do not undergo them. This can be accounted for by generalized faithfulness constraints outranking process-specific markedness constraints.

[10] In the following discussion, there will be no need for the distinction between input- and output-oriented PC nor will it be necessary to count tokens for markedness or subdivide outputs for faithfulness. This is because the following scenarios contain only two mappings. However, for continuity in the presentation of the argument, I will use all the types of constraints introduced so far. It is important to become familiar with them since they will become necessary once the scenarios get larger (see section 1.4).

$*\text{VOICEDOBSTRUENT}]_\sigma >> PC_{IN}(\text{voice}), PC_{OUT}(\text{voice})$

This is illustrated in the following tableau. Scenarios are formed as described in section 1.2.1. For a given three-segment underlying form "scenario-inputs" are all strings of length 0…7. These are all possible combinations of all P (phonological) properties including deletion and insertion of segments. For example, scenario-inputs for underlying form *vad* contain, among others, *vad* (the identity form), *vat* (by final devoicing), *va* (by deletion), *va:* (by deletion & lengthening), *ba* (by deletion & change in place), *thad* (by change in place). The inputs shown in the tableau are a subset of those. They are minimally distinct in obstruent voicing word-finally, *va**d*** *vs.* *va**t*** (This is a standard procedure in OT, where not all forms are shown in a tableau.)[11] In each scenario outputs are a subset (possibly improper) of the inputs. In scenario A, the set of outputs is a proper subset of the input. In scenarios B and C, the set of outputs is identical to the set of inputs. We now come to the evaluation.

(41) Final devoicing takes place

Scenarios		*Voi Obs]$_\sigma$	PC_{IN} (voice)	PC_{OUT} (voice)	(+vd)-FAITH	(-vd)-FAITH
A. Neutralization ☞ (Polish)	/va**d/** → va**t** /va**t/** → va**t**		* {/vad/,/vat/}	* [vat]		* d→t
B. Identity (English)	/va**d/** → va**d** /va**t/** → va**t**	*!				
C. Permuted (Not attested)	/va**d/** → vat /va**t/** → va**d**	*!			* t→d	* d→t

11 Another way to look at it is to let arguments of relevant PC constraints, here PC(voice), choose what input contrasts are shown in a tableau.

Scenario A, the neutralization scenario, is the winner as it satisfies high-ranked markedness. It contains no outputs with a voiced obstruent syllable-finally. The other two scenarios, scenario B and scenario C, violate high-ranked markedness since they contain a form with a voiced obstruent in a word-final position. The neutralization scenario, scenario A, incurs some PC violations - it merges contrast for one pair of inputs (violation of input-oriented PC) and in so doing creates an ambiguous output (violation of output-oriented PC), but PC constraints are low-ranked and so are less important than high-ranked markedness. Faithfulness violations are irrelevant here since the choice between candidates is already made in stage 1 of Eval, even before faithfulness gets a chance to apply. There is one violation of faithfulness in the actual scenario since there is voicing disparity in one of the mappings. There are two violations in the permuted scenario, scenario C, since there is voicing disparity in both mappings. (The permuted scenario will be discussed in more detail in the following section.)

1.3.2 Lack of Neutralization

Now consider the lack of neutralization. In this case, the underlying voicing contrast is preserved on the surface. In terms of a constraint ranking, PC dominates conflicting markedness. It is more important to preserve contrast than to avoid forms that violate markedness. The relevant ranking is below:

(42) Lack of neutralization
PC_{IN}(voice), PC_{OUT}(voice) >> *VOICEDOBSTRUENT$]_{\sigma}$

This is illustrated in the following tableau. Scenarios are formed as in the previous case.[12]

(43) No devoicing

Scenarios		PC_{IN} (voice)	PC_{OUT} (voice)	*Voi Obs$]_{\sigma}$	(+vd)-FAITH	(-vd)-FAITH
A. Neutralization (Polish)	/ni**d**/ → ni**t** /ni**t**/ → ni**t**	* {/nid/,/nit/}	*! [nit]			* d→t
B. Identity ☞ (English)	/ni**d**/ → ni**d** /ni**t**/ → ni**t**			*		
C. Permuted (Not attested)	/ni**d**/ → ni**t** /ni**t**/ → ni**d**			*	* t→d	*! d→t

Here the identity scenario, scenario B, is the winner as it satisfies high-ranked PC. In this scenario, forms distinct in voicing are kept distinct even at the cost of violating markedness. The neutralization scenario, scenario A, loses on PC.

The above tableau also illustrates the role of low-ranked FAITHFULNESS. Consider the so-called permuted scenario, candidate C, which is like the identity scenario except that in this scenario outputs correspond to different inputs. The choice between candidate B, the identity scenario, and candidate C, the permuted scenario, cannot be made on PC or markedness. The two fare the same on those two types of constraints. This is where we need faithfulness. Faithfulness favors candidate B (the identity scenario) over candidate C (the permuted scenario). In the identity scenario, outputs are closer to their inputs than in the competing permuted scenario (in fact they are the same), and this is preferred, all else being equal.

This illustrates an important prediction of PC theory that is different from rule-based approaches but similar to standard OT. In rule-based approaches mappings take place as long as there exist rules of a particular type. In standard OT, mappings are more restricted. They take place only when they improve on markedness (Moreton 1997). In PC theory, similarly, generalized faithfulness rules out unnecessary movement. For movement to take place, it must improve on either contrast or markedness. Otherwise, it will not take place. (For a discussion of this prediction see chapter 4.)

So far, PC works similarly to standard faithfulness. When markedness dominates conflicting PC, a phonological process takes place. When PC dominates conflicting markedness, a phonological process is blocked. The next section points to differences between PC and standard faithfulness.

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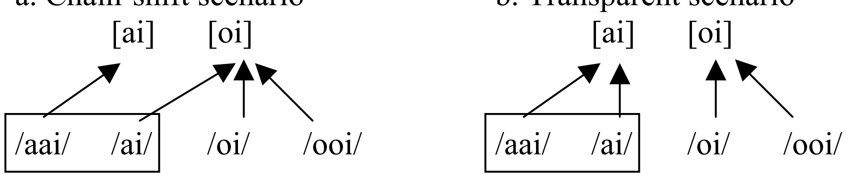
[12] In this example, the ranking is provable for only one PC constraint. This is expected, since the two PC constraints, input and output, both militate against neutralization, and thus if neutralization takes place, they are both violated. However, it will become clear in chapter 2 that both constraints are required. It is necessary to retain both of them for an opaque scenario to ever win over other scenarios in a candidate set. If there were no input-oriented PC constraints, the so-called total merger scenario would always win over competing chain-shift scenario (or any other competing opaque scenario for that matter). If there were no output-oriented PC constraints, the so-called transparent scenario would always win over the chain-shift scenario.

1.4 Application to Chain Shifts: Contrast Transformation and Neutralization

As has been observed, in Finnish the underlying length contrast is preserved despite shortening and realized as surface contrast in rounding. Some instances of the original rounding contrast are neutralized as a result. This is called *contrast transformation*. (A complete set of vowel alternations in Finnish is discussed in chapter 3.)

Compare the chain-shift scenario to a competing transparent scenario. In both scenarios there is shortening but only the chain-shift scenario involves rounding. In the chain-shift scenario, due to rounding, the length contrast is preserved for one minimal pair of inputs despite shortening. The length contrast is realized as a rounding contrast, /aai/ vs. /ai/ is manifested as [ai] vs. [oi]. In the transparent scenario, on the other hand, there is no rounding, and thus the two inputs, /aai/ vs. /ai/, map onto the same output. The relevant input pair is boxed.

(44) a. Chain-shift scenario b. Transparent scenario

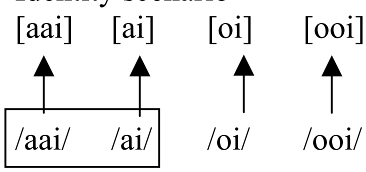


Shortening neutralizes all minimal length contrasts in the transparent scenario but is non-neutralizing for some input contrasts in the chain-shift scenario. Preservation of the length contrast versus its neutralization is the crucial difference between the chain-shift scenario and a competing transparent scenario.

Another way to look at the difference between the chain-shift scenario and the transparent scenario is in terms of output ambiguity. As was discussed in previous sections, rounding in the chain-shift scenario in comparison to the transparent scenario reduces the number of outputs that correspond to inputs distinct in length. In the chain-shift scenario there is only one output ambiguous in length, the [oi] output. In the transparent scenario, on the other hand, there are two such outputs, [ai] and [oi].

In the following discussion, I will first explain why shortening takes place and then account for rounding. Let us compare the chain-shift scenario to the identity scenario shown below. The identity scenario does not merge any contrasts, thus wins on PC constraints, but it contains long vowels in the output.[13]

(45) Identity scenario



For the chain-shift scenario to win over the identity scenario, it must be essential for long vowels to shorten.

I propose that in Finnish shortening takes place to avoid tri-moraic syllables. Some length contrasts are neutralized as a result. In terms of a constraint ranking, a markedness constraint against tri-moraic syllables, $*\sigma_{\mu\mu\mu}$, must outrank conflicting PC constraints against length mergers, PC_{OUT}(long) and PC_{IN}(long). The relevant markedness constraint and the constraint ranking that accounts for shortening are given below.

13 In reality, each scenario merges some contrasts due to ROTB, but the identity scenario does not merge length or rounding contrasts for the relevant inputs.

(46) a. $*\sigma_{\mu\mu\mu}$
Do not have syllables of three nuclear moras.

b. $*\sigma_{\mu\mu\mu} >> PC_{OUT}(long), PC_{IN}(long)$

This is illustrated in the following tableau. For clarity of exposition, in the following tableau I list each violation of a constraint as a star and I also indicate next to it a form or a pair of forms that incurs the violation. Markedness is evaluated for each output form in a scenario, and the forms in square brackets are the outputs that violate a particular markedness constraint. For output-oriented PC, the form in square brackets is the output that corresponds to inputs contrasting in length. For input-oriented PC, the pair in curly brackets is the pair that neutralizes length.

Scenarios in the candidate set are formed as described in section 1.2.1. All scenarios in the same candidate set contain the same inputs. Scenario-inputs are generated by a function Gen (similar to the role of Gen in correspondence theory). For an underlying form *maa-i-na*, and any other form of that length, scenario-inputs contain all strings of length 0…13 (I assume that long vowels count as one segment). Thus, scenario-inputs for that underlying form contain forms, such as, *maa-i-na* (identity form), *ma-i-na* (by shortening), *baa-i-na* (by denasalization), *ba-i-na* (by shortening & denasalization) etc. The forms shown in a tableau are a subset of those. They are minimally contrastive on vowel length and vowel rounding. Outputs in the scenarios are a subset (possibly improper) of the input. In the identity scenario, the forms in the output are identical to the forms in the input. In the actual scenario and in the total merger scenario, they constitute a proper subset of the input.

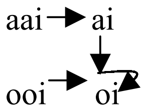
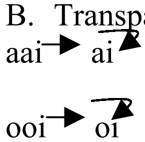
(47) Shortening takes place

Scenarios		$*\sigma_{\mu\mu\mu}$	PC_{OUT} (long)	PC_{IN} (long)
A. Identity aai ai ooi oi	/m**aa**-i-na/ → m**aa**-i-na /m**a**-i-na/ → m**a**-i-na /m**oo**-i-na/ → m**oo**-i-na /m**o**-i-na/ → m**o**-i-na	**! [aai], [ooi]		
B. Actual ☞ aai ai ooi oi	/m**aa**-i-na/ → m**a**-i-na /m**a**-i-na/ → m**o**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na		* [oi]	** {/ai/, /ooi/} {/oi/, /ooi/}
C. Total merger aai ai ooi oi	/m**aa**-i-na/ → m**o**-i-na /m**a**-i-na/ → m**o**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na		* [oi]	****! {/ai/, /ooi/} {/oi/, /ooi/} {/ai/, /aai/} {/oi/, /aai/}

The identity scenario, scenario A, loses on markedness since it contains tri-moraic syllables. The other two scenarios, the actual scenario and the total-merger scenario, both satisfy markedness, but the total-merger scenario incurs too many mergers of length. It merges length for four input pairs. Scenario B is optimal. It merges length but for fewer pairs than the total-merger scenario. In this scenario only two input pairs merge in length.

The ranking so far explains why shortening takes place but it does not account for rounding. Compare the actual scenario to a scenario with shortening but no rounding, the transparent scenario. In both, there is shortening at the cost of neutralizing length. But in the actual scenario there is also rounding and thus some rounding contrasts are neutralized in addition to length contrasts. Neutralizations of length and rounding contrasts in the actual scenario and in the competing transparent scenario are evaluated below.

(48) Input-oriented PC

Scenarios		PC_{IN} (long)	PC_{IN} (round)
A. Actual  	/m**aa**-i-na/ → m**a**-i-na /m**a**-i-na/ → m**o**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na	** {/oi/, /ooi/} {/ai/, /ooi/}	** {/ai/,/oi/} {/ai/, /ooi/}
B. Transparent  	/m**aa**-i-na/ → m**a**-i-na /m**a**-i-na/ → m**a**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na	** {/aai/, /ai/} {/ooi/, /oi/}	

In both scenarios length is merged for the same number of input pairs, but in the actual scenario in addition there are mergers of rounding. In the following discussion, I will explain what forces rounding in the actual scenario and how it aids length.

Observe that rounding improves on the distribution of length neutralizations in a scenario. In the actual scenario, due to rounding, length mergers are accumulated locally rather than distributed across outputs. As a result, there is an output that does not participate in any length mergers (in fact it does not participate in any merger at all), and thus stands in a bi-unique relation to its input. Thus, rounding reduces the number of ambiguous outputs in a scenario. If we take the number of ambiguous outputs to be an indication of the recoverability of a scenario, rounding improves recoverability (Gussmann 1976, Kaye 1974, 1975, Kisseberth 1976).

For the actual scenario to win, it must be more important to improve on the distribution of length neutralizations in a scenario (contributing to bi-uniqueness) than to avoid merging rounding. This is what forces rounding in Finnish.

(49) PC_{OUT}(long) >> PC_{IN}(round), PC_{OUT}(round)

This is illustrated in the following tableau.

(50) Vowel rounding takes place

Scenarios		$*\sigma_{\mu\mu\mu}$	PC_{IN} (long)	PC_{OUT} (long)	PC_{IN} (round)	PC_{OUT} (round)
A. Actual ☞ aai → ai ↓ ooi → oi	/m**aa**-i-na/ → m**a**-i-na /m**a**-i-na/ → m**o**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na		** {/oi/, /ooi/} {/ai/, /ooi/}	* [oi]	** {/ai/,/oi/} {/ai/, /ooi/}	* [oi]
B. Transparent aai → ai ooi → oi	/m**aa**-i-na/ → m**a**-i-na /m**a**-i-na/ → m**a**-i-na /m**oo**-i-na/ → m**o**-i-na /m**o**-i-na/ → m**o**-i-na		** {/aai/, /ai/} {/ooi/, /oi/}	**! [ai] [oi]		

The actual scenario, with rounding, wins on PC_{OUT}(long). It contains only one output ambiguous in length, whereas the transparent scenario contains two such outputs.

The constraint ranking established in this section is summarized below. Ranking arguments follow.

(51) Constraint ranking

$*\sigma_{\mu\mu\mu}$

PC_{OUT}(long) PC_{IN}(long)

PC_{OUT}(round) PC_{IN}(round)

(52) Ranking arguments

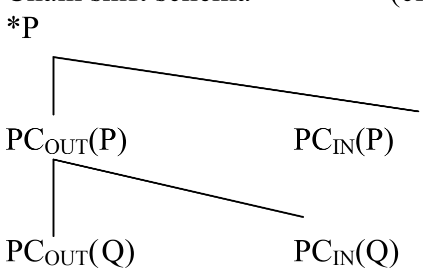
Ranking	Consequence
$*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(long), PC_{IN}(long)	Long vowels are avoided at the cost of merging length.
PC_{OUT}(long) >> PC_{OUT}(round), PC_{IN}(round)	Length neutralizations are accumulated in a scenario by merging rounding.

Recall that shortening takes place to avoid tri-moraic syllables. Due to shortening, some length contrasts are merged ($*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(long), PC_{IN}(long)). But length mergers need to be well-distributed (accumulated locally) in a scenario, and this is at the cost of merging rounding (PC_{OUT}(long) >> PC_{OUT}(round), PC_{IN}(round)). As a result, rounding takes place. Formally, rounding is an indirect consequence of shortening and a high-ranked requirement on the accumulation of length neutralizations in a scenario.

The chain-shift scenario preserves some length contrasts despite shortening. Length contrast is preserved for one minimal pair of inputs in a scenario, /aai/ vs. /ai/, and is manifested as a surface rounding contrast. Thus, *contrast transformation* takes place.[14]

Below is the general chain shift schema in cases like Finnish:

(53) Chain shift schema (cf. (51))



P-type segments are avoided due to high-ranked markedness and this results in some P mergers (*P >> PC_{OUT}(P), PC_{IN}(P)). But there is a high-ranking requirement on the distribution of P mergers in a scenario, output-oriented PC. It requires that fewer outputs

14 To capture this observation formally, one could employ PC constraints that would require preservation of minimal input contrasts only. The problem with such constraints is that they would not assign violation marks to mergers of non-minimal distinctions at all (those, for example, take place in the unattested cross-corner scenario discussed in chapter 2). Therefore, there would be a constraint ranking, under which a scenario that does not merge minimally distinct forms but incurs long-distance mergers wins. This is not a good prediction and that is why I do not pursue this approach further. (Another alternative would be to use both general PC constraints and PC constraints against mergers of minimal contrasts.)

correspond to inputs contrasting in P. That forces Q mergers, as only by merging along some other dimension of contrast can the contrast distribution requirement be satisfied as much as possible (PC_{OUT}(P) >> PC_{OUT}(Q), PC_{IN}(Q)). In effect, some original instances of the P contrast are preserved on the surface and manifested as contrast Q. Some instances of the Q contrast are lost.

This illustrates an important prediction of PC theory. In PC, a phonological process can take place solely to improve on the distribution of some contrast in a scenario. In the schematic example above, P distribution is improved by Q mergers. To improve P distribution means to accumulate neutralizations of P in one location in a scenario rather than distributing them among outputs. As a result, fewer outputs are ambiguous in P. This is the role of output-oriented PC. The high-ranking PC_{OUT}(P) constraint forces a phonological process (the Q process). This shows that PC constraints can activate a phonological process without reference to a high-ranking markedness constraint, as in standard OT. Before further discussion of this prediction, let us look at another example of a chain shift effect.[15]

1.5 Another Example: Kashubian Shift

As we have seen, in Finnish shortening forces rounding. Formally, rounding is a consequence of a high-ranked markedness constraint against tri-moraic syllables and a high-ranked PC constraint on the accumulation of length mergers in a scenario. This results in the preservation of some minimal input-length contrasts at the expense of

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[15] To explain rounding in Finnish, Harrikari (2000) and Anttila (2000) propose a high-ranking markedness constraint against diphthongs of the form *ai*. Harrikari formalizes it as a constraint against nuclei with maximal contour outside of the head syllable, $*[\text{MAXCONT}]_{\text{NUC(Non-H)}}$. In PC theory, though the *ai constraint is required to make all distinctions between scenarios in the same candidate set (see chapter 2), it is dominated by conflicting PC. Rounding takes place as a result of shortening together with the requirement on preserving contrast (see chapter 4).

rounding. In this section, I will analyze a parallel shift from a north-central Polish dialect, Kashubian. When analyzing Kashubian vowels, I will assume underlying representations of standard Polish. The evidence for this assumption comes from borrowings, some of which surface with standard Polish vowels (Lorentz 1958).

As will be discussed below, in Kashubian the chain shift effect involves processes of vowel fronting and raising. In particular, I will argue that fronting forces raising. The analysis will then proceed in parallel with the analysis of Finnish given in the previous section.

Before presenting the details of the analysis, let us look at the vowel inventory of standard Polish, given below.

(54) Vowel inventory of standard Polish (Rubach 1984)

i	ɨ	u
e		o
	a	

There are six oral vowels in Polish. Using the features of high, low, back and round, the following is the vowel classification, according to Rubach (1984). (SPE style.)

(55) Vowel features in Polish

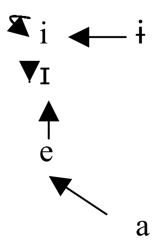
	i	u	ɨ	e	o	a
High	+	+	+	-	-	-
Low	-	-	-	-	-	+
Back	-	+	+	-	+	+
Round	-	+	-	-	+	-

Polish dialects show variation in vowel realization (Dejna 1993, Urbańczyk 1972). Some of the variation has the character of chain shifts. Kashubian shift is an example. The

Kashubian region is itself diverse. In the description below, I will attempt to concentrate on the most prevalent vowel mappings in Kashubian.

In Kashubian, the low vowel undergoes raising and is realized as the mid vowel [e].[16] As a result, the mid vowel [e] raises towards [i]. Sometimes it is realized slightly lower than [i], indicated as raised [ė] or [ɪ]. (In some areas it is also realized as [ie], [iy] or even central high vowel [ɨ]). The high vowels in Kashubian, [i] and [ɨ], tend to neutralize, both mapping onto [i].[17]

(56) Kashubian vowel shift



Some examples are given below.

(57) Some examples (Dejna 1993, Urbańczyk 1972)

Standard Polish	*Kashubian*	
	/a/ → [e]	
tr[a]va	tr[e]va	'grass'
pt[a]k	pt[e] χ	'bird'
g[a]d[a]	g[e]d[e]	'he talks'
por[a]nek	por[e]nk	'morning'

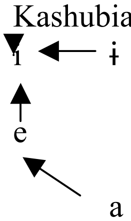
16 In some regions of Kashubian, as reported by Lorentz (1958), the low vowel raises but it does not make it all the way to [e]. It stops somewhere below [e]. In this section I will discuss raising in the front vowels only. But in some regions the low vowel [a] also surfaces as [o] or even [u]. This then causes the /o/ to [u] raising.

17 Sometimes both /i/ and /ɨ/ (and sometimes [u]) map onto an unrounded mid vowel [ë] ([ə]) (not after palatals). Thus, there is total neutralization in the high vowel set. In some sources, it is indicated that the original difference in backness between unrounded high vowels /i/ and /ɨ/ is preserved on the surface by palatalization or lack of it on the preceding consonant.

	/e/ → [ɪ]	
bž[e]k	bž[ɪ]k	‘shore’
s[e]r	s[ɪ]r	‘cheese’
ml[e]ko	ml[ɪ]ko	‘milk’
	/ɨ/ → [i]	
d[ɨ]m	d[i]m	‘smoke’
r[ɨ]ba	r[i]ba	‘fish’
b[ɨ]ć	b[i]ć	‘to be’
v[ɨ]ć	v[i]ć	‘to howl’
	/i/ → [i]	
ń[i]va	ń[i]va	‘soil’
b’[i]ć	b’[i]ć	‘to beat’
v’[i]ć	v’[i]ć	‘to plait’

For the purposes of the presentation of the argument, I will assume temporarily that /e/ raises all the way to [i] (which in fact is the case in some other dialects of Polish). Some sources on Kashubian also report this mapping. Once the argument is clear, I will then explain why /e/ stops at [ɪ]. This simplification has no effect on the analysis but allows us to achieve a full parallel with Finnish. Thus, we have the following set of mappings.

(58) Kashubian shift (simplified) (cf. Finnish in (43a))

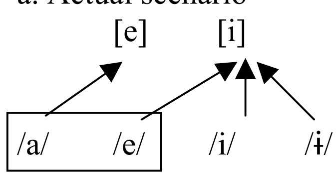


Drawing on the parallel with Finnish, I propose that in Kashubian, fronting takes place to avoid central vowels. Both high and low vowels undergo fronting. Vowel raising is then a result of fronting. Specifically, /e/ raises to [i] because /a/ fronts to [e].

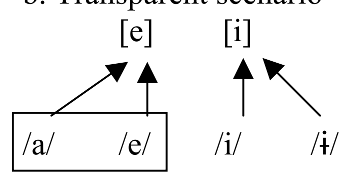
Kashubian shift represents *contrast transformation*. If there were no raising of /e/, the vowels /a/ and /e/ would map onto the same output - they would both map onto [e]. However, due to raising, the two vowels contrast on the surface despite fronting, /a/ vs. /e/ are realized as [e] vs. [i]. Descriptively, the underlying contrast in backness is transformed into surface contrast in height.

In terms of output ambiguity, due to raising, there is only one output in the scenario ambiguous with respect to underlying backness, the [i] output. If there were no raising, there would be two such outputs, [i] and [e]. (See the parallel with Finnish discussed in the previous section.) The actual scenario with fronting and raising, and the competing transparent scenario with no raising of /e/ are represented below.

(59) a. Actual scenario



b. Transparent scenario



In the actual scenario, mergers in backness are accumulated locally rather than distributed among outputs. This is at the cost of merging height. While in the transparent scenario, there are no inputs that merge height, in the actual scenario, there are two such input pairs, {/e/,/i/} and {/e/,/ɨ/}.[18]

For the actual scenario to win, it must be more important to reduce output ambiguity in backness than to avoid neutralizing height. The following ranking accounts for this effect:

(60) *central >> PC_{OUT}(back) >> PC_{IN}(high), PC_{OUT}(high) (cf. (51))

[18] I assume that /a/ and /e/ do not merge height. They are both [-high].

Informally, e-raising is a result of fronting together with the requirement on reducing output ambiguity in backness.

The constraint ranking is illustrated in the following tableau. The tableau includes the actual chain-shift scenario, the competing transparent scenario with no raising, and the identity scenario.

(61) Kashubian

Scenarios		*CENTRAL	PC_{IN} (bk)	PC_{OUT} (bk)	PC_{IN} (high)	PC_{OUT} (high)
A. Actual ☞ i ɨ e a	/b**a**ć/ → b**e**ć /b**e**ć/ → b**i**ć /b**i**ć/ → b**i**ć /b**ɨ**ć/ → b**i**ć		** {/i/, /ɨ/} {/e/, /ɨ/}	* [i]	** {/e/,/i/} {/e/, /ɨ/}	* [i]
B. Transparent i ɨ e a	/b**a**ć/ → b**e**ć /b**e**ć/ → b**e**ć /b**i**ć/ → b**i**ć /b**ɨ**ć/ → b**i**ć		** {/i/, /ɨ/} {/e/, /a/}	**! [i] [e]		
C. Identity i ɨ e a	/b**a**ć/ → b**a**ć /b**e**ć/ → b**e**ć /b**i**ć/ → b**i**ć /b**ɨ**ć/ → b**ɨ**ć	**!				

The chain-shift scenario, scenario A, is optimal. It avoids central vowels by merging some distinctions in backness but it reduces the number of outputs ambiguous in backness. There is only one output ambiguous in backness in the actual scenario, scenario A, but two such outputs in the competing transparent scenario, scenario B. The actual scenario reduces the number of outputs ambiguous in backness by means of e-raising. This results in neutralizations of some input height distinctions. In the actual scenario, some vowels distinct in height merge on the surface, while in the corresponding transparent scenario height contrasts are preserved in surface forms.

The constraint ranking is summarized below.

(62) Constraint ranking (cf. (49))

*CENTRAL

PC_{OUT}(back) PC_{IN}(back)

PC_{IN}(high) PC_{OUT}(high)

Ranking arguments are recalled below.

(63) Ranking arguments (cf. (51))

<u>Ranking</u>	<u>Consequence</u>
*CENTRAL>> PC_{OUT}(back), PC_{IN}(back)	Central vowels are avoided at the cost of merging backness.
PC_{OUT}(back) >> PC_{OUT}(high), PC_{IN}(high)	Front-back neutralizations are accumulated in a scenario by merging height.

In short, central vowels are avoided and this results in some mergers in backness. But those mergers tend to be accumulated in a scenario onto one output rather than distributed among outputs. This is at the cost of merging height.

Let us now go back to the actual shift and explain why /e/ does not raise all the way to [i] but stops at the lax vowel [ɪ]. I call it the incomplete shift. In the following tableau, the scenario where /e/ stops at [ɪ] (scenario A, the incomplete shift) is compared to scenarios where it raises all the way to [i] (scenarios B and C). Each scenario contains five inputs, one of which is the high lax vowel [ɪ]. In scenario A, the high lax vowel is one of the outputs. In the other two scenarios, it does not surface. In scenario B, it maps onto [i]. In scenario C, it deletes.

(64) Incomplete shift

Scenarios		*CENTRAL	PC$_{IN}$ (bk)	PC$_{OUT}$ (bk)	PC$_{IN}$ (high)	PC$_{OUT}$ (high)	*ɪ
A. Actual ☞ i ← ɨ ɪ ▲ e ← a	/bać/ → beć /beć/ → bɪć /bɪć/ → bɪć /bić/ → bić /bɨć/ → bić		* {/i/, /ɨ/}	* [i]	* {/e/,/ɪ/}	* [ɪ]	**
B. Raising to [i] i ← ɨ ɪ e ← a	/bać/ → beć /beć/ → bić /bɪć/ → bić /bić/ → bić /bɨć/ → bić		***! {/i/, /ɨ/} {/e/, /ɨ/} {/ɪ/, /ɨ/}	* [i]	***** {/e/, /ɪ/} {/e/, /i/} {/ɪ/, /i/} {/e/, /ɨ/} {/ɪ/, /ɨ/}	* [i]	
C. Raising to [i] i ← ɨ ɪ e ← a ∅	/bać/ → beć /beć/ → bić /bɪć/ → ∅ /bić/ → bić /bɨć/ → bić		**! {/i/, /ɨ/} {/e/, /ɨ/}	* [i]	** {/e/, /i/} {/e/, /ɨ/}	* [i]	

Scenario A, the incomplete shift, is optimal since it merges the fewest number of input pairs (in both backness and height). This is reflected in the violation marks for input-oriented PC constraints. In scenario A, there is only one input pair that merges backness and only one that merges height. In the other two scenarios, scenarios B and C, there are more such input pairs. Thus, raising “half way,” as in the actual scenario, reduces the number of input pairs that participate in neutralizations.

In traditional terms, the actual scenario in Kashubian is non-structure-preserving. It contains an output that does not surface elsewhere in the language, the [ɪ] output. A non-structure-preserving scenario, like the one in Kashubian, reduces the number of input mergers in a scenario. This is because it contains more outputs than the competing scenarios in the same candidate set, and thus offers more possibilities for the same inputs to map onto. At the same time, since it contains more outputs, it incurs more markedness violations.

Therefore, for a non-structure-preserving scenario to win it is more important to improve on input-oriented PC than to improve on markedness. In Kashubian, the actual scenario violates the markedness constraint *ɪ since it contains the [ɪ] output. But because *ɪ is ranked lower than conflicting input-oriented PC constraints, the non-structure-preserving scenario wins.[19]

The [ɪ] vowel in scenarios B and C does not surface. This raises an interesting question: what happens to inputs that never surface? Two possibilities are entertained here, they either delete (as in scenario C) or map onto one of the existing outputs (as in scenario B). In our example, there is no difference between the two alternatives. However, since deletion incurs mergers of the V/∅ type, it may be non-optimal in a language where V/∅ mergers are highly marked.

To conclude, in Kashubian raising is forced by the process of fronting. Formally, it is a result of a high-ranked markedness constraint against central vowels and a high-ranked PC constraint on the accumulation of backness mergers in a scenario. Thus, a parallel is established with the Finnish chain shift discussed in section 4.

1.6 PC as Faithfulness and Markedness

In standard Optimality Theory phonological mappings are accounted for by the relative ranking of markedness and faithfulness constraints. Markedness constraints demand output well-formedness. Faithfulness constraints call for input-output identity.

The two often conflict and their conflict is resolved by constraint ranking. When markedness outranks conflicting faithfulness, a phonological process takes place. With the opposite ranking, a phonological process is blocked.

In PC theory some of the role previously assigned to markedness and faithfulness constraints is taken over by novel PC constraints. As will be explained below, PC constraints infringe on the territory previously assigned to markedness and faithfulness. Since PC constraints take on some of the role of both markedness and faithfulness, they somewhat blur the distinction between the two seemingly distinct families of constraints. Let us consider the dual nature of PC constraints.

PC as Faithfulness. Standard faithfulness requires input-output identity in a particular phonological property. Thus, when ranked above conflicting markedness, faithfulness constraints block a phonological process. Like standard faithfulness, PC constraints block a phonological process when ranked higher than conflicting markedness and allow it to apply with the opposite ranking. This was shown in section 1.3 with the example of final devoicing. When PC against the voicing merger outranked markedness against voiced obstruents syllable-finally, final devoicing was blocked. It was more important to preserve the voicing contrast than to satisfy markedness. When, on the other hand, markedness was ranked higher than the conflicting PC constraint, final devoicing took place. Markedness satisfaction was the top priority. The rankings for neutralization and the lack of it are recalled below.

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[19] Structure preservation figures prominently in the work of Kiparsky (1968, 1971). Kiparsky proposes that lexical rules have to be structure preserving. It thus follows that they have to be neutralizing. This goes hand in hand with the generalization of PC theory, by which a structure-preserving scenario incurs more input mergers (thus is more neutralizing) than a competing non-structure-preserving scenario.

(65) Neutralization and the lack of it

Final devoicing *VOICEDOBSTRUENT]$_\sigma$ >> PC_{IN}(voice), PC_{OUT}(voice)

No devoicing PC_{IN}(voice), PC_{OUT}(voice) >> *VOICEDOBSTRUENT]$_\sigma$

Both PC constraints and standard faithfulness ensure contrast preservation but only PC constraints allow for contrast transformation. PC constraints are satisfied even when a given underlying contrast is transformed into a different surface contrast. Standard faithfulness does not allow for that. Thus, if the obstruent voicing contrast is manifested by contrast in vowel length, PC constraints are satisfied but standard faithfulness constraints are violated.

In other words, standard faithfulness constraints do not distinguish between the loss and transformation of a phonological property, treating the two as equal violations of a given faithfulness constraint. PC constraints, in turn, favor transformation to the loss of contrast. One can then ask whether in PC theory contrast transformation is not always better than the loss of contrast. After all, transformation preserves contrast. But transformation has consequences for a system of mappings. Transformation results in additional mergers, some of which may be disallowed in a given grammar. These are some of the differences between PC and standard faithfulness. Let us now move on the discussion of PC as markedness

PC as Markedness. Markedness constrains are constraints on output well-formedness. When ranked higher than conflicting faithfulness, they force a phonological process. PC constraints take on some of the role of markedness, in that they are able to activate a phonological process. In section 1.4 we have seen an example of a Finnish chain shift, where the latter process in the shift, the process of rounding, is forced by a high-ranking PC constraint on the accumulation of length mergers in a scenario. In section 1.5 we have seen an example of a Kashubian shift where raising is forced by a PC constraint on the accumulation of backness mergers in a scenario. The relevant rankings are recalled below.

(66) Chain shift rankings

Finnish	$*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(long) >> PC_{OUT}(round), PC_{IN}(round)
Kashubian	*CENTRAL >> PC_{OUT}(back) >> PC_{OUT}(high), PC_{IN}(high)

Unlike standard markedness, PC constraints can only activate a phonological process when there is another mapping that takes place in the system. In a chain-shift scenario, PC constraints can only force the latter mapping in the shift. The initial mapping has to take place for reasons of output well-formedness.

Thus we have seen that PC constraints act like both markedness and faithfulness constraints in standard OT. They combine the properties of the two previously distinct forces in the grammatical system. This double identity of PC constraints follows from the architecture of PC theory and allows us to provide a uniform explanation of opaque (chain shifts) and transparent processes. Opaque processes are such that they cannot always be accounted for by markedness ranking. PC accounts for them.

It is important to note that PC constraints do not simply replace markedness and faithfulness constraints from standard OT, but they take on some of the role previously assigned to the two families of constraints. It is indispensable, however, to retain separate markedness and faithfulness constraints (though the constraints are formulated in slightly different terms than in standard OT).

Generalized Faithfulness. In PC theory, faithfulness constraints are required to rule out unnecessary movement. This becomes relevant when two scenarios tie on PC and markedness, but one of the scenarios involves too much disparity between its inputs and corresponding outputs. Faithfulness then rules in favor of the scenario where outputs are overall closer to their inputs. Generalized faithfulness is also necessary to determine directionality of movement in a scenario.

Tokenized Markedness. Markedness constraints in PC are indispensable to ignite a shift. As we have seen, in Finnish, if there were no high-ranking markedness against tri-moraic syllables, there would be no shift – no shortening and thus no rounding. PC by itself can force the latter step in the shift, such as rounding, but it cannot force the initial step, such as shortening. Only markedness can do so. Tokenized markedness also determines the directionality of movement in a scenario.

In the PC proposal, generalized faithfulness and tokenized markedness constraints are in themselves a combination of markedness and faithfulness constraints. They both access information about the output (like standard markedness) and information about input-output disparity (like standard faithfulness). The question arises: are faithfulness and markedness ever distinct? Where is the boundary between the two types of constraints? PC theory suggests that the boundary between faithfulness and markedness is no longer clear-cut, and constraints infringe on the territory of markedness and faithfulness. The role of such constraints and their properties are further investigated in the following chapters.

CHAPTER 2

TYPOLOGICAL IMPLICATIONS

2.1 Introduction

The key concept in the PC theory is the interaction between mappings and the notion of a scenario. A scenario, as described in chapter 1, consists of a set of phonological mappings that cohere as a system. Mappings interact in various ways. The key idea is that only by evaluating sets of mappings simultaneously can all the relevant relations between mappings be traced. Otherwise, if mappings were considered in isolation, some valuable insights into the workings of a phonological system would be lost.

Mappings in a scenario are Input-Output. Scenario-inputs are generated by Gen. For a given underlying form, Gen returns scenario-inputs as its value. These are all inputs that can potentially interact. Outputs in a scenario constitute a subset (possibly improper) of the input. There is nothing in the output that is not also in the input. Scenarios in a candidate set contain the same inputs but differ in the set of outputs and/or input-output relations even if outputs are the same. In a tableau, only a subset of mappings from a scenario is represented. In Finnish, these are the interacting processes of shortening and rounding. For a detailed discussion of scenario construction, see chapter 1, section 2.1.

In the remaining part of this chapter I will consider all logically possible scenarios competing with the actual low-vowel-shift scenario in Finnish. These constitute the competition set for the actual scenario. We need to make sure that it is the actual scenario that is chosen over its competitors. It is also important to ensure that every other empirically attested scenario from the set of competitors will be optimal under some constraint ranking, and that unattested scenarios will never win. The remainder of this chapter addresses these three goals.

2.2 Logically Possible Scenarios

Let us first establish the set of logically possible scenarios that belong to the same candidate set as the actual scenario in Finnish. When discussing scenarios, I will consider interacting processes only. In Finnish, those are processes of shortening and rounding. They can be represented by four minimally distinct inputs, /aai/, /ooi/, /ai/, /oi/. The inputs are minimally distinct in vowel length, {/aai/, /ai/}, {/ooi/,/oi/}, and vowel rounding, {/aai/, /ooi/}, {/ai/, /oi/}. All scenarios in a candidate set contain the same inputs.[1]

Two of the four inputs cannot be used as outputs, as they violate high-ranked markedness against tri-moraic syllables. Scenarios with such outputs would lose to any other scenario in a candidate set since they violate high-ranked markedness, and thus will not be considered. Since in a scenario outputs are a subset of the inputs and two of the inputs cannot be used as outputs, there are only two possible outputs in a scenario, [ai] and [oi]. Altogether, there are 16 logically possible scenarios to be considered. These are shown below.[2]

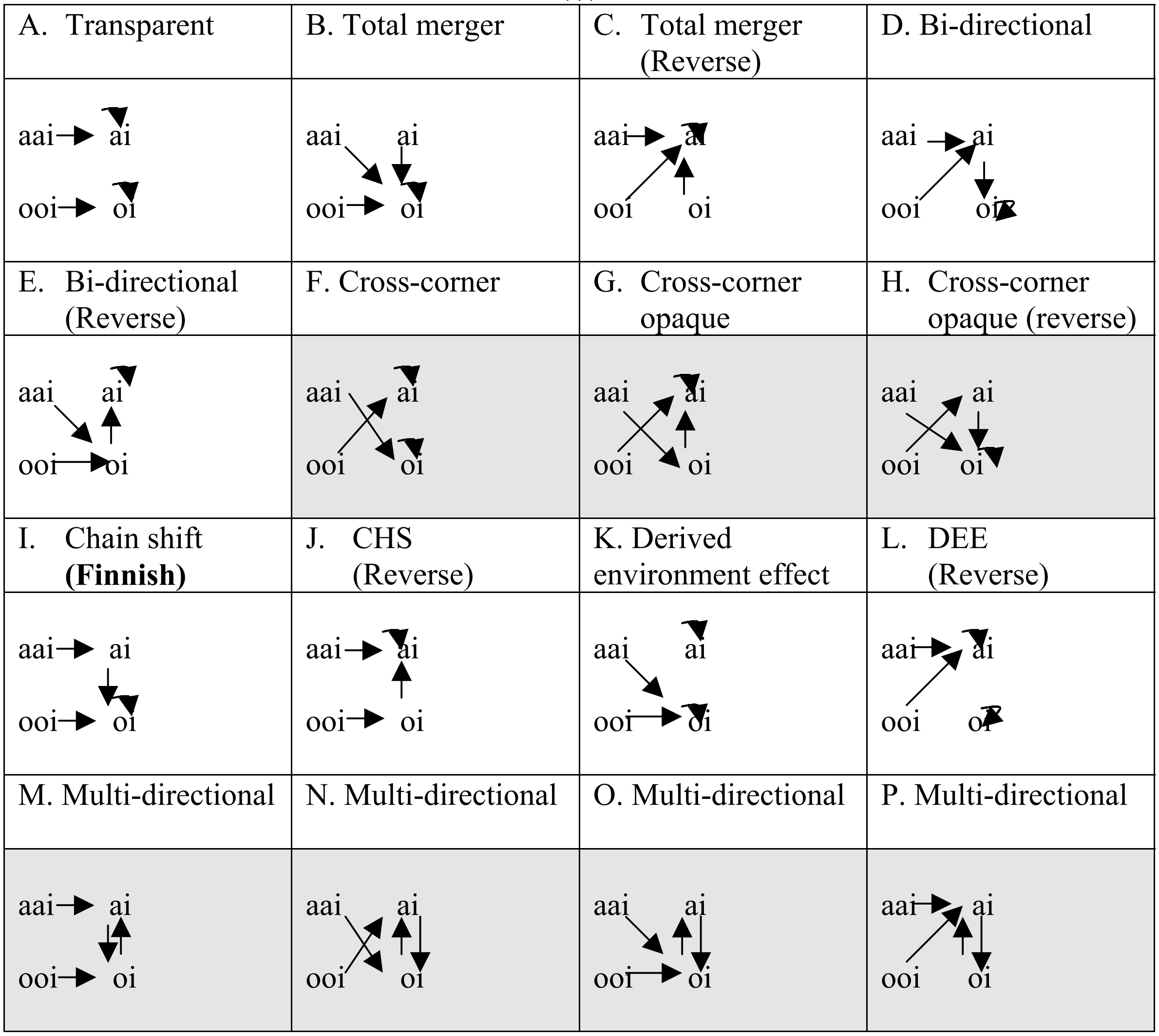
Below is the full set of logically possible scenarios involving the four inputs. Scenarios are labeled according to the types of mappings they contain. Some labels are familiar, others will be explained as we go along. Row one starts with scenarios where

[1] As described in chapter 1, Gen generates more than these four inputs. For an underlying form of length n, the set of scenario inputs contains all forms of length 0…2n+1. But the set of inputs that is ultimately shown in a tableau is a subset of those. In practice, it contains forms that contrast minimally on the arguments of the relevant PC constraints. In Finnish, these are properties of length and rounding, the arguments of PC(long) and PC(round) constraints.

[2] In case of deletion, the output with deletion is also part of the input set (see chapter 5).

rounding applies transparently: (i) there is either no rounding (scenario A), or (ii) rounding or lowering applies to all forms subject to it (scenarios B, C). The next two cells present bi-directional scenarios - those involve both rounding and lowering each. Opaque scenarios, chain shift and derived environment effect, are represented in row three. Row four shows scenarios that involve movement in various directions, thus called multi-directional. Scenarios called reverse constitute a mirror image of an immediately preceding scenario. Unattested scenarios are shaded. (Bi-directional scenarios and the derived-environment effect are discussed separately in section 2.3.)

(1) Full typology (given top-ranked $*\sigma_{\mu\mu\mu}$)



The actual scenario in Finnish is the chain-shift scenario, scenario I (row three). A competing transparent scenario with no rounding is shown in A (top left).

This is a significantly large number of scenarios to be evaluated. However, some of the scenarios are unattested. These are the shaded scenarios. In OT, to ensure that a mapping is unattested, it must be the case that there exists no constraint ranking under which a mapping would win. Such mapping is then harmonically bounded by its competitors. The same is true for scenarios in the PC theory. As will be shown below, given the inventory of constraints in the PC theory (*Eval* of PC), some of the scenarios will never come out optimal, regardless of the constraint ranking.

2.3 Harmonic Bounding

Let us start by determining the set of scenarios that can never come out optimal regardless of the constraint ranking, called harmonically bounded scenarios. Scenarios that are left after harmonic bounding are predicted to win in some language (under some constraint ranking).

Harmonic bounding is illustrated in the following tableau. Harmonically bounded scenarios are shaded. The following tableau contains every constraint of the PC Theory that is relevant in the evaluation process.[3] Scenarios in the candidate set correspond to the ones shown in (1). For reasons of space, I do not draw out each of the scenarios in the tableau. (For diagrams see (1).) Violation marks of constraints will be explained as we go along. See section 2.5 for discussion. The two stages of Eval, stage one with PC and markedness, and stage two with faithfulness, are separated with a double line.

[3] There is a relational PC constraint not considered here, PC_{REL}(long). This constraint is satisfied vacuously by each candidate scenario since none of them has a length contrast in the output (see (30), chapter 1 for a definition).

(2) Harmonic bounding

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (rd)	PC_{OUT} (long)	PC_{IN} (long)	PC_{OUT} (rd)	PC_{IN} (rd)	*ai	*oi	(-rd)-Faith	(+rd)-Faith
A. Transparent			**	**			**	**	*	*
B. Total merger			*	****	*	****		****		****
C. Total merger (reverse)			*	****	*	****	****		****	
D. Bi-directional		*			**	**	**	**	***	*
E. Bi-directional (reverse)		*			**	**	**	**	*	***
F. Cross-corner			**	**	**	**	**	**	**	**
G. Cross-corner			*	**	*	**	***	*	***	**
H. Cross-corner			*	**	*	**	*	***	**	***
I. CHS			*	**	*	**	*	***	*	**
J. CHS (reverse)			*	**	*	**	***	*	**	*
K. DEE			*	**	*	**	*	***		***
L. DEE (reverse)			*	**	*	**	***	*	***	
M. Multi-directional			**	**	**	**	**	**	**	**
N. Multi-directional			**	**			**	**	***	***
O. Multi-directional			*	**	*	**	*	***	*	****
P. Multi-directional			*	**	*	**	***	*	****	*

The constraint inventory shows that seven of the 16 scenarios in (1) are harmonically bounded. That is, they will never come out optimal. Scenarios are harmonically bounded either on PC in stage one of Eval (this is when they merge too many types of contrasts, involve too many input pairs in a merger, or contain too many ambiguous outputs), or on faithfulness in stage 2 of Eval (this is when they involve too much movement). Arguments for harmonic bounding are given below.

(3) Arguments for harmonic bounding

(i) The cross-corner scenarios, G and H, and multi-directional scenarios, O and P, are harmonically bounded by the opaque scenarios, I through L. They involve the same PC and markedness violations as the competing opaque scenarios but contain too much movement. That is, in these scenarios outputs and their corresponding inputs are too different from each other. Thus, these scenarios are harmonically bounded on FAITHFULNESS in stage 2 of Eval. The relevant tableaux follow. (Scenarios are grouped into the relevant tableaux according to the directionality of movement in a scenario, reflected by markedness violations, *ai and *oi.) The scenarios with rounding are presented first, followed by the ones with lowering.

Fewer unfaithful [ai]'s (=rounding)

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (rd)	PC_{OUT} (lg)	PC_{IN} (lg)	PC_{OUT} (rd)	PC_{IN} (rd)	*ai	*oi	(-rd) Faith	(+rd) Faith
H. Cross-corner			*	**	*	**	*	***	**	***
I. CHS			*	**	*	**	*	***	*	**
K. DEE			*	**	*	**	*	***		***
O. Multi-direct.			*	**	*	**	*	***	*	****

Fewer unfaithful [oi]'s (=lowering)

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (rd)	PC_{OUT} (lg)	PC_{IN} (lg)	PC_{OUT} (rd)	PC_{IN} (rd)	*ai	*oi	(-rd) Faith	(+rd) Faith
G. Cross-corner			*	**	*	**	***	*	***	**
J. CHS (reverse)			*	**	*	**	***	*	**	*
L. DEE(reverse)			*	**	*	**	***	*	***	
P. Multi-direct.			*	**	*	**	***	*	****	*

This shows that in PC theory, when scenarios tie on PC and markedness in stage 1 of Eval (see above), faithfulness in stage 2 chooses in favor of a scenario where inputs are overall closer to their outputs. In this case, those are the opaque (non-shaded) scenarios.

(ii) Similarly, the multi-directional scenario N is harmonically bounded by the transparent scenario A on FAITHFULNESS.

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (rd)	PC_{OUT} (lg)	PC_{IN} (lg)	PC_{OUT} (rd)	PC_{IN} (rd)	*ai	*oi	(-rd) Faith	(+rd) Faith
A. Transparent			**	**			**	**	*	*
N. Multi-direct.			**	**			**	**	***	***

The two scenarios incur the same PC and markedness violations (stage 1 of Eval), but the multi-directional scenario violates faithfulness too much (stage 2), and thus will never win over the competing transparent scenario.

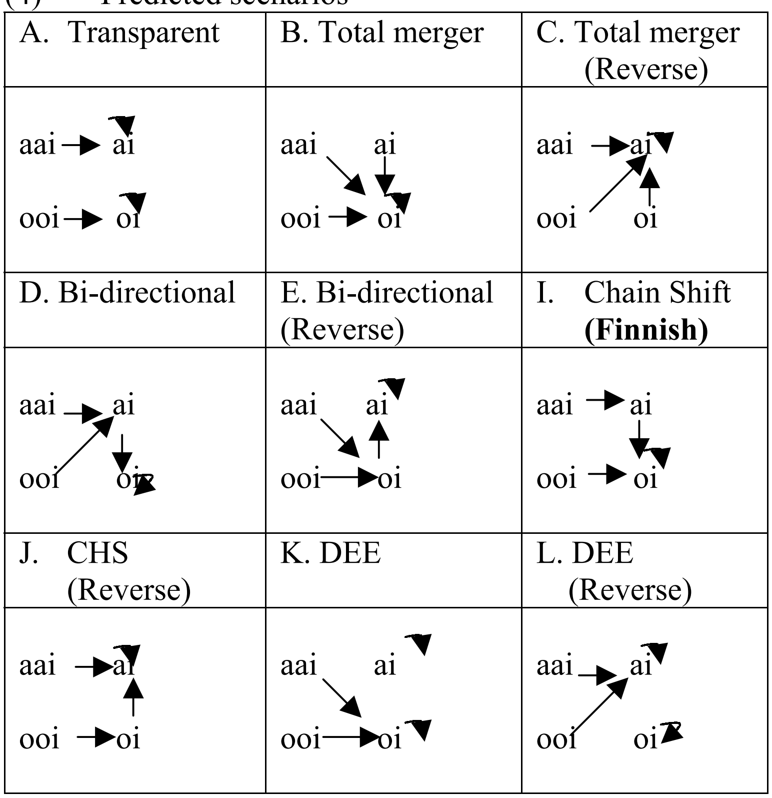
(iii) Finally, the cross-corner scenario F and the multi-directional scenario M are harmonically bounded by the transparent scenario A even before FAITHFULNESS comes into play. They fare the same on markedness but violate too many types of PC constraints.

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (rd)	PC_{OUT} (lg)	PC_{IN} (lg)	PC_{OUT} (rd)	PC_{IN} (rd)	*ai	*oi	(-rd) Faith	(+rd) Faith
A. Transparent			**	**			**	**	*	*
F. Cross-corner			**	**	**	**	**	**	**	**
M. Multi-direct.			**	**	**	**	**	**	**	**

The transparent scenario merges along fewer dimensions of contrast (it does not violate PC(round) constraints at all), and thus wins over the two competing scenarios, regardless of the constraint ranking.

The following table shows the set of predicted scenarios. Harmonically bounded scenarios have been excluded. To the best of my knowledge, this prediction coincides with the set of empirically attested phenomena (see next section for examples).[1]

(4) Predicted scenarios



The above table includes a transparent scenario with no rounding, a total merger scenario where rounding applies across the board, a bi-directional scenario with rounding and lowering, and two opaque scenarios, the chain-shift scenario from Finnish and a

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1 The claim here is about mapping interactions represented in (4) and not about the exact mappings.

competing derived-environment effect. For each scenario (except for the transparent scenario), there is a corresponding mirror-image effect, which I call a reverse scenario.

In the next section, I will give examples of attested scenarios. The scenarios that will be illustrated in the following section are not exactly like the scenarios given in (4), but they contain the same types of mappings, and thus represent the same types of scenarios. The overall geometry of the mappings is the same even though the features involved might be different.

2.4 Examples of Attested Scenarios

This section gives examples of attested scenarios. Scenarios differ in contrast preservation. In some, contrast is preserved transparently: a given output contrast corresponds to an identical input contrast. In others, contrast is preserved in an opaque way: a given input contrast is transformed into a different output contrast (contrast transformation takes place).

2.4.1 Transparent Scenarios

In a transparent scenario (see (4a)), a process applies to all forms in the language that are subject to it. For example, final devoicing in Polish applies to all voiced obstruents in word-final position (Rubach 1984). Thus, the underlying voicing contrast is neutralized on the surface for all voiced-voiceless input pairs in word-final context but preserved elsewhere.[2] Otherwise, contrasts are retained in the same way in which they are represented underlyingly.

Sometimes more than one process applies in a scenario, just as in the total-merger scenario. In a total-merger scenario, processes are in a feeding relation such that various inputs map onto one and the same output. The example given in (4) is of a language

[2] Neutralization also occurs in the environment of voicing assimilation.

where long vowels shorten and become rounded, and identical short vowels undergo rounding as well. Thus, many input contrasts are neutralized on the surface. The properties of transparent scenarios versus opaque scenarios will be discussed throughout this chapter.

Let us now move on to opaque scenarios: chain shifts, derived-environment effect, and bi-directional scenarios, in which contrasts are preserved but in a different way than in the input.

2.4.2 Opaque Scenarios

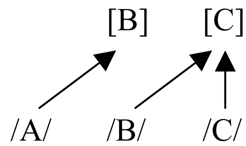
2.4.2.1 Derived-Environment Effect

In the previous chapter we discussed one example of an opaque mapping, a chain shift effect. A derived-environment effect (Mascaró 1976, Kiparsky 1982, Rubach 1984) provides another example. It was observed in chapter 1 that opacity involves contrast transformation. In an opaque mapping, some underlying contrast is preserved on the surface but manifested as a different surface contrast. Some original contrast is lost as a result. Both chain shifts and derived-environment effects have this property.

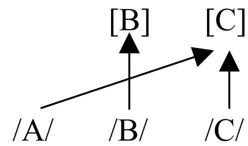
Given an A-B-C scale of similarity, in a chain shift, /A/→[B] and /B/→[C]. In a derived environment, on the other hand, /A/→[C] and /B/→[B].[3] In both scenarios, contrast between /A/ vs. /B/ is preserved and manifested as [B] vs. [C]. The only difference between chain shifts and derived-environment effects is what inputs map onto particular outputs. This is represented schematically below.

[3] This is called a derived-environment effect, since [B]'s are avoided only when they are "derived" and not underlying. In OT, "derived" means originating from a different source than itself.

(5) a. Chain shift



b. Derived-environment effect



In chain shifts, /A/ vs. /B/ → [B] vs. [C], whereas in a derived-environment effect, /A/ vs. /B/ → [C] vs. [B]. Differences between chain shifts and derived-environment effects are discussed in more detail in section 2.5.4.

We have already seen examples of a chain shift (see chapter 1 for Finnish and Kashubian). I will now illustrate two cases of derived-environment effects: the interaction of final devoicing and vowel raising in Polish, and the interaction of final devoicing and vowel lengthening in Friulian.

In Polish, obstruents devoice word-finally (see (6a)). But when the obstruent is preceded by a mid back vowel, devoicing is accompanied by vowel raising (shown in (6b)) (Grzegorczykowa *et al.* 1984, Gussmann 1980). Crucially, there is no raising before an underlyingly voiceless obstruent (see (6c)). Unlike mid vowels, high vowels remain high before both "devoiced" and underlyingly voiceless obstruents (see (6d)).

(6) Raising and final devoicing in Polish[4]

a. Final devoicing

nom.sg. or nom.pl	*gen.pl. or nom.sg.*	
te[z]a	te[s]	'hypothesis'
wa[d]a	wa[t]	'fault'
chle[b]y	chle[p]	'bread'

[4] The data presented here only include nouns, but raising also occurs in other morphological categories: verbs, adjectives, pronouns (see Grzegorczykowa et al. 1984, pp. 85-87, Gussmann 1980, pp. 113-130). Raising also occurs in closed syllables before sonorants: –r, -l, -w, -j, but since in those cases it is restricted to native vocabulary only (see Gussmann 1980), I will treat it as a separate process.

b. Vowel raising

k[oz]a	k[us]	‘goat’
l[od]y	l[ut]	‘ice’
r[og]i	r[uk]	‘horn’

c. No raising

k[os]a	k[os]	‘scythe’
l[ot]y	l[ot]	‘flight’
r[ok]u	r[ok]	‘year’

d. No lowering

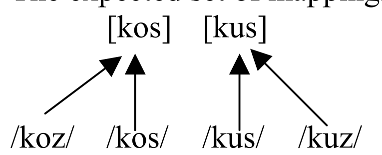
b[ud]a	b[ut]	‘kennel, shed’
b[ut]y	b[ut]	‘shoe’

The interaction of raising and final devoicing in Polish is an example of a derived-environment effect. Underlying /koz/ becomes surface [kus] with devoicing and raising, skipping over a more similar output [kos], even though there are surface instances of [kos] in Polish. The actual set of mappings is given below (it is compared to a hypothetical chain shift effect in (7b)):

(7) a. Derived-environment effect b. Chain shift

Polish raising and other derived-environment effects, similar to chain shifts discussed in the previous chapter, are not admitted to classic Optimality Theory (Prince and Smolensky 1993). OT is output-oriented. If [kos] is an acceptable output in Polish, then we expect /koz/ to map onto [kos] and not onto a more distant form [kus] (/koz/→[kos], *[kus]). Instead, in the actual mapping, final devoicing is accompanied by raising, causing the fell-swoop of /koz/ to [kus]. The problem is to explain why raising takes place. The expected set of mappings is given below.

(8) The expected set of mappings



Derived-environment effects are part of the synchronic grammar. Another example comes from Friulian (Baroni and Vanelli 2001, Hualde 1990, Repetti 1992, 1994, 2001). Friulian, like Polish, has a process of final devoicing, and final devoicing interacts with vowel lengthening, just as it interacts with vowel raising in Polish. In Friulian, vowels lengthen before devoiced obstruents but remain short before underlyingly voiceless obstruents. Some examples follow. Each voiced pair is followed by a voiceless pair.

(9) Lengthening and final devoicing in Friulian (cf. Polish in (6))

[ˈl**ad**e]	[ˈl**a:t**]	‘gone (f.) / (m.)’
[l**aˈt**a]	[ˈl**at**]	‘to breast-feed / milk’
[fiˈn**id**e]	[fiˈn**i:t**]	‘finished (f.) / (m.)’
[ˈm**at**e]	[ˈm**at**]	‘crazy (f.) / (m.)’
[l**uˈz**o:r]	[ˈl**u:s**]	‘diffuse light / light’
[ˈr**ɔs**e]	[ˈr**ɔs**]	‘red (f.) / (m.)’

This is problematic for standard OT. Why should devoicing be accompanied by vowel lengthening since there are surface instances of voiceless obstruents with a short vowel in the same context? We expect voiced obstruents to devoice word-finally, but there is no reason for the preceding vowel to lengthen (/ad/→[at], *[a:t]). In terms of mappings, there is no reason to map onto a more distant output when a more similar output is available. The question then is why lengthening takes place.

I will argue that lengthening allows preservation of the contrast between words that differ underlyingly in voiced-voiceless obstruent. Lengthening keeps the contrast, even though the obstruent devoices (see section 2.5).

Some other cases of derived-environment effects come from Campidanian Sardinian (Bolognesi 1998), Makassarese (McCarthy and Prince 1994), Polish (Gussmann 1980, Rubach 1984), Tiberian Hebrew (Prince 1975), Slovak (Rubach 1993).

2.4.2.2 Bi-directional Scenario

We are left with one other opaque scenario from the set of attested scenarios in (4). This is the bi-directional scenario. An example of a bi-directional scenario comes from the history of nasal vowels in Polish (Comrie and Corbett 1993, Rospond 1971, Rothstein 1993).

In the history of Polish, some nasal vowels lowered, others raised. As reported, lowering applied to underlying long nasal vowels (10a), and raising targeted their short counterparts (10b).

(10) a. Lowering (and shortening) (nom.sg.masc.)

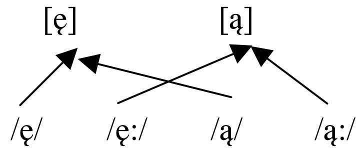
ę: > ą	*r[ę:]d	>	rz[ą]d	"row"
ą: > ą	* m[ą:]ż	>	m[ą]ż	"husband"

b. Raising (gen.sg.masc.)

ę > ę	* r[ę]du	>	rz[ę]du	"row"
ą > ę	* m[ą]ża	>	m[ę]ża	"husband"

As a result, contrast was preserved between underlying short and long nasal vowels. The two kinds mapped onto distinct outputs. Long nasal vowels mapped onto low vowels (10a). Short nasal vowels mapped onto mid vowels (10b). This is shown schematically below.

(11) Bi-directional scenario



The bi-directional scenario is opaque since it contains an output height contrast that does not correspond to any minimal instance of an input height contrast. It posits an underlying opposition that does not have any surface correlates (absolute neutralization). In the bi-directional scenario, every instance of the input-length contrast is preserved in the output and realized as height contrast. For a more detailed discussion of a bi-directional scenario see section 2.5.*2 Limits on Transformation*.

2.5 The Analysis: A Comprehensive View

We are now ready to present a comprehensive analysis of the low-vowel shift in Finnish, considering all the empirically attested scenarios in (4) that compete with the actual scenario. In the course of the discussion, I will establish a complete constraint ranking, under which the chain-shift scenario comes out optimal. The basic argument has been already developed in chapter 1, section 4. It will be recalled below and augmented so that the additional empirically attested scenarios shown in (4) are eliminated in favor of the actual scenario.

2.5.1 Chain Shift as Contrast Transformation

Recall that chain shifts involve *contrast transformation.* A given contrast is preserved on the surface but manifested in a different way than in the original form. This is at the expense of neutralizing some other contrast (contrast transformation). Contrast transformation minimizes the number of ambiguous outputs in a scenario (see chapter 1, section 4).

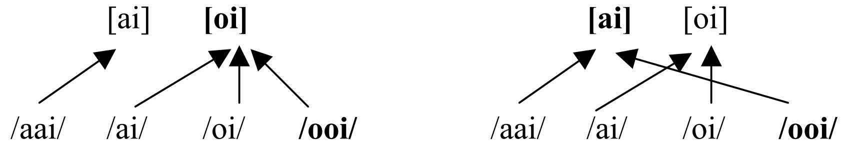
In Finnish, long vowels shorten, incurring some length mergers in a scenario, but despite shortening, length contrast is preserved on the surface for one minimal pair of inputs and is realized as a surface contrast in rounding. Some original rounding contrast is lost as a result. This improves on the distribution of length mergers in a scenario. Due to rounding, there are fewer outputs ambiguous in length. The ranking for Finnish is recalled below.

(12) $*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(long), PC_{IN}(long) >> PC_{OUT}(round), PC_{IN}(round)
(See chapter 1, section 4 for discussion.)

2.5.2 Limits on Transformation

However, under the current ranking, there is another scenario that comes out optimal. This is the scenario that does not incur any length mergers at all and thus satisfies the high-ranking constraints against length mergers, PC_{OUT}(long) and PC_{IN}(long). It is called a bi-directional scenario. The actual scenario with some length mergers and the competing bi-directional scenario with no length mergers are represented below.

(13) a. Chain-shift scenario b. Bi-directional scenario



The two scenarios differ in mapping for underlying /ooi/. Underlying /ooi/ shortens in both scenarios, but in the bi-directional scenario, it also undergoes lowering. Thus, in the bi-directional scenario, contrast is preserved between long and short vowels for each input pair.

The bi-directional scenario is optimal under the current constraint ranking. The following tableau shows it formally.

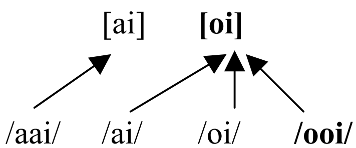
(14) Current constraint ranking – wrong result

Scenarios		$*\sigma_{\mu\mu\mu}$	PC_{IN} (long)	PC_{OUT} (long)	PC_{IN} (round)	PC_{OUT} (round)
A. Chain shift ☜ aai → ai ↓ ooi → oi	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi		** {/ai/, /ooi/} {/oi/, /ooi/}	*! [oi]	** {/ai/,/oi/} {/ai/,/ooi/}	* [oi]
B. Bi-directional ☞ aai → ai ↓ ooi oi	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → ai				** {/ai/,/oi/} {/aai/,/ooi/}	** [oi] [ai]

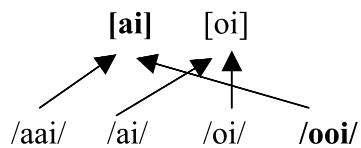
The bi-directional scenario, scenario B, satisfies high-ranking PC(long) constraints, PC_{IN}(long) and PC_{OUT}(long), since it does not merge length at all. The chain-shift scenario, scenario A, loses since it merges some input-length contrasts. This result is wrong. We need to ensure that it is the chain-shift scenario that surfaces in Finnish.

In the bi-directional scenario (14b), the length contrast is preserved for each pair of inputs and realized as a surface rounding contrast; long and short vowels map onto outputs distinct in rounding. As a result, each minimal rounding contrast from the input is neutralized, /aa/ vs. /oo/ → [a] and /a/ vs. /o/ → [o]. In a chain-shift scenario (14a), on the other hand, contrast is preserved for one minimal pair of inputs distinct in length and realized as a surface rounding contrast, /aa/ vs. /a/ → [a] vs. [o]. The other minimal length contrast, /oo/ vs. /o/, neutralizes. This results in the neutralization of one minimal rounding contrast, /a/ vs. /o/ → [o]. The other rounding contrast, /aa/ vs. /oo/, is retained in the output. The diagrams below show what minimal input contrasts are preserved in both types of scenarios.

(15) a. Chain-shift scenario



b. Bi-directional scenario



<u>Preserved contrasts</u>:

length: /aa/ vs. /a/	length: /aa/ vs. /a/, /oo/ vs. /o/
rounding: /aa/ vs. /oo/	rounding: none

In the chain-shift scenario, the output rounding contrast corresponds to both input minimal rounding and length contrasts. In the bi-directional scenario, on the other hand, the output rounding contrast corresponds to every input-length contrast but none of the minimal rounding contrasts. (The relation between contrasts is evaluated for minimal contrasts only.)

For chain shifts to be optimal, it must be more important to retain some minimal rounding contrasts from the input (to prevent absolute neutralization) than it is to avoid neutralizations of all length contrasts. This is the role of relational PC. The constraint is recalled below. The relevant constraint ranking follows.

(16) PC_{REL}(round) (cf. (30), chapter 1)
Assign a violation mark for a pair of outputs minimally contrasting in rounding that does not correspond to a pair of inputs minimally contrasting in rounding.

(17) PC_{REL}(round) >> PC_{OUT}(long), PC_{IN}(long)

The bi-directional scenario violates the PC_{REL} constraint, since in this scenario, none of the minimal rounding contrasts from the input are preserved in the output. The pair of outputs that contrast in [round], i.e., [ai] and [oi], does not correspond to any inputs that contrast for this feature. A chain-shift scenario satisfies this constraint since in a chain shift one of the minimal rounding contrasts is preserved on the surface. This is at the cost of merging some length contrasts. This is illustrated in the following tableau.

(18) CHS is preferred over bi-directionality

Scenarios		PC_{REL} (rnd)	PC_{IN} (lg)	PC_{OUT} (lg)	PC_{IN} (rnd)	PC_{OUT} (rnd)
A. Chain shift ☞ aai → ai ↓ ooi → oi ↻	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi		** {/ai/, /ooi/} {/oi/, /ooi/}	* [oi]	** {/ai/,/oi/} {/ai/,/ooi/}	* [oi]
B. Bi-directional aai → ai ↗ ↓ ooi oi ↻	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → ai	*!			** {/ai/,/oi/} {/aai/,/ooi/}	** [oi] [ai]

The chain-shift scenario wins under this ranking. Unlike the bi-directional scenario, it merges length contrasts but preserves a minimal rounding contrast from the input. This is preferred to avoiding length mergers altogether, as in the bi-directional scenario.

The augmented constraint ranking is given below.

(19) $*\sigma_{\mu\mu\mu}$ PC_{REL}(round)

PC_{OUT}(long) PC_{IN}(long)

PC_{OUT}(round) PC_{IN}(round)

In short, even though the bi-directional scenario satisfies PC(long) constraints, since it does not cause any length mergers in the system, it loses to the chain-shift scenario that incurs some violations of those constraints. The bi-directional scenario, unlike the chain-shift scenario, violates the high-ranking relational PC constraint, PC_{REL}(round). Since PC_{REL}(round) dominates PC constraints against length mergers (PC_{REL}(round) >> PC_{OUT}(long), PC_{IN}(long)), the bi-directional scenario is ruled out.[5]

2.5.3 Mirror Image Scenarios

Under the current constraint ranking, there are two scenarios that tie. This is the actual chain-shift scenario and its mirror image, reverse shift. The two scenarios differ only in the directionality of movement. The actual scenario contains rounding, while the reverse shift contains lowering. The two scenarios are represented below.

(20) a. Chain-shift scenario b. Reverse shift

Rounding, in the actual scenario, implies more tokens with rounded vowels than unrounded vowels. Lowering has the opposite effect. Our constraint ranking so far does not distinguish between the two scenarios.

In the rounding scenario (20a), both underlying round vowels, /oi/ and /ooi/, and a derived round vowel, /ai/, map onto a rounded output. In the reverse shift scenario, on the

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[5] Another way to rule out the bi-directional scenario is to use self-conjunction of output-oriented PC constraints. In this case, it would be self-conjunction of PC_{OUT}(round) (see Kirchner 1996; see also Smolensky 1993, 1997 for definition of local constraint conjunction). The bi-directional scenario would violate this constraint since it violates PC_{OUT}(round) twice (there are two outputs ambiguous in rounding). The chain-shift scenario would not violate the locally-conjoined constraint since it violates PC_{OUT}(round) only once. Since conjunction results in proliferation of constraints, I will not pursue it further. The self-conjunction analysis also leads to ranking ambiguity in the choice of the actual scenario. The actual scenario would win under either PC^2(rd) >> PC(lg) >> PC(rd) or PC^2(lg) >> PC(rd) >> PC(lg). We lose our original observation that in the opaque scenario, length is preserved at the cost of rounding.

other hand, there are more instances of unrounded vowels since they correspond to underlying low vowels, /ai/ and /aai/, and a derived low vowel, /oi/. For the actual shift to win, a markedness constraint against unrounded vowels must dominate a markedness constraint against rounded vowels. It is more important to avoid [ai]'s than it is to avoid [oi]'s. The relevant constraints and the ranking are given below.

(21) a. *ai
Assign a violation mark for every token [ai] in a scenario, where the number of tokens equals the number of inputs that map onto this output.

b. *oi
Assign a violation mark for every token [oi] in a scenario, where the number of tokens equals the number of inputs that map onto this output.

c. Markedness ranking
*ai >> *oi

For a discussion of tokenized markedness, see chapter 1, section 2.2.2. The ranking is illustrated in the following tableau.

(22) The role of tokenized markedness

Scenarios		*ai	*oi
A. Actual ☞ aai → ai ↓ ooi → oi ↺	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi	*	***
B. Reverse aai → ai ↺ ↑ ooi → oi	/aai/ → ai /ai/ → ai /oi/ → ai /ooi/ → oi	***!	*

The actual shift wins since it contains fewer unrounded tokens. The competing scenario with lowering contains more such tokens since there are more inputs in this scenario mapping onto [ai].

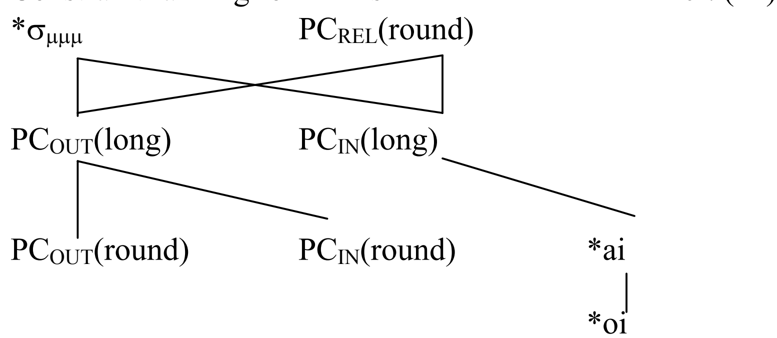
It is important to notice that not all instances of [ai]'s are avoided. This would be the case if all inputs merged onto rounded vowels, as in the total merger scenario. To avoid it, *[ai] must be ranked lower than a constraint against the total merger scenario. In Finnish, *[ai] must be dominated by PC_{IN}(long). The total merger scenario violates input-oriented PC too much.

(23) PC_{IN}(long) >> *ai

Scenarios		PC_{IN}(long)	*ai
A. Actual ☞ aai → ai ooi → oi	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi	** {/ai/, /ooi/} {/oi/, /ooi/}	*
B. Total merger aai → oi, ai → oi ooi → oi	/aai/ → oi /ai/ → oi /oi/ → oi /ooi/ → oi	****! {/ai/, /ooi/} {/oi/, /ooi/} {/ai/, /aai/} {/oi/, /aai/}	

The complete constraint ranking is given below.

(24) Constraint ranking for Finnish cf. (12)



Ranking arguments are recalled in section 2.5.5, *Summary Ranking*.[6]

[6] An alternative to tokenized markedness is an enriched theory of faithfulness or PC. Tokenized markedness seems a good alternative since it is needed in PC theory independently to initiate a chain shift effect and it is defined using the core property of PC theory - mappings evaluated as a system.

2.5.4 Chain Shift and Derived-Environment Effect

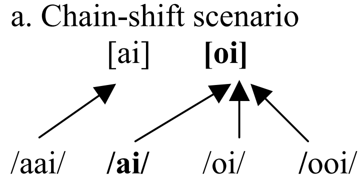
We now come to stage 2 of Eval. There are two scenarios that tie after stage 1. This is the actual chain-shift scenario and a competing derived-environment effect. We need to make the choice between the two. The two scenarios have the same outputs and involve the same types of movement, but they differ on which segments move and how much. The following tableau compares the two scenarios.

(25) A tie

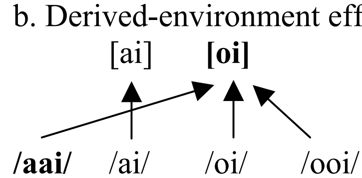
Scenarios	PC_{IN}(long)	PC_{IN}(rd)	PC_{OUT}(long)	PC_{OUT}(rd)	*ai	*oi
A. CHS /aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi	** {/ai/, /ooi/} {/oi/, /ooi/}	** {/ai/, /ooi/} {/ai/, /oi/}	* [oi]	* [oi]	*	***
B. DEE /aai/ → oi /ai/ → ai /oi/ → oi /ooi/ → oi	** {/aai/, /oi/} {/oi/, /ooi/}	** {/aai/, /ooi/} {/aai/, /oi/}	* [oi]	* [oi]	*	***

The two scenarios fare the same on PC and markedness constraints. However, they are distinct and we should be able to express that formally.

(26) a. Chain-shift scenario



b. Derived-environment effect



In a chain-shift scenario, movement is distributed among segments. The long low vowel shortens and the short low vowel rounds. Both segments undergo movement. In a derived-environment effect, on the other hand, movement is accumulated in one mapping in a scenario. The long low vowel both shortens and rounds. The short low vowel remains faithful.

Assume that outputs are divided into sets based on their value for a given P property, in this case, rounding. Assume furthermore that sets of properties differ in their resistance to unfaithful mappings. This is the idea behind the generalized faithfulness constraints introduced in chapter 1, section 2. The two scenarios differ in faithfulness of rounded and unrounded vowels. In the chain-shift scenario, both rounded and unrounded vowel outputs are unfaithful. In the derived-environment effect, on the other hand, the unrounded vowel output is fully faithful, but as a result, the rounded vowel output is worse on faithfulness than in the competing chain shift effect. Thus, for the chain shift to win, it must be more important to reduce unfaithfulness of rounded vowels than their unrounded counterparts.

In terms of constraints, the chain-shift scenario is selected when (+rd)-FAITH outranks (-rd)-FAITH, as shown below. (A competing derived-environment effect would be obtained with the opposite ranking.)

(27) a. (+rd)-FAITH
A (+rd) output is identical to its input correspondent in every property. Assign a violation mark for any type of disparity.

b. (-rd)-FAITH
A (-rd) output is identical to its input correspondent in every property. Assign a violation mark for any type of disparity.

c. The ranking
(+rd)-FAITH >> (-rd)-FAITH

For clarity of exposition, I list mappings that incur a violation of relevant faithfulness constraints. The number of stars indicates how many faithfulness violations a given mapping incurs. (For a detailed discussion of generalized faithfulness see chapter 1, section 2.2.3.)

(28) The role of generalized faithfulness

Scenarios		(+rd)-FAITH	(-rd)-FAITH
A. CHS ☞ aai → ai ↓ ooi → oi ↺	/aai/ → ai /ai/ → oi /oi/ → oi /ooi/ → oi	** /ooi/ → oi (*) /ai/ → oi (*)	* /aai/ → ai (*)
B. DEE aai ↘ ai ↺ ooi → oi ↺	/aai/ → oi /ai/ → ai /oi/ → oi /ooi/ → oi	***! /aai/ → oi (**) /ooi/ → oi (*)	

The chain-shift scenario wins as it minimizes faithfulness violations within the rounded vowel set. This is at the cost of faithfulness to unrounded outputs, (-rd)-FAITH. (Recall that rounding needs to take place, implying some (+rd)-FAITH violations. This is determined in stage 1 of Eval.)

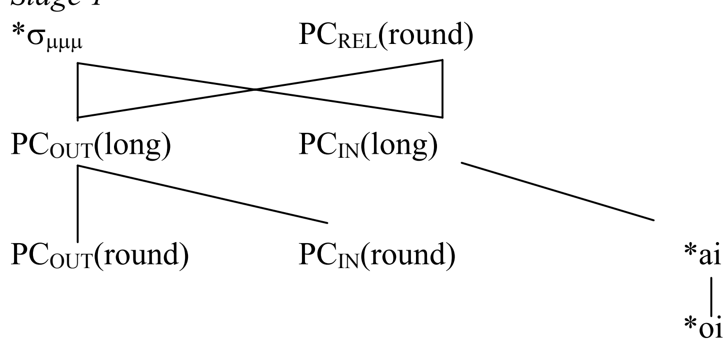
The direction of movement is determined by markedness ranking in stage 1 of Eval. In Finnish, *ai >> *oi, thus rounding takes place. When the ranking of generalized faithfulness coincides with markedness ranking (*ai >> *oi and (-rd)-FAITH >> (+rd)-FAITH), we get a derived-environment effect. In case of conflict between the two (*ai >> *oi but (+rd)-FAITH >> (-rd)-FAITH), a chain shift results. The logic behind it is as follows. In a chain-shift scenario, despite rounding (mapping towards [oi]), we still want to make rounded vowels as faithful as possible. We cannot avoid mappings onto rounded vowels altogether, since rounding takes place, but we can control how distant the mappings are. In a derived-environment effect, faithfulness agrees with the directionality of movement.

2.5.5 Summary Ranking

Altogether, the constraint ranking for Finnish is as follows. The two stages of Eval are shown separately. Stage 1 contains markedness and PC constraints. Stage 2 is generalized faithfulness.

(29) Constraint ranking for Finnish

Stage 1



Stage 2

(+rd)-FAITH >> (-rd)-FAITH

Ranking arguments are recalled below.

(30) Ranking arguments

Ranking	Consequence
Stage 1 of Eval	
$*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(long), PC_{IN}(long)	Shortening takes place to avoid tri-moraic syllables. It incurs some length mergers.
PC_{OUT}(long) >> PC_{OUT}(round), PC_{IN}(round)	Rounding takes place to achieve better distribution of length mergers in a scenario.

PC_{REL}(round) >> PC_{OUT}(long), PC_{IN}(long)	Bi-directional scenario (with no length mergers) is ruled out since it does not retain any identity between output and input contrasts.
*ai >> *oi	Mirror image scenario is ruled out. It contains too many [ai]'s.
PC_{IN}(long) >> *ai	Total merger is not an option. It merges every pair of inputs distinct in length.
Stage 2 of Eval	
(+rd)-FAITH >> (-rd)-FAITH	CHS is favored over DEE.

To recall, the main argument is as follows. Shortening takes place to avoid tri-moraic syllables. This results in some length mergers. But length mergers need to be accumulated in a scenario rather than distributed among outputs and this is at the cost of merging rounding. However, even though preserving length contrasts is important in Finnish, and it takes place at the cost of rounding, not all length mergers are avoided. This would result in neutralizations of all minimal rounding contrasts from the input, and this is militated against by a high-ranking relational PC constraint. Finally, tokenized markedness constraints choose between mirror images of scenarios and segmental faithfulness makes the choice between chain shifts and derived-environment effects.

The relevant tableau is given below. Scenarios correspond to the ones established in (4). The established ranking selects the actual chain-shift scenario as optimal.

(31) Ranking for Finnish

	*$\sigma_{\mu\mu\mu}$	PC_{REL} (round)	PC_{OUT} (long)	PC_{IN} (long)	PC_{OUT} (round)	PC_{IN} (round)	*ai	*oi	(+rd)-FAITH
A. Transparent			**!	**			**	**	*
B. Total merger			*	****!	*	****		****	****
C. Total merger (Reverse)			*	****!	*	****	****		
D. Bi-directional		*!			**	**	**	**	*
E. Bi-directional (Reverse)		*!			**	**	**	**	***
I. CHS ☞ (Finnish)			*	**	*	**	*	***	**
J. CHS (Reverse)			*	**	*	**	***!	*	*
K. DEE			*	**	*	**	*	***	***!
L. DEE (Reverse)			*	**	*	**	***!	*	

Let us discuss the ranking. The bi-directional scenarios, scenarios D and E, are ruled out on relational PC. They transform each underlying length contrast into a surface rounding contrast. In consequence, in those scenarios none of the input rounding contrasts are preserved in the output. This is a violation of a high-ranked PC_{REL}(round) constraint (See section 2.5.2 for discussion.) The two total merger scenarios, scenarios B and C, lose on input-oriented PC, as they both merge too many input pairs distinct in length. In a total merger scenario, each input maps onto one and the same output. The transparent scenario, scenario A, loses on output-oriented PC, PC_{OUT}(long). It contains too many outputs ambiguous in length. (See chapter 1, section 4 for discussion.) The opaque scenarios, scenarios I-L, tie so far.

There are four competing opaque scenarios. Two of them, scenarios J and L, contain lowering. The other two, scenarios I and K, involve rounding. The opaque scenarios with lowering are ruled out on markedness since they contain too many tokens of unrounded vowels. The other two scenarios, scenario I and K, pass on to stage 2 of Eval.

In stage 2, the choice is made between the two opaque scenarios that tie so far. The scenario where rounded vowels are more faithful wins. This is the chain-shift scenario, scenario I. (See section 2.5.4.)

Thus, we have seen that the constraint ranking established for Finnish chooses the actual scenario as optimal. In the next section, I will show that each of the empirically attested scenarios from the candidate set is predicted to win in some language.

2.6 Discussion

This section discusses each of the attested scenarios shown in (4). Let us start with the actual scenario. The actual scenario neutralizes both length and rounding contrasts. This has been described in detail in chapter 1, section 4. But not every scenario in the same candidate set merges along both dimensions. In particular, there are two scenarios, transparent and bi-directional, that merge only one dimension of contrast. The transparent scenario (4a) merges length but not rounding, and the bi-directional scenario (4d-e) merges rounding but not length. The transparent scenario, therefore, wins if rounding mergers are not permitted as a result of shortening, whereas the bi-directional scenario is optimal if length mergers are ruled out (see below).

(32)

Type	Property
Transparent	No rounding mergers
Bi-directional	No length mergers

Each of the two scenarios would be optimal in a language that bans the relevant kind of merger.

The total merger scenario (4b-c) is similar to the chain-shift scenario, in that it merges both length and rounding. But, unlike the chain-shift scenario, it merges length and rounding for each input pair and thus violates input-oriented PC too much in comparison to other scenarios. As a result, the total merger scenario would never win solely on PC constraints. But it would be optimal if markedness against some output type were high-ranking in the language. The total merger scenario would be favored in this situation, since it contains only one output type. In fact, it is the only scenario in the candidate set that violates only one markedness constraint. Each of the remaining scenarios contains two output types and thus performs worse on markedness (assuming that there are markedness constraints against each output type). The properties of the total merger scenarios are given below.

(33)

Type	Property
Total merger	No [ai]'s
	No [oi]'s

Here is a summary of constraint rankings established so far. The dividing lines in the "rankings" column show distinctions already made between scenarios.

(34) Constraint rankings

Scenarios	Stage 1 of Evaluation
Transparent	Saves rounding: $*\sigma_{\mu\mu\mu}$, PC_{OUT}(rd), PC_{IN}(rd) >> PC_{OUT}(lg), PC_{IN}(lg), *ai, *oi
Total merger	Leader on markedness: *ai (or *oi) >> PC
Bi-directional	Saves length: $*\sigma_{\mu\mu\mu}$, PC_{OUT}(lg), PC_{IN}(lg) >> PC_{OUT}(rd), PC_{IN}(rd), *ai, *oi, PC_{REL}(rd)
Opaque	Minimizes the number of outputs ambiguous in length: $*\sigma_{\mu\mu\mu}$, PC_{REL}(rd) >> PC_{OUT}(lg), PC_{IN}(lg) >> PC_{OUT}(rd), PC_{IN}(rd), *ai, *oi

So far major distinctions have been made between scenarios, but we still need to distinguish between mirror images (reverse scenarios) and the two types of opaque scenarios, chain shift and derived environment effect. This is necessary to make sure that each scenario can win under some ranking.

Distinctions between mirror image scenarios are made on either tokenized markedness or segmental faithfulness. In cases when directionality results in a different number of tokens of a particular type, tokenized markedness makes the choice between scenarios (compare the two chain-shift scenarios and derived environment scenarios; I refer to them as opaque scenarios). Tokenized markedness makes the choice between opaque scenarios that contain rounding and the same scenarios that contain lowering. However, when there is no difference in the number of tokens between mirror images, segmental faithfulness comes into play (compare the two bi-directional scenarios). The role of tokenized markedness and segmental faithfulness is illustrated below:

(35)

Type	Ranking
Total merger:	*ai >> *oi
	*oi >> *ai
Bi-directional:	(+rd)-FAITH >> (-rd)-FAITH
	(-rd)-FAITH >> (+rd)-FAITH
Opaque w/rounding:	*ai >> *oi
Opaque w/lowering:	*oi >> *ai

(36) Augmented constraint rankings

Stage 1 of Evaluation	Stage 2 of Evaluation
Transparent: $*\sigma_{\mu\mu\mu}$, $PC_{OUT/IN}$(rd) >> $PC_{OUT/IN}$(lg), *ai, *oi	
Total merger onto [oi]: *ai >> PC, *oi	
Total merger onto [ai]: *oi >> PC, *ai	
Bi-directional: $*\sigma_{\mu\mu\mu}$, $PC_{OUT/IN}$(lg) >> $PC_{OUT/IN}$(rd), *ai, *oi, PC_{REL}(rd)	Lg vowels map onto [ai]: (+rd)-FAITH>>(-rd)-FAITH Lg vowels map onto [oi]: (-rd)-FAITH>>(+rd)-FAITH
Opaque (with rounding): $*\sigma_{\mu\mu\mu}$,PC_{REL}(rd)>>$PC_{OUT/IN}$(lg)>>$PC_{OUT/IN}$(rd),*ai>>*oi	Needs to be determined
Opaque (with lowering): $*\sigma_{\mu\mu\mu}$,PC_{REL}(rd)>>$PC_{OUT/IN}$(lg)>>$PC_{OUT/IN}$(rd),*oi>>*ai	Needs to be determined

We still need to make distinctions between chain shifts and derived environment effects of the same direction of movement. Those distinctions are made in stage 2 of Eval by segmental faithfulness.

(37) Rounding pair: (+rd)-FAITH >> (-rd)-FAITH Chain shift
(-rd)-FAITH >> (+rd)-FAITH DEE

Lowering pair: (-rd)-FAITH >> (+rd)-FAITH Chain shift
(+rd)-FAITH >> (-rd)-FAITH DEE

The final constraint ranking is given below.

(38) Final rankings

Stage 1 of Evaluation	Stage 2 of Evaluation
Transparent: $*\sigma_{\mu\mu\mu}$, $PC_{OUT/IN}$(rd) >> $PC_{OUT/IN}$(lg), *ai, *oi	
Total merger onto [oi]: *ai >> PC, *oi	
Total merger onto [ai]: *oi >> PC, *ai	
Bi-directional: $*\sigma_{\mu\mu\mu}$, $PC_{OUT/IN}$(lg) >> $PC_{OUT/IN}$(rd), *ai, *oi, PC_{REL}(rd)	Lg vowels map onto [ai]: (+rd)-FAITH>>(-rd)-FAITH Lg vowels map onto [oi]: (-rd)-FAITH>>(+rd)-FAITH
Opaque (with rounding): $*\sigma_{\mu\mu\mu}$,PC_{REL}(rd)>>$PC_{OUT/IN}$(lg)>>$PC_{OUT/IN}$(rd),*ai>>*oi	Limit mergers on [oi]: (+rd)-FAITH>>(-rd)-FAITH Save [ai]: (-rd)-FAITH>>(+rd)-FAITH
Opaque (with lowering): $*\sigma_{\mu\mu\mu}$,PC_{REL}(rd)>>$PC_{OUT/IN}$(lg)>>$PC_{OUT/IN}$(rd),*oi>>*ai	Limit mergers on [ai]: (-rd)-FAITH>>(+rd)-FAITH Save [oi]: (+rd)-FAITH>>(-rd)-FAITH

All distinctions are made among scenarios. This shows that our constraint inventory generates all of the attested scenario types – a basic goal of OT.

CHAPTER 3

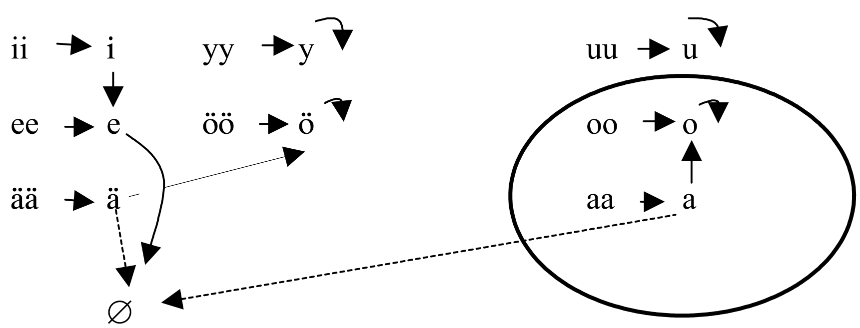
CASE STUDY: FINNISH

"No man is an Island, entire of itself;
every man is a piece of the Continent,
a part of the main…"
John Donne (1571 - 1631), Meditation XVII

3.1 Finnish Vowel Alternations[1]

The core of PC theory is the interaction between mappings. Mappings influence one another. Therefore, to understand the workings of a phonological system, we need to look at a set of vowel alternations in some environment. This chapter examines vowel alternations in Finnish before the plural suffix –i (Anttila 2000, Harrikari 2000, Keyser & Kiparsky 1984). This is illustrated below. The chain shift discussed so far is circled and represented in the context of the Finnish vowel space.[2]

(1) Vowel alternations in Finnish before -i



The following are examples of each mapping shown in the diagram. Examples are divided into sets of unrounded and rounded vowels, respectively.

[1] I would like to thank participants of the annual Finnish Festival held at the University of Minnesota in the summer of 2002 for verifying the data and providing examples.
[2] The vowel space, as shown here, represents only single segments. Diphthongs are not included.

(2) Examples of mappings in Finnish (due to Heli Harrikari (p.c.))

Unrounded vowels

	singular nom.	*gloss*	*plural essive*
/ii/→i	kallii- (kallis)	‘expensive (stem)’	kalli-i-na
/i/→e	lasi	‘glass’	lase-i-na
/ee/→e	essee	‘essay’	esse-i-nä
/e/→∅	lapse- (lapsi)	‘child’	laps-i-na
/ää/→ä	jää	‘ice’	jä-i-nä
/ä/ → ö	tekijä	‘author’	tekijö-i-nä
↘ ∅	ystävä	‘friend’	ystäv-i-nä
	kesä	‘summer’	kes-i-nä
/aa/→a	tehtaa- (tehdas)	‘factory’	tehta-i-na
/a/ → o	matka	‘trip’	matko-i-na
↘ ∅	1. Some words more than two syllables long		
	asema	‘station’	asem-i-na
	2. –u(V)Ca; -o(V)Ca		
	kuva	‘picture’	kuv-i-na

Rounded vowels

/yy/→y	revyy	‘revue’	revy-i-nä
/y/→ y	kyky	‘ability’	kyky-i-nä
/uu/→u	paluu	‘return (noun)’	palu-i-na
/u/→u	savu	‘smoke (noun)’	savu-i-na
/öö/→ö	miljöö	‘milieu’	miljö-i-nä
/ö/→ö	näkö	‘(eye)sight’	näkö-i-nä
/oo/→o	ehtoo	‘evening’	ehto-i-na
/o/→o	katto	‘roof’	katto-i-na

Let us now move on to generalizations. As shown above, long vowels shorten before the plural suffix. This is true for all vowels in Finnish, /ii/→[i], /yy/→[y] etc. The shortening of long vowels can potentially result in their neutralization with corresponding short vowels. To avoid the neutralization of length, in some cases, short vowels move away from their underlying position. They change in some feature(s). As a result, there is a chain shift effect, as the one discussed so far. To take an example, in the set of low vowels, the long low vowel shortens (e.g., /aa/→[a]) and the corresponding short vowel undergoes rounding (e.g., /a/→[o]). In consequence, the two vowels, /aa/ and /a/, do not neutralize.

Altogether, there are three chain shift effects in Finnish. They all take place in the set of unrounded vowels. I will now recall the examples with specific chain shifts indicated.[3]

(3) Finnish chain shifts in nouns

Unrounded vowels

/ii/→i	kallii-	'expensive (stem)'	kalli-i-na	**Chain shift 1:**
/i/→e	lasi	'glass'	lase-i-na	non-low front
				unrounded
/ee/→e	essee	'essay'	esse-i-nä	vowels
/e/→∅	lapse-	'child'	laps-i-na	

/ää/→ä	jää	'ice'	jä-i-nä	**Chain shift 2:**
/ä/ → ö	tekijä	'author'	tekijö-i-nä	low front
↘ ∅	ystävä	'friend'	ystäv-i-nä	unrounded
	kesä	'summer'	kes-i-nä	vowels

/aa/→a	tehtaa-	'factory'	tehta-i-na	**Chain shift 3:**
/a/ → o	matka	'trip'	matko-i-na	low back
↘ ∅	1. Some words more than two syllables long			unrounded
	asema	'station'	asem-i-na	vowels
	2. –u(V)Ca; -o(V)Ca			
	kuva	'picture'	kuv-i-na	

One of the chain shifts is the shift in the low back vowels discussed so far, indicated here as chain shift 3. There is also a mirror shift in the low front vowels (chain shift 2), and a shift in the high front vowels (chain shift 1). These are all illustrated below:

3 In the discussion, I will focus on the nominal paradigm.

(4)	Finnish vowel shifts						
	High front vowels	ii	→	i	→	e	→ ∅
	Low front vowels	ää	→	ä	→	ö	(or ä→∅)
	Low back vowels	aa	→	a	→	o	(or a→∅)

This chapter accounts for each shift. (The low vowel shifts also include deletion as the last step.) [4]

Besides the three chains shifts in Finnish, there is another interesting fact about the dynamics of the Finnish vowel space. Namely, there is a clear difference between rounded and unrounded vowels. Rounded vowels do not participate in shifts, unlike unrounded vowels. That is, when long rounded vowels shorten, their short counterparts stay where they originally are and a merger takes place (e.g., /oo/ vs. /o/ → [o]). The difference in the behavior of rounded and unrounded vowels is summarized below.

[4] These are shifts in nouns. Similar mappings take place for verbs before the past tense marker –i, and for adjectives before the superlative –in. Just as in nouns, there are no shifts in the rounded vowels before the other two –i suffixes. But there are differences in the shifts themselves. The low back vowel shift (/aa/→a, /a/→o or /aa/→a, /a/→∅) is the same for nouns and verbs; adjectives do not show the rounding alternation (/aa/→a, /a/→∅ only). The low front vowel shift (/ää/→ä, /ä/→ö or /ää/→ä, /ä/→∅) is true only for nouns; verbs and adjectives do not include the rounding alternation (/ää/→ä, /ä/→∅ only). (Anttila argues that this is a tendency rather than a categorical change.) The high front vowel shift is the same for nouns and adjectives (/i/→e, /e/→∅) but in case of adjectives the long high vowel also lowers (/ii/→e); verbs show deletion of both high and mid short vowels but no shift (/i/, /e/→∅).

Overall, nouns represent the biggest variety of shifts. This supports the observation that nouns are often more faithful than other grammatical categories (Smith 1997); they preserve more contrasts. In the remainder of this chapter, I will concentrate on nouns.

(5) Rounding as factor in chain-shifting

	Unrounded				Rounded			
Short▶ Long▼	i	e	ä	a	y	ö	u	o
ii	*							
ee	√	*						
ää			*					
aa				*				
yy					√			
öö			√			√		
uu							√	
oo				√				√

√'s: length mergers are allowed
stars: length mergers are banned
shaded cells: length mergers are not attested

The length contrast is neutralized in the rounded vowel set (yy/y, öö/ö, uu/u, oo/o). But unrounded short vowels do not merge with long vowels of the same height (*aa/a, *ee/e, *ii/i, *ää/ä). Instead, they participate in shifts. I will deal with rounding in chain-shifting in section 3.4.

Finally, in each of the low vowel shifts, sometimes deletion takes place instead of rounding (Antilla 2000). When deletion takes place, the low vowel shift is of the form shortening *plus* deletion instead of shortening *plus* rounding.

(6) Schematically, deletion versus rounding

aa	→	**a**	→	∅	(deletion)	versus
aa	→	**a**	→	**o**	(rounding)	

The following are examples of deletion. Compare with rounding in (8).

(7) Deletion (/a/→∅)

singular	*gloss*	*plural essive*
asema	'station'	asem-i-na
ravintola	'restaurant'	ravintol-i-na
kukka	'flower'	kukk-i-na

(8) Rounding (/a/→o)

singular	*gloss*	*plural essive*
matka	'trip'	matko-i-na
raha	'money'	raho-i-na
aika	'time'	aiko-i-na

I will follow Antilla in assuming that deletion is a result of labial dissimilation. Deletion will be discussed in detail in section 3.2.

The goal of this chapter is to give a global view of vowel alternations in Finnish. The chapter is organized as follows. Deletion in the low vowel shift (chain shift 2 and 3) is discussed in section 3.2. The shift in the front high vowels (chain shift 1) is discussed in section 3.3. Finally, the chapter concludes with a discussion in section 3.4 of the difference between rounded and unrounded vowels and their participation in shifts in Finnish.

3.2 Chain Shift with Deletion

In the low vowel shift discussed so far, shortening forces rounding. The short low vowel undergoes rounding to avoid a merger with a long vowel that shortens, /a/→o because /aa/→a. But in some cases, the low vowel deletes instead of rounding, /a/→∅ instead of /a/→o. Deletion takes place if the preceding vowel is rounded ([o] or [u] or equivalent long vowel) or when the immediately preceding consonant is a labial ([m], [p], [b], [v], [f]).[5] Some examples of deletion follow. These are examples of deletion in both nouns and verbs. Next to each form, there is an incorrect output with a rounded vowel.

[5] Antilla (2000) shows that the effects of deletion are quantitative. The effects are strongest when both the consonant and the preceding vowel are rounded. Antilla also notices the effect of foot structure on rounding dissimilation. Dissimilation is more consistent when the trigger and target of dissimilation belong to the same foot.

(9) Deletion before –i (/a/→∅)

singular	*gloss*	*plural essive*	
ase**ma**	'station'	ase**m**∅-i-na	*ase**mo**-i-na
ravint**o**l**a**	'restaurant'	ravint**o**l∅-i-na	*ravint**o**l**o**-i-na
present		*past*	
matk**u**st**a**-n	'to travel'	matk**u**st-i-n	*matk**u**st**o**-i-n
ot**a**-n	'to take from'	**o**t-i-n	***o**t**o**-i-n

I will claim, following Antilla (2000), that deletion is a result of labial (rounding) dissimilation. Deletion takes place to avoid two adjacent labial articulations, which would be a result of rounding. In the examples above, the vowel that deletes and the labial that causes dissimilation are in bold font. In dissimilation, it is important to state the domain for co-occurrence restrictions. In Finnish, both vowels and consonants cause dissimilation. For dissimilation to take place, the labial consonant needs to be the immediately preceding consonant, whereas the vowel needs to be in the nucleus of the preceding syllable. In what follows, I will state the domain uniformly as adjacent segments, where adjacency is defined separately at the vocalic and consonantal tier (Gafos 1996, NiChiosain & Padgett 1997).[6]

The OCP constraint militates against having two labial (=round) segments in the same domain. There are various ways to formalize it. To use the existing tools of OT, one can formalize it as self-conjunction of markedness constraints (following Alderete 1997). I call it OCP_{Adj}(round) in traditional autosegmental terms. This does not have any effect on the analysis here. The relevant OCP constraint (Leben 1973, McCarthy 1986) is defined below:

(10) OCP_{Adj}(round)
Adjacent round (labial) articulations are prohibited.

Dissimilatory deletion is limited to derived labial sequences in Finnish (as will be discussed later, underlying /o/ and shortened /oo/ do not delete). Other cases of labial dissimilation are Palauan (Finer 1986), Akkadian (Von Soden 1969, McCarthy 1979) etc.

The argument is as follows. Deletion, just like rounding, preserves some length contrasts despite shortening, /asemaa-i-na/ vs. hypothetical /asema-i-na/ → [asema-i-na] (with shortening) vs. [asem-i-na] (with deletion). Rounding is a preferred way to preserve length contrasts (it takes place in more instances; after any vowel except for [o, u, oo, uu] and labial consonants) but deletion takes place if rounding would result in an OCP_{Adj}(round) violation.[7]

Let us review the argument for rounding. Formally, long vowels are avoided at the cost of merging some length contrasts. But length neutralizations are accumulated in Finnish at the cost of merging rounding. This is the ranking already established and recalled below:

(11) $*\sigma_{\mu\mu\mu}$ >> PC_{OUT}(lg), PC_{IN}(lg) >> PC_{OUT}(rd), PC_{IN}(rd)

---

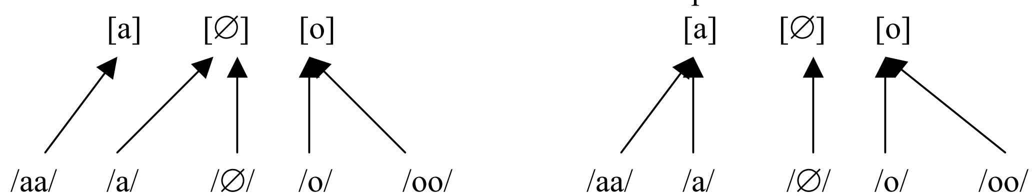
[6] The presence of a labial further away in the stem does not cause dissimilation i.e., /**p**al**a**-i/→**p**al**o**i 'burn-PAST', /a**p**in**a**-i-ssa/→a**p**in**o**issa 'monkey-PL-INE', /**m**atk**a**-i-ssa/→**m**atk**o**issa 'trip', /l**u**sikk**a**-i-ssa/→l**u**sik**o**issa 'spoon'. Compare with deletion in: /m**u**n**a**-i-ssa/→m**u**nissa 'egg', /ase**ma**-i-ssa/→ase**m**issa 'railroad station'.

[7] Antilla (2000) argues that both deletion and rounding are motivated to resolve OCP violations. Rounding is blocked after labials since it would create an OCP(round) violation but deletion is blocked after coronals since it would create an OCP(high) violation; a coronal would be adjacent to a high front vowel if deletion took place. Here I am taking a different route: rounding is a default and deletion takes place only in some instances. In this proposal, the fact that rounding is a default follows from constraint ranking. It is predicted by constraint permutation that there are languages where deletion is preferred to rounding. No claims are being made about the universality of the relative ranking of constraints on contrast preservation.

In short, high-ranked markedness $*\sigma_{\mu\mu\mu}$ forces some length mergers, but length mergers need to be accumulated in a scenario rather than distributed across outputs, and this is at the cost of rounding mergers. This explains why rounding takes place.

Like rounding, deletion accumulates length mergers in a scenario and thus improves on PC_{OUT}(long) constraint. Compare the following two scenarios. Both have shortening, but only the actual scenario, scenario A, shows deletion.

(12) a. Deletion scenario b. Transparent scenario



Scenario A has only one output ambiguous in length, the [o] output, whereas the competing transparent scenario has two such outputs, [a] and [o]. It is assumed here that deletion does not incur a length merger. Deletion results in a merger of contrast with words that end in a consonant to begin with, /asem**a**-i-na/ vs. /asem-i-na/ → asem-i-na. Some examples of mappings for consonant-final stems follow.[8]

(13) Consonant-final stems

singular nom.	*gloss*	*plural essive*	*stem*
kuus(i)	'spruce tree'	kuus-i-na	kuus-
vuos(i)	'year'	vuos-i-na	vuot-
huol(i)	'trouble, worry'	huol-i-na	huol-
sisar	'sister'	sisar-i-na	
present		*past*	
pur(e)n	'to bite'	pur-i-n	
kävel(e)n	'to walk'	kävel-i-n	
pääs(e)n	'to get to'	pääs-i-n	
pan(e)n	'to put'	pan-i-n	

[8] These are possible but not necessarily the existing forms of the language. This follows from the architecture of the theory; see chapter 1 for discussion. Consonant stems in Finnish can only end in an alveolar consonant: *l,r,n,s* and *t*. The input /asem-i-na/ mapping onto [asem-i-na] comes from richness of the base. It is used here to illustrate the merger with words where the /a/ vowel deletes.

I am assuming here that deletion is a violation of a separate PC constraint, $PC_{IN/OUT}(V/\varnothing)$.

For the scenario with deletion to win, it must be more important to have fewer outputs ambiguous in length than it is to avoid deletion. Therefore, constraints militating against mergers of the V/∅ contrast must be ranked lower than the PC_{OUT}(long) constraint. Altogether, the ranking is as follows:

(14) $*\sigma_{\mu\mu\mu} >> PC_{OUT}(lg), PC_{IN}(lg) >> PC_{OUT}(V/\varnothing), PC_{IN}(V/\varnothing)$

We now move a step further and try to account for the choice between deletion and rounding to aid length. Even though in Finnish both deletion and rounding accumulate length mergers, rounding mergers are preferred to deletion. Formally:

(15) $PC_{IN/OUT}(V/\varnothing) >> PC_{IN/OUT}(round)$

It is more important to avoid mergers of the V/∅ type than it is to avoid merges of rounding.

Nevertheless, deletion is chosen as a repair when rounding would result in an OCP violation. Deletion avoids an OCP_{Adj}(round) violation by deleting the vowel. To ensure that deletion takes place when OCP_{Adj}(round) is at stake, the constraint militating against deletion must be ranked lower than the OCP_{Adj}(round) constraint. Thus:

(16) $OCP_{Adj}(round) >> PC_{IN/OUT}(V/\varnothing)$

It is more important to avoid an OCP_{Adj}(round) violations than it is to avoid deletion.

It is important to note that some OCP violations do exist due to shortening. When the long mid vowel shortens, as in /rokokoo-i-na/→[rokokoina] 'rococo', it incurs some

OCP$_{Adj}$(round) violations. To allow for these violations, it must be more important to shorten the vowel than it is to avoid OCP violations.

(17) $*\sigma_{\mu\mu\mu}$ >> OCP$_{Adj}$(round)

The ranking established so far is illustrated in the following tableaux. The first tableau contrasts a chain-shift scenario with deletion and a chain-shift scenario with rounding. The basic idea is that deletion takes place to avoid OCP$_{Adj}$(round) violations which would be a result of rounding.

(18) Deletion instead of rounding[9]

	Scenarios	OCP$_{Adj}$(round)	PC$_{IN/OUT}$(V/∅)	PC$_{IN/OUT}$ (rnd)
☞	A. CHS with deletion /asem**oo**+i+na/ → asem**o**+i+na /asem**o**+i+na/→ asem**o**+i+na /asem**aa**+i+na/ → asem**a**+i+na /asem**a**+i+na/ → asem∅+i+na /asem∅+i+na/ → asem∅+i+na	(**) oo, o → o	** PC$_{IN}$: {/a/,/∅/} PC$_{OUT}$: [∅]	
	B. CHS with rounding /asem**oo**+i+na/ → asem**o**+i+na /asem**o**+i+na/ → asem**o**+i+na /asem**aa**+i+na/ → asem**a**+i+na /asem**a**+i+na/ → asem**o**+i+na /asem∅+i+na/ → asem∅+i+na	(**)*! oo, o, a → o		*** PC$_{IN}$: {/o/,/a/}, {/oo/,/a/} PC$_{OUT}$: [o]

Both scenarios incur some OCP violations due to shortening and keeping underlying /o/ as such but the scenario with deletion, scenario A, avoids additional OCP violation, which would be a result of rounding. Therefore, the scenario with deletion is optimal. The relative ranking of PC constraints is irrelevant in this case, since the choice is already made on OCP$_{Adj}$(round) that outranks both of the PC constraints.

9 It is important to note that the words shown in a scenario are not all the existing words of the language. As far as constraints go, for reasons of space, input and output-oriented PC constraints are represented together. Violations are explained in columns below the constraints.

If there were no OCP_{Adj}(round) violation, rounding would be chosen over deletion. In that case, the OCP constraint would be inactive and the choice would be made on the relative ranking of the PC constraints. This is illustrated in the following tableau.

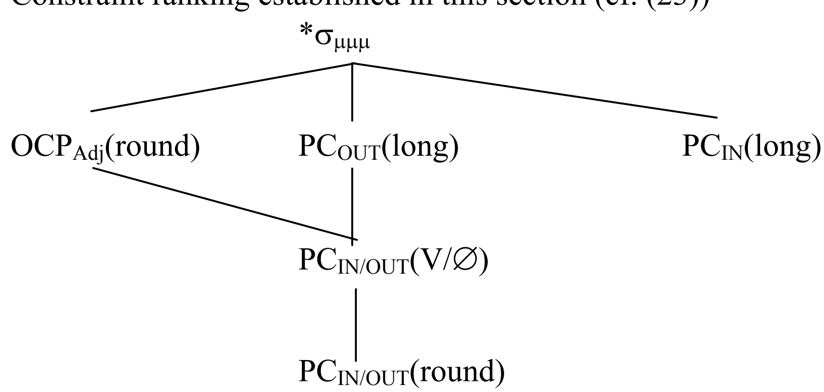
(19) Rounding otherwise

	Scenarios	OCP_{Adj}(round)	$PC_{IN/OUT}$(V/∅)	$PC_{IN/OUT}$ (round)
	A. CHS with deletion /val**oo**+i+na/ → val**o**+i+na /val**o**+i+na/ → val**o**+i+na /val**aa**+i+na/ → val**a**+i+na /val**a**+i+na/ → val∅+i+na /val∅+i+na/ → val∅+i+na		**! PC_{IN}: {/a/,/∅/} PC_{OUT}: [∅]	
☞	B. CHS with rounding /val**oo**+i+na/ → val**o**+i+na /val**o**+i+na/ → val**o**+i+na /val**aa**+i+na/ → val**a**+i+na /val**a**+i+na/ → val**o**+i+na /val∅+i+na/ → val∅+i+na			*** PC_{IN}: {/o/,/a/}, {/oo/,/a/} PC_{OUT}: [o]

The chain shift with rounding wins since it incurs a violation of a lower ranked PC constraint.

The ranking is as follows:

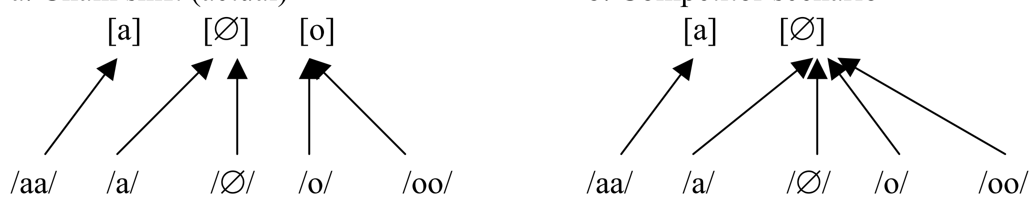
(20) Constraint ranking established in this section (cf. (23))



In essence, rounding neutralizations are preferred to neutralizations in presence versus absence of a segment but rounding is not an option when it would result in an OCP_{Adj}(round) violation. In that case, deletion takes place instead.

There are other possible alternatives to the actual scenario not considered so far. One of them is a scenario where the long mid vowel /oo/ and its short counterpart /o/ delete. Such a scenario satisfies both high-ranking markedness constraints, $*\sigma_{\mu\mu\mu}$ and OCP_{Adj}(round). It contains no long vowels and incurs no OCP_{Adj}(round) violations. Therefore, as the constraint ranking stands right now, such a scenario wins over the actual scenario. Consider the actual scenario versus its competitor.

(21) a. Chain shift (actual) b. Competitor scenario

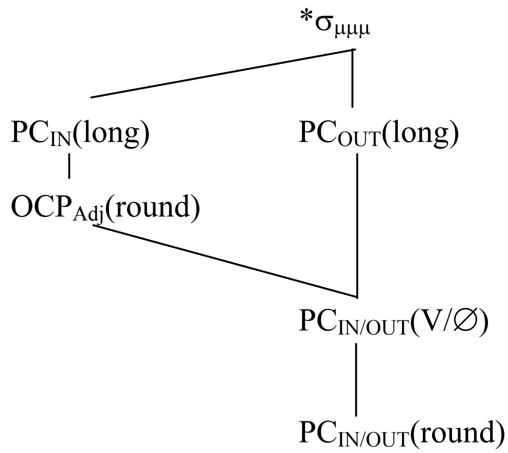


The competitor scenario wins on markedness since it does not violate either $*\sigma_{\mu\mu\mu}$ or OCP_{Adj}(round), but to do so, it merges two input pairs in length, {/a/, /oo/} and {/o/, /oo/}. In the actual scenario, on the other hand, there are two OCP_{Adj}(round) violations, /oo/, /o/ → [o], but only one length merger, {/oo/, /o/}. To ensure that the actual scenario wins, it must be more important to minimize the number of inputs that merge in length than it is to avoid OCP_{Adj}(round) violations. In terms of constraints, PC_{IN}(long) dominates OCP_{Adj}(round).

(22) PC_{IN}(long) >> OCP_{Adj}(round)

The logic is as follows. Even though OCP_{Adj}(round) violations are avoided, some violations are compelled by high-ranking PC_{IN}(long) constraint. Altogether, the constraint ranking is as follows:

(23) Final constraint ranking



(24) Ranking arguments

<u>Ranking</u>	<u>Consequence</u>
*$\sigma_{\mu\mu\mu}$ >> $PC_{IN/OUT}$(long)	Long vowels are avoided by shortening.
PC_{OUT}(long) >> $PC_{IN/OUT}$(V/∅)	Length mergers are accumulated by deletion.
PC_{OUT}(long) >> $PC_{IN/OUT}$(round)	Length mergers are accumulated by rounding.
$PC_{IN/OUT}$(V/∅) >> $PC_{IN/OUT}$(round)	Rounding is better than deletion.
OCP_{Adj}(round) >> $PC_{IN/OUT}$(round)	Deletion takes place to satisfy OCP.
PC_{IN}(long) >> OCP_{Adj}(round)	Some OCP violations exist to minimize the number of inputs that neutralize length.

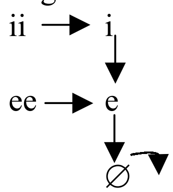
An alternative way to account for surface OCP_{Adj}(round) violations would be to ensure that a scenario can contain mergers of deletion or rounding but not both. The scenario that avoids OCP_{Adj}(round) violations, unlike the actual scenario, contains some mergers of both contrasts.

3.3 High Front Vowel Shift

There is also a shift in the high front vowels in Finnish. The long high vowel shortens (/ii/→i), the short high vowel lowers (/i/→e) and the short mid vowel deletes

(/e/→∅). Thus, there is a chain shift effect of the form: ii→i→e→∅, as represented below. There is also another mapping that participates in the shift: the long mid vowel /ee/ that shortens to [e].

(25) High front vowel shift



Some examples follow.

(26) Examples of the high front vowel shift (p.215)

	singular	*plural essive*	
/ii/→i	saalii- (salis)	saali-i-na	‘a catch’
	kallii- (kalis)	kalli-i-na	‘expensive, dear’
	kaunii- (kaunis)	kauni-i-na	‘beautiful, lovely’
/i/→e	kuppi	kupe-i-na	‘cup’
	teevati	teevate-i-na	‘saucer’
	koti	kote-i-na	‘home’
	lasi	lase-i-na	‘glass’
/ee/→e	huonee- (huone)	huone-i-na	‘room’
	kirjee- (kirje)	kirje-i-nä	‘letter’
	lainee- (laine)	laine-i-na	‘glove’
/e/→∅	nime- (nimi)	nim-i-nä	‘name’
	lapse- (lapsi)	laps-i-na	‘child’

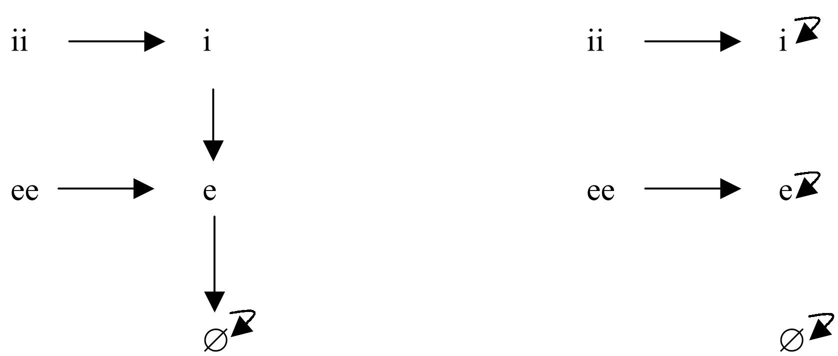
The shift originates with vowel shortening. The long vowels /ii/ and /ee/ shorten to avoid tri-moraic syllables (this is true of any other long vowel in Finnish in the same environment). In response, the short high vowel lowers (/i/→e) and the short mid vowel deletes (/e/→∅). In terms of contrasts, there is a merger in presence vs. absence of a segment (/e/ vs. /∅/ → ∅). This is where the shift terminates. There is also a merger of length and height at the point where the long mid vowel shortens (/ee/ vs. /i/ → e).

3.3.1 The Analysis

Let us now proceed to the analysis. In Finnish, long vowels are avoided due to high-ranked markedness constraint against tri-moraic syllables, $*\sigma_{\mu\mu\mu}$. Due to shortening, there are some length mergers in a scenario. But length mergers are minimized by lowering and deletion. If the short vowels [i] and [e] stayed as they are in the underlying form, there would be more length mergers in a scenario. The short vowels would merge with identical long vowels that shorten. As a result, there would be more input pairs that merge in length and there would be more outputs ambiguous in length. Compare the actual scenario to a scenario with no deletion and no lowering.

(27) Fewer length mergers

a. Chain shift (actual) b. Competitor scenario



Let us start with the competitor scenario, scenario B. In this scenario, there are two input pairs that neutralize in length, /ii/ vs. /i/→[i] and /ee/ vs. /e/→[e], and there are two outputs that correspond to inputs contrasting in length, [e] and [i]. No other mergers take place in this scenario. In the actual scenario, on the other hand, lowering and deletion result in some V/∅ and height mergers (/e/ vs. /∅/ → [∅], /ee/ vs. /i/ → [e]). But, due to lowering and deletion, there is only one input pair that neutralizes in length (/ee/ vs. /i/→[e]) instead of two such pairs as in the competitor scenario (/ii/ vs. /i/→[i], /ee/ vs. /e/→[e]). There is also only one output ambiguous in length in the actual scenario in comparison to two such outputs in the competitor scenario. To ensure that the actual scenario wins over the competitor scenario, it must be more important to minimize length neutralizations than to avoid height and V/∅ mergers. Altogether, the ranking is as follows:

(28) $*\sigma_{\mu\mu\mu}$ >> $PC_{OUT/IN}$(long) >> $PC_{OUT/IN}$(high), $PC_{OUT/IN}$(V/∅)

(29) Ranking arguments

Ranking	Consequence
$*\sigma_{\mu\mu\mu}$ >> $PC_{OUT/IN}$(long)	Long vowels shorten at the cost of length mergers
$PC_{OUT/IN}$(long) >> $PC_{OUT/IN}$(high), $PC_{OUT/IN}$(V/∅)	Length mergers are minimized by lowering and deletion

This is illustrated in the following tableau. The actual chain-shift scenario, scenario A, is compared to a competitor scenario with no lowering and no deletion, scenario B, and to an identity scenario with no shortening, scenario C.

(30) Illustration

	Scenarios	*$\sigma_{\mu\mu\mu}$	$PC_{IN/OUT}$ (long)	$PC_{IN/OUT}$ (high)	$PC_{IN/OUT}$ (V/∅)
☞	A. Actual /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na/ → las**e**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**∅**+i+na /las**∅**+i+na / → las**∅**+i+na		** PC_{IN}: {/ee/,/i/} PC_{OUT}: [e]	** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/e/,/∅/} PC_{OUT}: [∅]
	B. Shortening only /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**i**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**e**+i+na /las**∅**+i+na / → las**∅**+i+na		****! PC_{IN}: {/i/,/ii/}, {/e/,/ee/} PC_{OUT}: [i], [e]		
	C. Identity /las**ii**+i+na/ → las**ii**+i+na /las**i**+i+na/ → las**i**+i+na /las**ee**+i+na / → las**ee**+i+na /las**e**+i+na / → las**e**+i+na /las**∅**+i+na / → las**∅**+i+na	**! [ii], [ee]			

The actual scenario wins. It avoids long vowels and thus satisfies the markedness constraint against tri-moraic syllables. It also minimizes length mergers and thus fares better on $PC_{IN/OUT}$(long) constraints than the competitor scenario with no lowering and no deletion, scenario B.

3.3.2 Problems

Lowering and deletion limit the number of length mergers in a scenario, but there are other scenarios in the same candidate set that win under the current constraint ranking. Consider the following scenarios: scenario B with no deletion and C-E, with no lowering. Three of the scenarios shown below, C-E, are problematic given the constraint ranking established so far.

(31) Competing scenarios

	Scenarios	*$\sigma_{\mu\mu\mu}$	$PC_{IN/OUT}$ (long)	$PC_{IN/OUT}$ (high)	$PC_{IN/OUT}$ (V/∅)
☞	A. Actual /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na/ → las**e**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**∅**+i+na /las**∅**+i+na / → las**∅**+i+na		** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/e/,/∅/} PC_{OUT}: [∅]
	B. No deletion /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**e**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**e**+i+na /las**∅**+i+na / → las**∅**+i+na		***! PC_{IN}: {/i/,/ee/}, {/e/,/ee/} PC_{OUT}: [e]	*** PC_{IN}: {/i/,/ee/}, {/i/,/e/} PC_{OUT}: [e]	
	C. No lowering /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**i**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**∅**+i+na /las**∅**+i+na / → las**∅**+i+na		** PC_{IN}: {/ii/,/i/} PC_{OUT}: [i]		** PC_{IN}: {/e/,/∅/} PC_{OUT}: [∅]
	D. No lowering /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**∅**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**e**+i+na /las**∅**+i+na / → las**∅**+i+na		** PC_{IN}: {/ee/,/e/} PC_{OUT}: [e]		** PC_{IN}: {/i/,/∅/} PC_{OUT}: [∅]
	E. No lowering /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**∅**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**∅**+i+na /las**∅**+i+na / → las**∅**+i+na			** PC_{IN}: {/i/,/e/} PC_{OUT}: [∅]	*** PC_{IN}: {/i/,/∅/}, {/e/,/∅/} PC_{OUT}: [∅]

Scenario B with lowering but no deletion loses on $PC_{IN/OUT}$(long). It merges too many length contrasts compared to the actual scenario, scenario A. Thus it is ruled out under the current constraint ranking. The other scenarios, scenarios C-E, are problematic. Scenarios C and D with deletion but no lowering, unlike the actual scenario, incur no height mergers. They satisfy $PC_{IN/OUT}$(high). Since they otherwise have the same violations as the actual scenario, given the current constraint inventory, they harmonically bind the actual scenario. They have a subset of the violation marks of the actual scenario. Scenario E, the one where both /i/ and /e/ undergo deletion, does not merge length at all and so wins under the current constraint ranking. It satisfies $PC_{IN/OUT}$(long). In what follows, I will first discuss scenario E (with no length mergers) and then scenarios C-D (with no height mergers). I will propose a possible solution to the problem.

3.3.2.1 Limit on Deletion

Let us start with scenario E. There are no length mergers in this scenario; both /i/ and /e/ delete. Under the current constraint ranking, scenario E should win over the actual scenario since it satisfies $PC_{IN/OUT}$(long). To rule out scenario E, we need a constraint ranked above $PC_{IN/OUT}$(long).

In comparison to the actual scenario, in scenario E there are more neutralizations of the V/∅ contrast; more input pairs merge in V/∅. As already established, deletion takes place to avoid neutralizations in length. Thus, to rule out scenario E, we need to put a limit on how many V/∅ contrasts can be neutralized to preserve length.

Among the constraints introduced so far, there is a constraint that plays just that role. It is the relational PC constraint (see (30), chapter 1). The relational PC constraint, as defined in chapter 1, demands that an output contrast in P correspond to at least one instance of an input contrast in P. In other words, it prohibits absolute neutralization (if there is an output P contrast, some input P contrasts need to be retained).

Let us take this idea a step further and assume that there is a family of relational PC constraints, where relational PC constraints differ on how many instances of a given P contrast need to be preserved in a scenario.

(32) PC-REL n (P)
An output contrast in P needs to correspond to at least n minimal instances of a given input contrast in P.

(33) PC-REL family (fixed ranking)
PC-REL (P) >> PC-REL 2 (P) >> PC-REL 3 (P) …

The constraints are in a fixed order, that is, if for a given property P, PC-REL 3 is satisfied, PC-REL 2 and PC-REL are satisfied as well. If three instances of a given contrast are preserved, then two instances are preserved as well etc. PC-REL 3, in particular, demands that an output contrast in P corresponds to at least three instances of input contrast in P. In other words, it demands preservation of at least three P contrasts from the input. To summarize, deletion is a good way to minimize length mergers but it cannot be overused. [10]

Consider the actual scenario versus the scenario with no length mergers. The constraint ranking is as follows:

(34) PC-REL3(V/∅) >> $PC_{IN/OUT}$(long) >> $PC_{IN/OUT}$(high), $PC_{IN/OUT}$(V/∅)

The following tableau illustrates the ranking.

[10] Another way to put limit on neutralizations of a given contrast is to propose locally-conjoined PC constraints. See chapter 1 for a discussion of this alternative. There exists a parallel between the two alternatives: locally-conjoined PC constraints and a family of PC-REL constraints.

(35) The role of relational PC

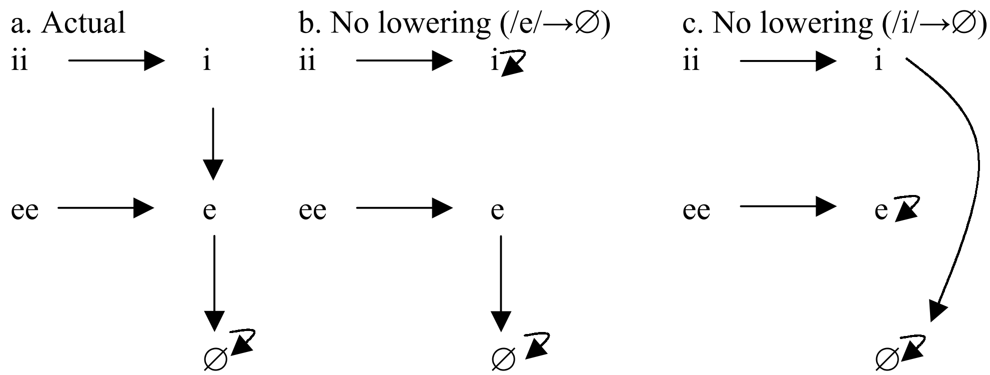
	Scenarios	*$\sigma_{\mu\mu\mu}$	PC-REL3(V/∅)	$PC_{IN/OUT}$ (long)	$PC_{IN/OUT}$ (high)	$PC_{IN/OUT}$ (V/∅)
☞	A. Actual /las**ii+**i+na/ → las**i+**i+na /las**i+**i+na/ → las**e+**i+na /las**ee+**i+na / → las**e+**i+na /las**e+**i+na / → las∅+i+na /las∅+i+na / → las∅+I+na			**	** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/e/,/∅/} PC_{OUT}: [∅]
	B. No lowering /las**ii+**i+na/ → las**i+**i+na /las**i+**i+na / → las∅+i+na /las**ee+**i+na / → las**e+**i+na /las**e+**i+na / → las∅+i+na /las∅+i+na / → las∅+i+na		*!		**	***

The scenario with no length mergers, scenario B, loses on the PC-REL3(V/∅) constraint since it preserves fewer than three V/∅ contrasts from the input. In this scenario, only /ii/ vs. /∅/ and /ee/ vs. /∅/ are preserved.

3.3.2.2 No Minimal Mergers

In tableau (31) we have seen two other scenarios that are problematic given our current inventory of constraints. These are scenarios with deletion but no lowering where only one pair of vowels undergoes deletion. We have seen that these scenarios harmonically bind the actual scenario. In the diagrams below, the two scenarios are represented together with the actual scenario.

(36)



So far, scenarios B and C win since they incur no height mergers and are otherwise identical to the actual scenario. They have a subset of the violation marks of the actual scenario.

But there is another property, besides no height mergers, that distinguishes the two competing scenarios from the actual scenario. The difference is that in the two "no lowering" scenarios there are minimal mergers in length (/ii/ vs. /i/ → [i], /ee/ vs. /e/ → [e]) whereas in the actual scenario length merger takes place between segments that are distinct on more than one dimension (/ee/ vs. /i/ → [e]).

PC constraints, as stated right now, do not distinguish between minimal and non-minimal neutralizations. They treat the two the same. In fact, merging non-minimal contrasts implies more types of mergers and thus violates more types of PC constraints.

It seems that in Finnish, merging minimal length contrasts is worse than merging length contrasts that are non-minimal. To take the idea a step further, it seems that merging within the set of P properties (here, [+/- high]) is worse than merging across sets (for example, [+high] with [-high]). One way to capture this observation is to propose domain-specific PC constraints in addition to general PC constraints. (In the next section we are going to see further support for this proposal.):

(37) PC_{IN}(Property/Domain)
inputs that belong to domain D, where D consists of inputs identical in some property Q, e.g., +/-high, that contrast in property P, e.g., +/-long, need to contrast in the output.

In Finnish, the relevant domain-specific PC constraint is as follows:

(38) PC_{IN}(long/high)
inputs of the same height (high vowels, mid vowels etc.) that contrast in length need to contrast in the output.
"do not merge length within the set of vowels of the same height"

This constraint prohibits both minimal mergers and mergers between vowels that have at least Q property in common (not necessarily minimally distinct in Q). For example, it prohibits length mergers among vowels that are of the same height but of different rounding etc. Section 3.4 discusses it in more detail.

Limiting our discussion to front vowels, the above constraint is satisfied by mergers of length among vowels of different height. Merging length among vowels of different height is better than merging length among vowels of the same height.

(39) No minimal length mergers

	Scenarios	$PC_{IN/OUT}$ (long)	PC_{IN} (long/high)	$PC_{IN/OUT}$ (high)	$PC_{IN/OUT}$ (V/∅)
☞	A. Actual /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na/ → las**e**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las∅+i+na /las∅+i+na / → las∅+i+na	**		** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/e/,/∅/} PC_{OUT}: [∅]
	B. No lowering /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las**i**+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las∅+i+na /las∅+i+na / → las∅+i+na	**	*! {/ii/,/i/}		**
	C. No lowering /las**ii**+i+na/ → las**i**+i+na /las**i**+i+na / → las∅+i+na /las**ee**+i+na / → las**e**+i+na /las**e**+i+na / → las**e**+i+na /las∅+i+na / → las∅+i+na	**	*! {/ee/,/e/}		**

Scenarios B and C are ruled out since they violate the domain-specific PC constraint. They merge length between /ii/ vs. /i/ and /ee/ vs. /e/, respectively.

To summarize, long vowels are shortened in Finnish to avoid tri-moraic syllables. This results in some length mergers in a scenario, but length mergers are minimized by lowering and deletion. Two claims have been made about those processes: (i) deletion cannot avoid all length mergers (this is due to the relational PC constraint), and (ii) length mergers cannot take place within the set of vowels of identical height (this is due to the domain specific input-oriented PC constraint). Altogether, the ranking is as follows:

(40) Final constraint ranking

$PC_{REL}{}^{3}(V/\varnothing)$ $*\sigma_{\mu\mu\mu}$

PC_{IN}(long/high) $PC_{IN/OUT}$(long)

$PC_{IN/OUT}$(high) $PC_{IN/OUT}(V/\varnothing)$

(41) Ranking arguments

<u>Ranking</u>	<u>Consequence</u>
$*\sigma_{\mu\mu\mu}$ >> $PC_{IN/OUT}$(long)	Shortening causes length mergers.
$PC_{IN/OUT}$(long) >> $PC_{IN/OUT}$(high), $PC_{IN/OUT}(V/\varnothing)$	Length mergers are minimized by lowering and deletion.
PC_{IN}(long/high) >> $PC_{IN/OUT}$(high)	Lowering avoids minimal length mergers.
PC_{REL} 3 $(V/\varnothing)$ >> $PC_{IN/OUT}$(long)	There is a limit put on deletion at the cost of length mergers.

3.4 Rounded Vowels

Finally, in Finnish there is a difference between rounded and unrounded vowels. Only unrounded vowels participate in shifts.

(42) Rounding as factor in chain-shifting (recalled from (5))

	Unrounded				Rounded			
Short▶ Long▼	i	e	ä	a	y	ö	u	o
ii	*							
ee	√	*						
ää			*					
aa				*				
yy					√			
öö			√			√		
uu							√	
oo				√				√

√'s: length mergers are allowed
stars: length mergers are banned
shaded cells: length mergers are not attested

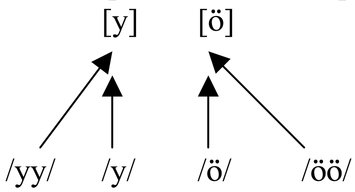
In terms of contrasts, length contrasts are merged within the set of rounded vowels (yy/y, öö/ö, uu/u, oo/o), and in some cases across rounded/unrounded vowel set (ä/öö, a/oo), but preserved within the set of unrounded vowels of the same height (ii/i, ee/e, ää/ä, aa/a).[11]

The logic is as follows. Long vowels are avoided at the cost of merging length contrasts. But length contrasts need to be re-distributed in a scenario and this is at the cost of merging rounding. That is what accounts for the chain shift effect (/a/→[o] because /aa/→[a]). This is the core of the analysis proposed so far. But rounded vowels behave differently. Rounded vowels shorten, just like unrounded vowels, but they do not re-distribute length contrasts (/y/→[y] even though /yy/→[y]).

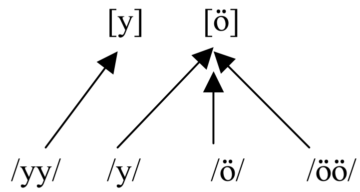
[11] In Finnish, /ee/ merges with /i/ (both unrounded vowels), so there is a merger of length in unrounded vowels but only if the two differ in height.

Consider the following scenarios with rounded vowels. Scenario A is the actual scenario in Finnish with shortening. Scenario B is a competing chain-shift scenario with shortening and lowering in which contrast is preserved between /yy/ and /y/.

(43) a. Transparent scenario (optimal)



b. Chain-shift scenario



In both, long vowels shorten, but in the chain-shift scenario, the mid vowel also lowers (/y/→[ö]). Consequently, in the chain-shift scenario, there is only one output ambiguous in length, the [ö] output. In the actual scenario, there are two such outputs. In Finnish, it is important to minimize the number of outputs ambiguous in length and therefore in the set of unrounded vowels, a chain shift wins over the competing transparent scenario. So why is the chain shift not optimal for rounded vowels?

One way to approach this problem is to propose that height contrasts need to be maintained within the set of rounded vowels in Finnish unlike in the set of unrounded vowels (for similarities with positional faithfulness theory see Beckman 1997). Formally, this can be achieved by proposing a high-ranking specific PC constraint on preserving height contrasts within the set of rounded vowels that would dominate output-oriented PC(long). Thus, it is more important to maintain height distinctions within the set of rounded vowels than it is to limit the number of outputs ambiguous in length.[12]

(44) PC_{IN}(high/+round)
Height contrasts need to be maintained within the set of rounded vowels.

(45) PC_{IN}(high/+round) >> $PC_{IN/OUT}$(long) >> $PC_{IN/OUT}$(high)

In effect, height mergers are not allowed within the set of rounded vowels but permitted elsewhere.

(46) The role of rounding in chain-shifting

	Scenarios	PC_{IN} (high/+round)	$PC_{IN/OUT}$ (long)	$PC_{IN/OUT}$ (high)
☞	A. Chain shift (actual) /las**ii+**i+na/ → las**i+**i+na /las**i+**i+na/ → las**e**+i+na /las**ee+**i+na / → las**e+**i+na /las**e+**i+na / → las∅+i+na /las∅+i+na / → las∅+I+na		** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]	** PC_{IN}: {/i/,/ee/} PC_{OUT}: [e]
	B. No shift /las**ii+**i+na/ → las**i+**i+na /las**i+**i+na / → las**i+**i+na /las**ee+**i+na / → las**e+**i+na /las**e+**i+na / → las**e+**i+na /las∅+i+na / → las∅+I+na		****! PC_{IN}: {/ii/,/i/}, {/ee/,/e/} PC_{OUT}: [i], [e]	
	Scenarios	PC_{IN} (high/round)	$PC_{IN/OUT}$ (long)	$PC_{IN/OUT}$ (high)
	C. Chain shift /las**uu+**i+na/ → las**u+**i+na /las**u+**i+na / → las**o+**i+na /las**oo+**i+na / → las**o+**i+na /las**o+**i+na / → las∅+i+na /las∅+i+na / → las∅+I+na	*! PC_{IN}: {/u/,/oo/}	** PC_{IN}: {/u/,/oo/} PC_{OUT}: [o]	** PC_{IN}: {/u/,/oo/} PC_{OUT}: [o]
☞	D. No shift (actual) /las**uu+**i+na/ → las**u+**i+na /las**u+**i+na / → las**u+**i+na /las**oo+**i+na / → las**o+**i+na /las**o+**i+na / → las**o+**i+na /las∅+i+na / → las∅+i+na		***** PC_{IN}: {/uu/,/u/}, {/oo/,/o/} PC_{OUT}: [u], [o]	

In the set of unrounded vowels, the chain-shift scenario wins. It minimizes the number of length mergers. In the set of rounded vowels, on the other hand, the no-shift scenario is the winner. The domain-specific PC constraint, PC_{IN}(high/+round), blocks lowering.

[12] To ensure that rounded vowels do not have to differ in height when merging length, PC(high/+round) needs to dominate PC(long/high).

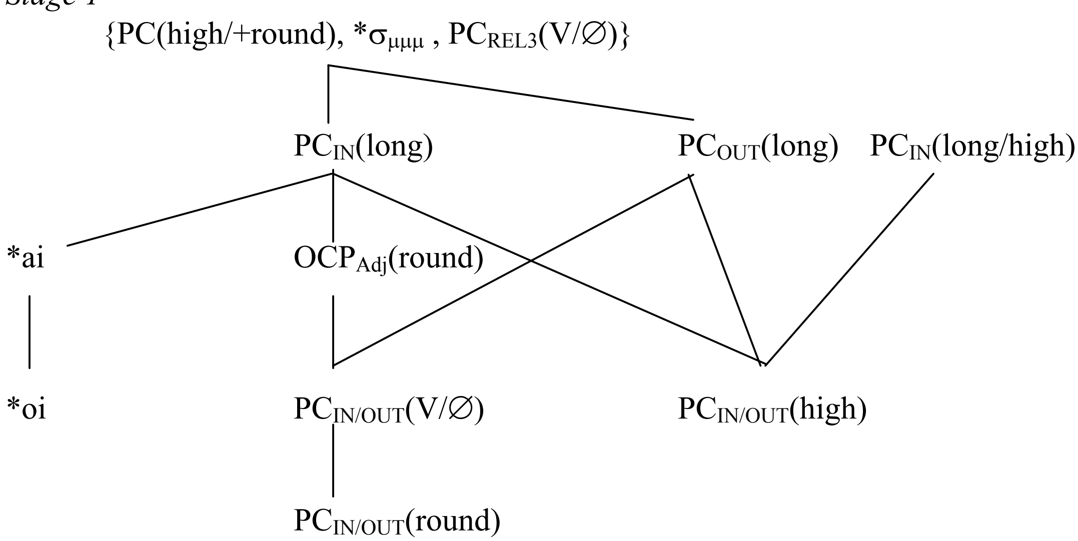
Domain-specific PC constraints resemble generalized faithfulness. Just like generalized faithfulness, they specify a set of segments for which contrast is evaluated. The question is whether there are restrictions on what sets can constitute the domain of PC constraints, for example, perceptually prominent positions only. The other question is whether there needs to be a relation between the domain of a PC constraint and the P property that is evaluated. Are rounded vowels special with respect to height mergers? I leave those questions open for further research.

3.5 Conclusion

Let us summarize the ranking established for Finnish and recall ranking arguments. This is by no means an exhaustive treatment of Finnish vowel alternations but it is an attempt at one.

(47) Mega ranking (combines (36), (59), and (70))

Stage 1



Stage 2

(+rd)-FAITH >> (-rd)-FAITH

(48) Ranking arguments

Ranking	Consequence
$*\sigma_{\mu\mu\mu}$ >> $PC_{IN/OUT}$(long)	Some length neutralizations take place due to shortening.
PC_{OUT}(long) >> $PC_{IN/OUT}$(round)	Rounding takes place to accumulate length neutralizations.
PC_{OUT}(long) >> $PC_{IN/OUT}$(V/∅)	Deletion takes place to accumulate length neutralizations.
$PC_{IN/OUT}$(V/∅) >> $PC_{IN/OUT}$(round)	Rounding is preferred to deletion.
OCP(round) >> $PC_{IN/OUT}$(V/∅)	Deletion takes place to satisfy OCP(round).
PC_{IN}(long) >> OCP(round)	But OCP(round) is violated in some forms to minimize length mergers.
PC_{REL3}(V/∅) >> $PC_{IN/OUT}$(long)	There is a limit put on deletion.
PC_{OUT}(long) >> $PC_{IN/OUT}$(high)	Height neutralizations take place to accumulate and minimize length mergers.
PC_{IN}(high/+round) >> $PC_{IN/OUT}$(long)	No height neutralizations within the set of rounded vowels.
PC_{IN}(long/high) >> $PC_{IN/OUT}$(high)	Height mergers take place to avoid minimal length mergers.

This chapter has investigated contrast in Finnish vowel alternations. The core of the proposal is vowel shortening that triggers the chain shift effects. The next step in the shift is rounding/deletion for the low vowels and lowering with deletion for the high vowels. Both shifts reduce the number of outputs ambiguous in length. Formally, the shifts are initiated by a high-ranking markedness constraint against tri-moraic syllables and then perpetuated by high-ranking PC constraints.

Furthermore, there are various conditions on the shifts. First, rounded vowels do not participate in height shifts that unrounded vowels do. Second, within the set of unrounded vowels, there are no length neutralizations among vowels of the same height. Those conditions are captured by domain- specific PC constraints where the domain argument specifies what set of segments is being evaluated, i.e., rounded vowels, high vowels, mid vowels.

Moreover, although in Finnish deletion aids the length contrast, there is a limit put on deletion. Too much deletion is not allowed, and thus there are some length mergers in a scenario. This is achieved by relational PC, a constraint that originally prohibits absolute neutralization. To account for Finnish, a family of relational PC constraints is proposed. Such constraints demand preservation of a particular number of input-length contrasts in the output.

CHAPTER 4

PREDICTIONS OF THE THEORY

4.1 Introduction

Chain shifts are problematic for standard OT. Consider Finnish. In Finnish, underlying short low vowels undergo rounding but underlying long low vowels do not round. The standard interaction of markedness and faithfulness constraints does not admit chain shifts. If markedness outranks faithfulness, we expect every segment to undergo a process, whether underlying or derived. Thus, under this ranking in Finnish, both segments should undergo rounding. If faithfulness outranks markedness, on the other hand, we predict that none of the segments will undergo the process. In this case in Finnish, none of the segments should round.

There have been several approaches to chain shifts developed in OT so far, among them the local conjunction (LC) approach of Kirchner (1996), the scale approach of Gnanadesikan (1997), and the Sympathy Theory of McCarthy (1999). This last approach is a general approach to opaque interactions in OT, of which chain shifts are an example. All of those approaches propose special faithfulness constraints to handle chain shifts (see section 4.2 for discussion).

PC theory proposes a different explanation for chain shift mappings. The key observation is that chain shifts involve *contrast transformation*: some underlying contrast is preserved on the surface in a different form than underlyingly at the expense of neutralizing some other contrast. To capture this observation, PC theory proposes that contrast preservation exists as an imperative in a phonological system, formalized as constraints on preserving contrast. Given its architecture, PC theory makes different predictions than previous OT approaches with respect to chain shifts. This chapter compares the predictions of PC theory with those of previous approaches.

I will show that, unlike previous OT approaches to chain shifts, PC theory predicts there exist shifts with a high-ranked markedness constraint against the initial stage in the shift, but no high-ranked markedness against the intermediate stage – push shifts (section 4.3.1). But, like other OT approaches, PC theory rules out shifts with no high-ranked markedness against the initial stage – pull shifts (section 4.3.2), and shifts with no termination point – circular shifts (section 4.3.3).[1]

4.2 Previous Approaches to Chain Shifts in OT

To account for chain shifts, Kirchner (1996) and Gnanadesikan (1997) propose special faithfulness constraints. Kirchner postulates locally-conjoined (Smolensky 1995) faithfulness constraints. Gnanadesikan formulates IDENT-ADJACENT type constraints in addition to classic IDENT-type constraints.

Let us look at Finnish under the two approaches. In both approaches, shortening and rounding are forced by high-ranking markedness constraints. The relevant rankings are given below.

(1)

Ranking	Consequence
$*\sigma_{\mu\mu\mu}$ >> IDENT(long)	Shortening takes place.
*ai >> IDENT(round)	Rounding takes place.

Shortening takes place to avoid tri-moraic syllables. Rounding avoids diphthongs of type [ai]. Those two processes are illustrated below.

[1] "High-ranked" markedness refers to markedness constraints ranked higher than conflicting PC constraints (and conflicting markedness constraints).

(2a) Shortening

	/aai/	*$\sigma_{\mu\mu\mu}$	IDENT(long)
☞	ai		*
	aai	*!	

(2b) Rounding

	/ai/	*ai	IDENT(round)
☞	oi		*
	ai	*!	

In (2a), the candidate with shortening, candidate [ai], wins. It satisfies high-ranked markedness *$\sigma_{\mu\mu\mu}$. Similarly, in (2b), the candidate with rounding, candidate [oi], is optimal. It satisfies high-ranked markedness *ai.

But those rankings predict that underlying long low vowels should undergo rounding as well to satisfy high-ranked markedness against [ai]. This is illustrated in the following tableau.

(3) Rounding of underlying long vowels – wrong result

	/aai/	*$\sigma_{\mu\mu\mu}$	*ai	IDENT(long)	IDENT(round)
☜	oi			*	*
☞	ai		*!	*	
	aai	*!			

Candidate [oi] wins as it satisfies both high-ranked markedness constraints. This is the wrong result for Finnish. In Finnish, the optimal form is the one with no rounding, [ai], indicated here with the forward-pointing hand, and not [oi], as predicted by the current constraint ranking.

To achieve the chain shift effect, in Finnish (/aai/→[ai], /ai/→[oi]), we need to block rounding from applying to underlying long vowels (/aai/→[ai],*[oi]) but ensure it applies to underlying short vowels (/ai/→[oi],*[ai]).

In both Kirchner's and Gnanadesikan's proposals, this is the role of high-ranking special faithfulness constraints. In the LC approach of Kirchner, a high-ranked locally conjoined faithfulness constraint blocks rounding from applying if it would result in a double violation of faithfulness in the same segment. In effect, due to local conjunction, a segment cannot both shorten and round. Local conjunction is defined below.

(4) Def. of local conjunction (Smolensky 1993)
The Local Conjunction of C_1 and C_2 in domain D, C_1 $\&_D$ C_2, is violated when there is some domain of type D in which both C_1 and C_2 are violated.

Thus, if the domain of local conjunction is a segment, both C_1 and C_2 cannot be violated together in the same segment.

As indicated by the following constraint ranking, the role of local conjunction is to block rounding from applying to vowels that shorten, that is to underlying long low vowels in the shortening context.

(5) The role of local conjunction
[IDENT(long) & IDENT(round)]$_{Seg}$ >> *ai >> IDENT(round)

This is illustrated in the following tableaux.

(6) /ai/ undergoes rounding

/ai/	[IDENT(long) & IDENT(round)]$_{Seg}$	*ai	IDENT(round)
ai		*!	
☞ oi			*

(7) /aai/ does not round

/aai/	[IDENT(long) & IDENT(round)]$_{Seg}$	*ai	IDENT(round)
☞ ai		*	
oi	*!		*

The short vowel /ai/ in (6) undergoes rounding (/ai/→[oi]) but an identical long vowel

/aai/ in (7) does not round in the same environment (/aai/→[ai], *[oi]). Consider first tableau (6) with an underlying short vowel. In this case, the locally conjoined constraint is satisfied by both candidates (there is no shortening, thus no violation of the LC constraint). The choice between candidates then goes to the markedness constraint *ai. The candidate that satisfies *ai, the rounding candidate, candidate [oi], is optimal. Consider now tableau (7) with shortening. In this case, the locally conjoined constraint is activated. It bans a candidate with both shortening and rounding, candidate [oi], even though it satisfies markedness *ai. Thus, it is the candidate with no rounding, candidate [ai], that wins in (7).[2]

We now move on to Gnanadesikan (1997). In Gnanadesikan's approach, chain shifts are viewed as one-step movement on some scale of similarity. Thus, to account for the Finnish shift, we need to combine the two steps, shortening and rounding, into a single scale. Assuming that this is possible, then there is a high-ranking faithfulness constraint that prohibits two step movements on some scale of similarity, IDENT-ADJACENT [X scale].[3]

(8) Def. of IDENT-ADJACENT [X scale]
Given an input segment α and its correspondent output segment β, then α and β must have related values on scale X, where the defined relations are identity and adjacency. (In other words, the output may not have moved more than one step on the scale.)

In Finnish, the role of high-ranking IDENT-ADJACENT is to prohibit rounding in segments that also undergo shortening.

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[2] Also, in Finnish it is more important to avoid tri-moraic syllables than to avoid the [ai] diphthong. Thus, $*\sigma_{\mu\mu\mu}$ >> *ai.

[3] Combining the two steps into a single scale is quite improbable, since they refer to very different dimensions. For types of possible scales, see Gnanadesikan (1997).

(9) The role of IDENT-ADJACENT
IDENT-ADJACENT >> *ai >> IDENT(round)

The tableaux below are analogous to the ones in the local conjunction approach discussed earlier. For clarity of exposition, they are recalled below.

(10) /ai/ undergoes rounding

	/ai/	IDENT-ADJACENT	*ai	IDENT(round)
	ai		*!	
☞	oi			*

(11) /aai/ does not round

	/aai/	IDENT-ADJACENT	*ai	IDENT(round)
☞	ai		*	
	oi	*!		*

IDENT-ADJACENT is active only in the latter case, tableau (11). It chooses in favor of the candidate with one-step movement, even though it implies a violation of a high-ranked markedness constraint *ai. Otherwise, when IDENT-ADJACENT is satisfied by both candidates, as in (10), the markedness constraint *ai is decisive. It chooses in favor of the candidate with rounding, candidate [oi].

We now come to the final approach to chain shifts and other opaque interactions discussed in this section, Sympathy Theory. In the Sympathy Theory of McCarthy (1999), there are special inter-candidate faithfulness constraints in addition to standard faithfulness. In case of chain shifts, the role of inter-candidate faithfulness is to explain why an otherwise regular process fails to apply in some forms of the language. Inter-candidate faithfulness constraints are like standard faithfulness, in that they evaluate identity between forms, but the dimension along which identity is evaluated is now different (no longer input-output). Inter-candidate faithfulness constraints demand that a candidate resemble a designated failed candidate in some property or set of properties.[4]

In Finnish, the relevant inter-candidate faithfulness constraint demands faithfulness in rounding of the actual candidate to a candidate that did not undergo shortening, candidate [aai]. The candidate that sets the standards for identity, in Finnish [aai], is chosen on some designated IO faithfulness constraint, called the selector. In Finnish, the selector is the faithfulness constraint that militates against shortening, IDENT(long). The failed candidate that influences the actual output, in Finnish [aai], is indicated with a ❀-symbol. The faithfulness constraint that demands identity of the actual output to this candidate is the one with a subscript, $\text{IDENT(round)}_{\text{IDENT(long)}}$. The subscript indicates the faithfulness constraint that chooses the ❀-candidate.

The role of inter-candidate faithfulness is to block rounding from applying to forms, where the input has the long low vowel [aai]. In terms of constraint ranking, the inter-candidate faithfulness constraint outranks the markedness constraint against diphthongs of type [ai]. This is illustrated below.

(12) The role of inter-candidate faithfulness
$\text{IDENT(round)}_{\text{IDENT(long)}}$ >> *ai >> IDENT(round)

As shown in the following tableaux, the high-ranking inter-candidate faithfulness constraint prohibits rounding in cases where the ❀-candidate is the one with a long low vowel [aai], as in (13). Yet it demands rounding when the ❀-candidate is the one with a short rounded vowel [oi], as in (14).

4 For a more recent approach, cumulativity, see McCarthy (to appear).

(13) No rounding of long vowels

	/aai/	*$\sigma_{\mu\mu\mu}$	IDENT(round)$_{IDENT(long)}$	*ai	IDENT(long)	IDENT(round)
	oi		*!		*	*
☞	ai			*	*	
❀	aai	*!				

(14) Rounding of short vowels

	/ai/	*$\sigma_{\mu\mu\mu}$	IDENT(round)$_{IDENT(long)}$	*ai	IDENT(long)	IDENT(round)
☞ ❀	oi					*
	ai		*!	*!		

In (13) the inter-candidate faithfulness constraint, IDENT(round)$_{IDENT(long)}$, rules out the candidate with rounding, candidate [oi], since it is unfaithful in rounding to a candidate that did not shorten, candidate [aai]. In (14), the actual output is itself the ❀-candidate and since it is identical to itself, it vacuously satisfies the inter-candidate faithfulness constraint.

4.3 Predictions of PC theory

In this section I will discuss the predictions of PC theory with respect to chain shifts and compare them to the predictions of other OT approaches (Kirchner 1996, Gnanadesikan 1997). The predictions will be evaluated with respect to four types of chain shift mappings:

(a) *push shifts*, with high-ranked markedness constraint against the initial stage in the shift but no high-ranked markedness against the intermediate stage,

(b) *pull shifts*, with high-ranked markedness constraint against the intermediate stage but no high-ranked markedness against the initial stage,

(c) *circular shifts*, with no termination point, and

(d) *regular shifts*, with high-ranked markedness against each stage in the shift.

These are illustrated below. Mappings incurred by markedness are indicated with a solid arrow. Mappings that are a consequence of something other than markedness are shown with a dotted line. In the circular shift emphasis is on the type of movement rather than on markedness violations, and thus markedness violations are not indicated.

(15) Types of shifts

a. Push shifts (*A)	b. Pull shifts (*B)
A ➔ B --> C	A --> B ➔ C
c. Circular shifts	d. Regular shifts (*A, *B)
A ➔ B ➔ C (C ➔ A)	A ➔ B ➔ C

Not all shifts are predicted to exist under every approach. The goal is to make sure the predictions of the theory coincide with the set of empirically attested phenomena.

It will be shown here that the predictions of PC theory differ from previous approaches with respect to push shifts - PC theory admits push shifts, while previous approaches do not allow for them. The predictions with respect to other types of shifts - regular shifts, pull shifts and circular shifts, are the same in PC as in previous approaches, though their execution is different.

4.3.1 PC Admits Push Shifts

In PC, a phonological process can take place solely to preserve contrast. Push shifts are an example. Assuming A-B-C scale of similarity, push shifts occur when the /B/ to [C] mapping (the latter step in the shift) is an indirect consequence of the /A/ to [B] mapping (the prior step in the shift). In terms of constraints, there is a high-ranked markedness constraint against the initial stage in the shift (*A) but no high-ranked markedness against the intermediate stage. Thus, the /B/ to [C] mapping (the latter step in the shift) has to be a result of something other than markedness.

The Finnish chain shift, *aai→ai→oi*, provides an example. In Finnish, there is a high-ranked markedness constraint against trimoraic syllables, $*\sigma_{\mu\mu\mu}$, but there is no high-ranked markedness against *ai*. This is not to say that there is no markedness constraint against *ai* at all. It only means that *ai is not the constraint responsible for rounding in Finnish.

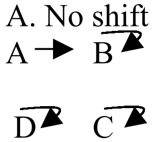
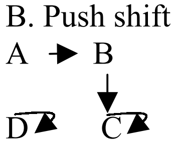
There is empirical evidence for this claim. If *ai were responsible for rounding in Finnish, then segments that this markedness constraint refers to should be ruled out from the language in all environments. Yet they surface in some cases, e.g., in initial syllables *aidata* "bar, enclose", *aie* "intention", *aika* "time". This is the environment where shortening does not take place. Otherwise, when shortening takes place, /ai/ undergoes rounding. Thus, in Finnish rounding takes place only in the environment where shortening takes place but not elsewhere. (It can be also seen as a positional faithfulness effect in other approaches.)

Formally, since [ai]'s are allowed in the language except for the environment of shortening, I propose that the markedness constraint *ai needs to be ranked lower than conflicting PC(round) constraints. Otherwise, if *ai were high-ranking, [ai] segments would be ruled out across the board. To explain why rounding takes place in the environment of shortening, I propose that it is a push-shift effect where shortening forces rounding. In terms of constraints, rounding is forced by output-oriented PC constraint, PC_{OUT}(long), ranked above $PC_{IN/OUT}$(round).

Previous OT approaches to chain shifts (and standard OT generally) do not admit push shifts. In standard OT, the only way to account for a phonological mapping is by a high-ranked markedness constraint (cf. Moreton 1996/1999). Therefore, for a chain shift to take place, there has to be a high-ranked markedness constraint against each stage in the shift. In Finnish, if there is no high-ranked markedness constraint against *ai*, there is no way to force rounding (thus no shift). As shown in the previous section, the role of LC (and other special faithfulness constraints) is to block a process from applying, but they cannot force it.

Unlike previous approaches to chain shifts, PC theory predicts that there exist shifts without high-ranking markedness against the intermediate stage, push shifts. If /A/ maps onto [B] to satisfy markedness, then a constraint on preserving contrast between /A/ and /B/ can by itself force the /B/ to [C] mapping. We no longer need a high-ranking markedness constraint against B to force the latter step in the shift. This prediction is illustrated in the following tableau.[5]

(16) /B/→C as a consequence of /A/→B

Scenarios		PC_{IN}(A/B)	*A	PC_{IN}(B/C)	FAITH
A. No shift 	/A/ → B /B/ → B /C/ → C /D/ → D	*!			*
B. Push shift ☞ 	/A/ → B /B/ → C /C/ → C /D/→ D			*	**

Both scenarios avoid A-type segments (due to *A) but it is only in the push-shift scenario, scenario B, that /A/ and /B/ map onto distinct outputs. Therefore, only the push-

5 The actual scenario in the tableau above is slightly different from the one discussed in chapter 1. The difference is in the mapping for /D/. Underlying /D/ maps onto itself and not onto [C]. This makes the argument more transparent. The reasoning, however, stays the same, regardless of this modification.

shift scenario satisfies the high-ranking PC_{IN}(A/B) constraint. PC_{IN}(A/B) demands that /A/ and /B/ contrast on the surface in some way, which they do in scenario B.

Thus, as shown in (16), in PC a shift can take place as long as there is a high-ranking markedness constraint against the initial step in the shift, here *A. The subsequent step, /B/→[C], is then a result of high-ranking PC, PC_{IN}(A/B), and we no longer need high-ranking markedness, *B, to force it. In the next section, I will show that the opposite situation – where there is no high-ranked markedness constraint against the initial stage in the shift but there is one against the intermediate stage - is not predicted.

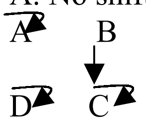
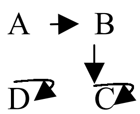
4.3.2 No Pull Shifts

Even though the latter step in the shift can be forced by high-ranking PC, there needs to be a high-ranking markedness constraint against the initial stage in the shift. In other words, markedness is indispensable to ignite the shift. Therefore, in PC theory, as in previous approaches to chain shifts in OT, pull shifts are not admitted.

A pull shift, also known as a drag shift, takes place when the /A/ to [B] mapping (prior step in the shift) is an indirect consequence of the /B/ to [C] mapping (the latter step). In terms of constraints, in a pull shift there is no high-ranking markedness constraint against the initial stage in the shift but there is a high-ranking markedness constraint against the intermediate stage.

PC, like previous OT approaches to chain shifts, predicts no pull shifts. In previous approaches, if there is no high-ranked markedness against [A], there is no way to force /A/ to map onto a distinct output. In PC, similarly, if /B/ maps onto [C] and there is no high-ranking markedness against [A], contrast between /A/ and /B/ is preserved on the surface and there is nothing that forces the /A/ to [B] mapping. To put it differently, if contrast is preserved and markedness is satisfied, then we do not move away from the input segment. This is illustrated in the following tableau.

(17) No /A/→B as a result of /B/→C

Scenarios		PC_{IN}(A/B)	*B	PC_{IN}(B/C)	FAITH
A. No shift ☞ 	/A/ → A /B/ → C /C/ → C /D/→ D			*	*
B. Pull shift 	/A/ → B /B/ → C /C/ →C /D/→ D		*!	*	**

Both scenarios satisfy PC_{IN}(A/B), since in both, /A/ and /B/ map onto distinct outputs. But the pull shift scenario, scenario B, incurs a violation of the high-ranking *B markedness constraint. Therefore, the pull shift scenario, scenario B, loses to the no shift scenario, scenario A.[6]

Thus, PC theory predicts there exist shifts without high-ranking markedness against the intermediate stage (push shifts – see section 4.3.1) but there are no shifts without high-ranking markedness against the initial stage (no pull shifts – current section). Push shifts improve on high-ranking PC, whereas pull shifts do not do so and in addition incur a violation of high-ranked markedness.

Though not allowing for pull shifts, PC theory admits a sequence of changes that resemble a pull shift effect. Take a situation where /A/→[B] "wants to happen" (*A is high-ranking) but is blocked by /B/→[B] (to avoid neutralization). Then /B/→[C] comes along. Now the /A/→[B] map can emerge. Though this set of mappings resembles a pull shift, in the rest of this section, I will show that it can be understood as a regular shift. For this shift to take place, there must be a high-ranking markedness constraint against each stage in the shift.

Labov provides an example of the Northern Cities Shift (Labov 1994:177-201). In the Northern Cities shift, /æ/ as in *cad* maps onto /ie/ as in *idea*, /a/ as in *cod* maps onto /æ/, and /ɔ/ as in *cawed* maps onto /o/. Thus, there is a chain shift effect of the form: [ɔ]→[a]→[æ]→[ie]. There are also other changes that take place in the Northern Cities Shift but we are going to concentrate on the ones mentioned above. Not all speakers reported by Labov show every mapping listed here. However, if a speaker shows evidence of the latter mapping in the shift, then the speaker also shows evidence of the earlier mapping. For example, if a speaker has the /o/→[æ] mapping in his grammar, then the speaker also shows raising of /æ/ to [ie], the subsequent mapping in the shift. Similarly, if a speaker shows the /ɔ/→[o] mapping, then the speaker also shows fronting of /o/ to [æ] and raising of /æ/ to [ie]. The mapping further back in the shift only takes place if the mapping(s) further front occur. Labov explains this effect as symmetry, called The Chain-Shifting Principle: "When the phonetic space between two members of a subsystem is increased by the shifting of one member (the leaving element), the other member will shift its phonetic position to fill that space (the entering element)" (also see Martinet 1955). In the following part of this section, I will argue that what Labov calls a pull shift effect should be understood as a regular shift in the theory of constraints. The logic is as follows: the initial mapping in the shift "wants to happen" due to markedness

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[6] Assume that the markedness constraint *A is dominated by *B. Therefore, A's are OK.

but it can only emerge once the subsequent mapping takes place. Crucially, there is a high-ranking markedness against each stage in the shift.

Let us first see whether the Chain-Shifting Principle stated by Labov (see also King 1969) can be expressed in OT. Labov's observation cannot be directly incorporated into the theory of constraints. In standard OT, phonological mappings follow from the interaction of markedness and faithfulness constraints, and there are no constraints on symmetry per se. But there is a version of OT, the Dispersion Theory of contrast (Flemming 1995; see section 4.5.2), in which principles of this type are present. In Dispersion Theory, there is a principle on the maximization of the distinctiveness of contrasts which refers directly to the shape of a particular space of contrasts. However, this principle has exactly the opposite effect from the Chain-Shifting Principle formulated by Labov (after Martinet). Namely, it prefers more distance between elements of a given space. Thus, if a segment deletes (or moves away), the segment that precedes it should stay where it originally is to take advantage of the increased distance between the two elements. There is another principle in the Dispersion Theory, called minimize articulatory effort, which resembles markedness constraints in other versions of OT. Minimizing articulatory effort can account for chain-shifting. This brings us back to the original observation that mappings like the Northern Cities Shift can be accounted for in OT if there are markedness constraints against each step in the shift.

Let us now give a PC account of the above mentioned sequence of changes: /A/→[B] takes place because /B/→[C] is introduced. Consider two competing languages. In both, there are markedness constraints against each stage in the shift, A and B, but *A can only emerge in the language in which *B is free to operate.

I will assume that the only difference between the two languages is in the relative ranking of the markedness constraint *B versus a conflicting PC constraint, PC(B/C). In the language without the shift, PC(B/C) dominates *B, thus blocking the /B/→[C] mapping. It is more important to avoid the B/C merger than it is to avoid segments of type B. As a result, the mapping /B/→[C] does not take place and the mapping /A/→[B] does not either. In the language with the shift, the ranking is reversed. Now *B dominates PC(B/C). It is more important to avoid B's than it is to avoid the B/C merger. Consequently, the /B/→[C] mapping is introduced and /A/→[B] can emerge. Altogether:

(18) No shift

PC(B/C)   PC(A/B)

*A

*B

/A/→[B] emerges

PC(A/B)

*A

*B

PC(B/C)

Not every ranking relation shown above can be proved for each language. I assume the same ranking of constraints, besides *B versus PC(B/C), for the sake of uniformity.

In the tableaux below, I consider four scenarios. In scenario A, neither /A/ nor /B/ move (no shift). In scenario B, /B/ maps onto [C] and /A/ maps onto [B] (pull shift effect). In scenario C, /B/ maps onto [C] but /A/ stays where it is (no A movement). In scenario D, /A/ maps onto [B] even though /B/ stays where it is (no B movement).

Consider first the language in which /A/→[B] is blocked because /B/→[C] does not happen. In terms of constraint ranking, PC(B/C) outranks *B.

(19) /A/→[B] is blocked because /B/→[B]

Scenarios	PC_{IN} (A/B)	PC_{IN}(B/C)	*A	*B
A. No shift ☞ A B D C			*	*
B. Shift A →B D C		*!		*
C. Partial shift A B D C		*!	*	
D. Partial shift A B D C	*!			**

Scenario A wins since it does not merge any contrasts, unlike any other scenario in the tableau. In scenario A, /B/ stays where it is, and so to preserve contrast with /B/, /A/ does not map onto [B], even though [A]'s are avoided in the language (*A >> *B). All the other scenarios violate high-ranking constraints on contrast. Scenarios B and C, where /B/ maps onto [C], merge B and C type segments, thereby violating PC(B/C). Scenario D merges A and B, violating PC(A/B).

We now discuss the language in which /B/ maps onto [C]. In terms of constraints, *B outranks PC(B/C). In this situation, /A/ is free to map onto [B].

(20) /A/→[B] because /B/→[C]

Scenarios	PC_{IN}(A/B)	*A	*B	PC_{IN}(B/C)
A. No shift A B D C		*!	*	
B. Shift ☞ A →B D C			*	*
C. Partial shift A B D C		*!		*
D. Partial shift A B D C	*!		**	

Scenario B is optimal. It avoids [A]'s, therefore satisfying markedness *A, and it does not merge the contrast between /A/ and /B/ because /B/ maps onto [C]. Scenarios A and C, on the other hand, lose on markedness *A, since they both contain A-type segments. Scenario D, in turn, is ruled out on contrast, since it merges A and B (thus a violation of PC(A/B)).

Therefore, in this case, one could say that /A/→[B] takes place because /B/→[C] is introduced. However, we still need a high-ranking *A constraint (*A >> *B) for the /A/→[B] mapping to take place. Without this constraint ranked above *B even if /B/→[C] were introduced /A/ would not map onto [B]. Scenario C would then win (see the above tableau for the violation profile of scenario C). Thus, what resembles a pull shift effect is really a regular shift. In the next section, we proceed to circular shifts.

4.3.3 No Circular Shifts

Circular shifts involve movement without termination point. This type of movement does not improve on either markedness or PC. It takes place for no apparent reason. PC theory rules it out. In PC, a circular shift is harmonically bounded by a competing identity scenario. In this section, I will show that circular shifts incur the following types of fatal violations: (i) fatal violation of relational PC constraints, (ii) fatal violation of the generalized faithfulness constraints, and (iii) fatal violation of too many PC constraint types.

Let us start with the violation of relational PC. The following table compares the circular shift scenario to an identity scenario.

(21) No circular shifts – unnecessary PC-REL violations

Scenarios		$PC_{IN/OUT}$	PC_{REL}	MARK	FAITH
A. Circular shift A B D C	/A/ → B /B/ → C /C/ → D /D/ → A		*!	A,B,C, D	**** A→B B→C C→D D→A
B. Identity ☞ A B D C	/A/ → A /B/ → B /C/ → C /D/ → D			A,B,C, D	

Both scenarios satisfy input- and output-oriented PC constraints. In both, all input segments map onto distinct outputs and none of the outputs is ambiguous. Both scenarios incur the same violations of markedness since they contain the same outputs and the same number of them. But the circular shift scenario, scenario A, violates relational PC constraints by permuting contrasts. In the circular shift, none of the original input contrasts are preserved in the output (see (30), chapter 1).

Let us now consider a different type of circular shift, a shift with two symmetrical exchange processes. This shift incurs an unnecessary violation of generalized faithfulness.

(22) No circular shifts – too many violations of faithfulness

Scenarios		$PC_{IN/OUT}$	PC_{REL}	MARK	FAITH
A. Circular shift A B D C	/A/ → D /B/ → C /C/ → B /D/ → A			A,B,C, D	****! A→D B→C C→B D→A
B. Identity ☞ A B D C	/A/ → A /B/ → B /C/ → C /D/ → D			A,B,C, D	

Both scenarios satisfy PC constraints: they do not neutralize input contrasts, have no ambiguous outputs and preserve some original input contrasts in the output. But the circular shift scenario involves unnecessary movement and thus is ruled out on generalized faithfulness in stage 2 of Eval.

Circular shifts can also result in more PC violations. Consider a set of mappings, part of which is an exchange process versus a corresponding transparent mapping. The two competing scenarios are shown in the following tableau. The regular mapping and the circular shift fare the same on markedness since they contain the same segments but the circular shift involves too many types of PC violations. Since in this scenario, /A/ and /C/ merge, in terms of mergers, it is a violation of both $PC_{IN/OUT}$(A/B) and $PC_{IN/OUT}$(B/C). The segments /A/ and /C/ are distinct on two dimensions. This is illustrated below.

(23) No circular shifts – too many types of PC violations

Scenarios		$PC_{IN/OUT}$ (A/B)	$PC_{IN/OUT}$ (B/C)	PC_{REL}	MARK	FAITH
A. Circular shift A → B D C	/A/ → B /B/ → C /C/ → B /D/ → D	**!	**!		B,B,C,D	*** A→B B→C C→B
B. Transparent ☞ A → B D C	/A/ → B /B/ → B /C/ → C /D/ → D		**		B,B,C,D	* A→B

Scenario B wins as it violates fewer types of PC constraints.[7]

To sum up, in PC theory there is no movement unless it improves on PC or markedness. This shows that in PC theory, circular shifts are ruled out in favor of non-circular mappings (similarly exchange rules, see Anderson and Browne 1973). The same prediction is made in standard OT (Moreton 1996/1999).

4.3.4 Regular Shifts

So far we have discussed cases where PC constraints activate a phonological process (see push shifts in 4.3.1). But PC constrains can also block a process. In cases like that, a process applies unless it would result in the loss of some contrast. Regular shifts are an example. In a regular shift, there is a high-ranking markedness constraint against each stage in the shift. Thus, each process in a regular shift is forced by a high-ranking markedness constraint. The key assumption of PC theory is that, despite high-ranking markedness, not all segments can get to the unmarked output, due to high-ranking PC constraints.

An example of a regular shift comes from language acquisition. As discussed by Kisseberth (1976) and Velten (1943), in child speech, there are processes of final devoicing and denasalization (both due to high-ranking markedness constraints), but final devoicing targets only underlying non-nasals. De-nasalized voiced stops do not devoice. Thus:

(24) Interaction of final devoicing and denasalization

<u>adult</u>	<u>child</u>	<u>adult</u>	<u>child</u>
ba**d**	ba**t**	brea**d**	bu**t**
broo**m**	bu**b**	trai**n**	du**d**

Since underlying nasals do not devoice, contrast is preserved between underlying nasal and non-nasal stops in word-final position, /n/ vs. /d/ → [d] vs. [t].[8]

Regular shifts like the one above are predicted to exist under any of the OT approaches to chain shifts discussed so far. In fact, in the non-PC approaches, where we need high-ranking markedness to force a phonological process, this is the only type of shift possible. In PC, this is one of two. (The other one is push shift – see 4.3.1.)

In PC, a regular shift is obtained under PC blocking, when a PC constraint outranks conflicting markedness, thus blocking an otherwise regular phonological process in contexts where it neutralizes contrast. In effect, a process applies unless it results in the loss of contrast.

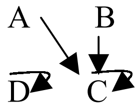
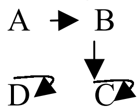
(25) Chain shift ranking - PC blocking
$PC_{IN}(A/B) >> *B >> PC_{IN}(B/C)$

The process /B/→[C] applies due to high-ranked markedness *B, but /A/ maps onto [B] and not [C] since contrast between /A/ and /B/ needs to be preserved on the surface. Consequently, in the optimal scenario, there is a violation of the *B constraint. (Crucially, *A dominates *B, since [A] is not an acceptable output.)

---

7 In the examples in (23), both scenarios satisfy PC-REL constraints. Both preserve each type of input contrast in the output.

(26) Regular shift

Scenarios		PC_{IN}(A/B)	*B	PC_{IN}(B/C)	FAITH
A. No shift 	/A/ → C /B/ → C /C/ → C /D/→ D	*!		*	***
B. Regular shift ☞ 	/A/ → B /B/ → C /C/ →C /D/→ D		*	*	**

Scenario B, in which /A/ and /B/ map onto distinct outputs, is optimal. Thus, even though [B]'s are avoided in the language, if /B/ maps onto [C], then /A/ stops at [B] instead of moving all the way to [C]. This preserves contrast with /B/.

4.3.5 Summary

This section examined predictions of PC theory with respect to chain shifts. It has been shown that PC theory predicts push shifts and regular shifts but rules out pull shifts and circular shifts.

For A→B→C to exist as a chain shift under PC theory, there must be a high-ranking markedness constraint against the initial stage in the shift, *A. The markedness constraint against the subsequent stage, *B, must exist in CON but it is not necessarily high-ranking (see the difference between push shifts versus regular shifts). Thus, the difference between PC theory and its alternatives turns entirely on the matter of whether *B must be high-ranking or not. This has empirical consequences. It predicts push shifts, where segments that *B markedness constraint militates against exist but not in the chain-shifting environment.

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8 I assume that this is a regular shift and not a push-shift effect, since not all obstruents that devoice have corresponding nasals. Thus, not all instances of devoicing could be a result of denasalization.

In section 4.3.1 it was shown that PC constraints can by themselves activate a phonological process without recourse to high-ranking markedness constraints, as in standard OT. Therefore, push shifts are predicted in the PC approach to chain shifts. In section 4.3.2 we observed that although PC constraints can force a phonological mapping, there has to be a high-ranked markedness constraint to force the initial step in the shift. Thus, pull shifts with no high-ranked markedness against the initial step are not allowed in the theory. Section 4.3.3 showed, in addition, that PC theory rules out unnecessary movement, thus not allowing for circular shifts, and finally section 4.3.4 discussed cases where PC constraints block a phonological process, thereby accounting for regular shifts. The properties of PC theory and their predictions discussed in this section are summarized below.

(27) Properties of PC theory

	Property	Effect
(i)	PC can activate a process.	Push shifts exist (4.3.1)
(ii)	Markedness is needed to initiate a shift.	No pull shifts (4.3.2)
(iii)	PC does not allow for unnecessary movement.	No circular shifts (4.3.3)
(iv)	PC can block a process.	Regular shifts exist (4.3.4)

This concludes our discussion of possible chain shift mappings within PC theory. The following sections discuss other predictions of PC theory: diverse ways of preserving contrast (4.4.1), multiple opacity (4.4.2) and contrast in acquisition (4.4.3). This is followed by a discussion of the differences and similarities between PC constraints, standard faithfulness and previous approaches to contrast in OT, among those the Dispersion Theory of contrast (Lindblom 1986, Flemming 1995) (section 4.5.2).

4.4 Further Predictions

4.4.1 Types of Transformations

The main observation of PC theory is that in chain shift mappings and other opaque alternations, contrast is preserved but transformed into some other surface contrast. In PC theory the way in which contrast is preserved follows solely from the relative ranking of constraints on preserving contrast and markedness constraints. This allows for a very rich array of preserving contrasts. Through ranking permutations, it is predicted that contrast can be preserved in many diverse ways. For example, contrast in obstruent voicing can be preserved as contrast in vowel length, as will be discussed below, but also as nasality, ATR, labialization etc. In fact, any contrast can be preserved as any other contrast as long as contrast transformation is generated by the constraint ranking. This is problematic since it generates unattested ways of preserving contrast. In this section, I will examine this prediction of PC theory and try to come up with a possible solution to the problem.

Consider the obstruent voicing contrast. In PC theory, it is predicted that the obstruent voicing contrast can be preserved by vowel length, as in Friulian (see chapter 2), but also as any other contrast. Consider the following constraints: a markedness constraint against voiced obstruents syllable-finally, *voiobs$]_{\sigma}$, a conflicting PC constraint, PC(voice), as well as PC(long) and PC(nasal). By permutations of these constraints, assuming that no other conflicting constraints are ranked higher than those, four types of languages are predicted. Among them, there is a language with no final devoicing. In this language, markedness is ranked below PC constraints, thus unable to compel neutralizations. The other three languages show final devoicing. In all of them, markedness outranks one of the PC constraints. In one of those, the obstruent voicing contrast is neutralized on the surface. In the other two, the obstruent voicing contrast is preserved but manifested as a different surface contrast, vowel length and vowel nasality, respectively. Let us now look at the languages and corresponding rankings.

(28) Typological predictions

a. No final devoicing (English)
PC(voice), PC(nasal), PC(long) >> *voiobs]$_\sigma$

b. Final devoicing, voicing contrast neutralized (German)
*voiobs]$_\sigma$, PC(nasal), PC(long) >> PC(voice)

c. Final devoicing, voicing contrast preserved as length (Friulian)
*voiobs]$_\sigma$, PC(voice), PC(nasal) >> PC(long)

d. Final devoicing, voicing contrast preserved as nasality (unattested)
*voiobs]$_\sigma$, PC(voice), PC(long) >> PC(nasal)

Three of the four ways of preserving contrast generated above (A-C) are found cross-linguistically but one of them, case D, is unattested. Case D represents a language where the obstruent voicing contrast is preserved as contrast in nasality, which is, to my knowledge, not attested.

Let us consider the problematic language in more detail. In this language voiced obstruents are ruled out syllable-finally due to a high-ranking markedness constraint *voiced/obstruent]$_\sigma$. Furthermore, avoiding voiced obstruents syllable-finally compels a merger in nasality (*voiced/obstruent]$_\sigma$ >> $PC_{IN/OUT}$(nasal)) and a merger in nasality is better than a merger in voicing or vowel length ($PC_{IN/OUT}$(voice), $PC_{IN/OUT}$(long) >> $PC_{IN/OUT}$(nasal)). In this situation, if nothing else is involved, words that contrast underlyingly in obstruent voicing, contrast on the surface in nasality of the preceding vowel. This seems like a troubling prediction.

So far we have seen the following ways of preserving contrasts. Let us start with vowel length and vowel height contrasts in Finnish. In Finnish, length is transformed into rounding, height and sometimes presence vs. absence of a segment. Undoubtedly, there is a relation between length, height and rounding (Ladefoged 2001). It has been reported that (i) lower vowels are longer than higher vowels, (ii) higher vowels are more rounded than lower vowels – low vowels are most often not rounded at all, and (iii) more peripheral vowels are both longer and if non-low also higher than less peripheral ones. Since there is a relation between length, height and rounding, it is predicted that the three properties form an alliance when contrast transformation comes into play.

Arabic (see chapter 5) will further support this observation. In Arabic, the epenthesis contrast is realized as stress contrast. That is, the presences vs. absence of a vowel in the input (V/∅ contrast) is realized as surface contrast in segmental prominence. This is predictable. The presence vs. absence of a vowel implies the presence vs. absence of a mora, and since dialects of Arabic are weight-sensitive, stress assignment also correlates with mora-hood. Therefore, transforming the V/∅ contrast into a stress contrast in Arabic is predictable. It takes place along the dimension of mora-hood.

Finally, the obstruent voicing contrast in Polish or Friulian (see chapter 2) is realized in predictable ways, by vowel height and vowel length, respectively. Both properties are correlates of the obstruent voicing contrast and thus those two ways of preserving the obstruent voicing contrast are predictable.

Is there a principled way to determine what P properties pair up in transformations? To explain the concept of a phonological feature/property, Kingston and Diehl (1994) propose that there is a set of surface correlates of a given contrast (phonological feature/opposition) and thus a phonological property P is not an abstract entity but rather results from co-occurrence of multiple P properties locally in the same context. For example, obstruent voicing in word-final position is realized as (i) glottal pulsing during the production of the obstruent (closure voicing), (ii) shorter closure duration of the obstruent, (iii) longer preceding vowel, and (iv) lowering of F_1 on the preceding vowel (vowel raising). Thus, a given opposition, in this case obstruent voicing, has multiple surface correlates. When one of the correlates is not present in the output, the remaining correlate(s) are often enhanced since they are now the sole exponent of the original contrast.

If we assume that certain types of contrast transformations are unattested, it is necessary to put restrictions on the set of satisfaction conditions of PC constraints. One way to do so is to establish a set of surface correlates for each P property, following Kingston and Diehl, and further propose that PC constraints are satisfied only when in addition to preserving contrast, the replacing contrast is chosen from the set of surface correlates of a given property P. For example, in case of the obstruent voicing contrast, PC_{IN}(voice) is satisfied only when a pair of forms that contrasts in *voice*, contrasts on the surface in a property P that belongs to the set of surface correlates of *voice*. Therefore, a pair of forms /bat/ vs. /bad/, contrasting in voicing, that maps onto [bat] vs. [ba:t], contrasting in length, satisfies the constraint PC_{IN}(voice). But the same pair of forms that maps onto [bat] vs. [bãt], contrasting in nasality, violates PC_{IN}(voice). Nasality is not one of the correlates of voicing. This way of thinking about P properties would eliminate impossible ways of preserving contrasts. It requires further research but that is the direction I would take.[9]

4.4.2 Multiple Opacity

PC constraints are satisfied when contrast is minimally preserved for a given pair of inputs. Consider two inputs distinct in presence versus absence of a segment, /$C_1V_2C_3$/ vs. /C_1V_2/. Assume furthermore that C_3 deletes to avoid a coda consonant. For contrast to be preserved between the two inputs, it is enough for the preceding vowel to lengthen when the consonant deletes. No other trace of the deleted consonant needs to be present in the output to mark a distinction between the two inputs. In fact, it is predicted that if contrast is preserved in one way, for example by vowel lengthening, as in the hypothetical example above, it should not be preserved in another way as well. This would create additional (unmotivated) violations of generalized faithfulness. But in some cases, it has been reported that contrast is preserved in multiple ways, called multiple opacity or more recently piling-up of faithfulness violations. In the rest of this section, I will show that multiple opacity is not admitted to PC theory if it were to follow solely from the interaction of input-oriented PC constraints, but it is predicted to occur if output-oriented PC is at stake.

Consider a Bantu language of East Africa, Luganda. In Luganda (Clements 1986, Rosenthall 1994) vowel length is contrastive, there are both long and short vowels, but length contrasts are neutralized in some environments, one of which is before a pre-

9 This view of satisfaction conditions of PC constraints would also explain why contrast, when dislocated from the original locus, is kept locally rather than dislocated far away in the string of segments (see Friulian, Polish). In chapter 5, I will propose separate PC constraints that guard locality but it is possible that locality can be inscribed into the generic PC constraints themselves, once the component of PC theory that deals with predictability of contrast transformation is developed. This is the subject for further research.

nasalized consonant. In Luganda, before pre-nasalized consonants, vowels surface as long. This is traditionally described as compensatory lengthening before pre-nasalized consonants (Wetzels & Sezer 1986).[10]

In Luganda, there are no syllable codas except for geminates and there are no complex onsets except for the consonant/glide combination. Thus, a post-vocalic nasal avoids being in a coda position or in a complex onset by merging with the following consonant. This causes the following consonant to nasalize and the preceding vowel to lengthen.

(29) Prenasalization & lengthening

/mu+ntu/	→	mu:^{n}tu	'person'
/mu+lenzi/	→	mule:^{n}zi	'boy'
/ku+linda/	→	kuli:^{n}da	'to wait'
/ba+ntu/	→	ba:^{n}tu	'people'

As shown above, the nasal is retained in the output in the form of prenasalization and lengthening. This preserves contrast with words that do not have the nasal to begin with (/mutu/ vs. /muntu/ → [mutu] vs. [mu:^{n}tu], /mu:tu/ vs. /mu:ntu/ → [mu:tu] vs. [mu:^{n}tu]) but merges contrast with words that have a pre-nasalized consonant in the input (/mu^{n}tu/ vs. /muntu/ → [mu:^{n}tu], /mu:^{n}tu/ vs. /mu:ntu/ → [mu:^{n}tu]). Consider the following set of corresponding input and output contrasts in Luganda:

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10 For other environments of Luganda length neutralization, see Clements (1986).

(30) Luganda

a. Input contrasts

Short vowels	*Long vowels*		
$mutu_1$	$mu{:}tu_4$	*Non-nasals*	
$muntu_2$	$mu{:}ntu_5$	*Nasal C*	*Nasals*
mu^ntu_3	$mu{:}^ntu_6$	*^nC*	

b. Output contrasts

Short vowels	*Long vowels*		
$mutu_1$	$mu{:}tu_4$	*Non-nasals*	
↘	↓	*Nasal C*	*Nasals*
→	$mu{:}^ntu_{2456}$	*^nC*	

As shown above, contrast is preserved between nasal and non-nasal sets. But it is merged across the set of nasal and pre-nasalized consonants, and across the long-short vowel set.

Let us consider the problem formally. Following Clements (1986), McCarthy (1999), I will assume that nasal codas are banned in Luganda (*mun.ta). Even though nasal codas are not allowed in the output, the nasal does not delete but is realized as pre-nasalization on the following consonant. I will claim that this is to preserve contrast with words that do not have the nasal to begin with. If the nasal dropped out completely, words with and without a nasal would be realized the same. Yet, retaining the nasal is at the cost of merging contrast between inputs with nasal and pre-nasalized consonants. The preceding vowel also lengthens and so there is also a merger of the length contrast. (More on it below.) The following tableau shows the problem formally.[11]

(31) Reason for pre-nasalization

	NO-CODA	PC$_{OUT/IN}$ (N/∅)	PC$_{OUT/IN}$ (NC/^{n}C)	PC$_{OUT/IN}$ (VV/V)
A. Actual ☞ /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu:^{n}tu /mu:ntu/→ mu:^{n}tu /mu^{n}tu/ → mu:^{n}tu /mu:^{n}tu/→ mu:^{n}tu			* **** PC$_{OUT}$(NC/^{n}C): [mu: ^{n}tu] PC$_{IN}$(NC/^{n}C): /mu:ntu/,/mu:^{n}tu/ /mu:ntu/,/mu^{n}tu/ /muntu/,/mu:^{n}tu/ /muntu/,/mu^{n}tu/	* **** PC$_{OUT}$(VV/V): [mu: ^{n}tu] PC$_{IN}$(VV/V): {/mu:ntu/,/mu^{n}tu/} {/muntu/,/mu:^{n}tu/} {/muntu/,/mu:ntu/} {/mu^{n}tu/,/mu:^{n}tu/}
B. No pre-nasal. /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu:tu /mu:ntu/ → mu:tu /mu^{n}tu/ → mu:^{n}tu /mu:^{n}tu/→ mu:^{n}tu		* **! PC$_{OUT}$(N/∅): [mu:tu] PC$_{IN}$(N/∅): /mu:tu/,/mu:ntu/ /mu:tu/,/muntu/		** *** PC$_{OUT}$(VV/V): [mu: ^{n}tu], [mu:tu] PC$_{IN}$(VV/V): {/mu:^{n}tu/,/mu^{n}tu/} {/muntu/,/mu:tu/} {/muntu/,/mu:ntu/}
C. Nasal coda /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → muntu /mu:ntu/→mu:ntu /mu^{n}tu/ → mu:^{n}tu /mu:^{n}tu/→ mu:^{n}tu	**! /mu:ntu/→[mu:ntu] /muntu/→[muntu]			* * PC$_{OUT}$(VV/V): [mu: ^{n}tu] PC$_{IN}$(VV/V): {/mu:^{n}tu/,/mu^{n}tu/}

Scenario A is optimal. There is no nasal coda and words with and without a nasal are pronounced differently. This is not true of the other two competitor scenarios. In scenario B, there is a merger between words with and without a nasal since the nasal drops out

11 As far as constraints go, I assume that both words with a separate nasal in the input (/muntu/) and a pre-nasalized consonant in the input (/mu^{n}tu/) "contain a nasal" and thus when they neutralize on the surface, there is no merger of the contrast in presence vs. absence of a nasal. The constraint PC(N/∅) is satisfied. Since this constraint is high-ranked in Luganda, this rules out any competing scenario in which words with and without a nasal map onto the same output.

completely. In scenario C, the nasal surfaces as a coda and so there is a violation of the NO-CODA constraint.

But to preserve contrast in presence vs. absence of a nasal, it would be enough to nasalize the following consonant. Why, in addition, lengthen the vowel?

(32) Possible competitor: the set of outputs (cf. (30b))

Short vowels	*Long vowels*		
mutu$_{1}$	mu:tu$_{4}$	*Non-nasals*	
↓	↓	*Nasal C*	*Nasals*
mu^{n}tu$_{24}$	mu:^{n}tu$_{56}$	^{n}C	

In the competitor scenario above, words with and without a nasal are kept distinct and there are no mergers of the vowel length contrast since there is no lengthening.

Compare the actual scenario (30) to the competitor scenario above. Under the current constraint ranking, the competitor scenario comes out optimal.

(33) Wrong result: no lengthening

	NO-CODA	PC$_{OUT/IN}$ (N/∅)	PC$_{OUT/IN}$ (NC/^{n}C)	PC$_{OUT/IN}$ (VV/V)
A. Actual ☞ /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu:^{n}tu /mu:ntu/ → mu:^{n}tu /mu^{n}tu/ → mu:^{n}tu /mu:^{n}tu/ → mu:^{n}tu			* **** PC$_{OUT}$(NC/ ^{n}C): [mu: ^{n}tu] PC$_{IN}$(NC/ ^{n}C): {/mu:ntu/,/mu:^{n}tu/} {/mu:ntu/,/mu^{n}tu/} {/muntu/,/mu:^{n}tu/} {/muntu/,/mu^{n}tu/}	* ****! PC$_{OUT}$(VV/V): [mu: ^{n}tu] PC$_{IN}$(VV/V): {/mu:ntu/,/mu^{n}tu/} {/muntu/,/mu:^{n}tu/} {/muntu/,/mu:ntu/} {/mu^{n}tu/,/mu:^{n}tu/}
B. No lengthening ☜ /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu^{n}tu /mu:ntu/ → mu:^{n}tu /mu^{n}tu/ → mu^{n}tu /mu:^{n}tu/ → mu:^{n}tu			** ** PC$_{OUT}$(NC/ ^{n}C): [mu: ^{n}tu],[mu ^{n}tu] PC$_{IN}$(NC/ ^{n}C): {/mu:ntu/,/mu:^{n}tu/} {/muntu/,/mu^{n}tu/}	

Both scenarios satisfy NO-CODA and do not merge the N/∅ contrast. But the "no lengthening" scenario in addition does not merge the contrast between words of different vowel length. If there is a short vowel, it stays short. If there is a long vowel, it remains long. It also fares better on input-oriented PC(NC/^{n}C).

The question then is why both contrasts, pre-nasalization and length, are neutralized in Luganda to preserve contrast in presence vs. absence of a nasal. It seems that it would enough to neutralize only one dimension of contrast, in this case pre-nasalization, and leave length contrast intact. The contrast in presence vs. absence of a nasal would be preserved in that case and NO-CODA would be satisfied.

To explain lengthening, I will propose that there is a high-ranking output-oriented PC constraint. Compare the actual scenario (30b) with the alternative in (32). Both scenarios merge some pre-nasalization contrasts but the actual scenario, in which there is lengthening, contains only one output that corresponds to inputs distinct in pre-nasalization. Therefore, the actual scenario improves on the $PC_{OUT}(NC/^{n}C)$ constraint. In the actual scenario, there is only one output that violates this constraint, whereas in the competitor scenario, with no length neutralizations, there are two such outputs. The two competing scenarios are presented in tableau (33). This is the core property of opacity. Opacity reduces the number of outputs ambiguous in property P at the cost of neutralization in some other property. In Luganda, opacity reduces the number of outputs ambiguous in $NC/^{n}C$ at the cost of length mergers.

For the actual scenario to win, the output-oriented PC constraint needs to outrank constraints against length mergers, as well as the input-oriented $PC_{IN}(NC/^{n}C)$. The relevant ranking and tableau are given below.

(34) Opacity ranking
NO-CODA, $PC_{OUT/IN}(N/\varnothing)$, $PC_{OUT}(NC/^{n}C)$ >> $PC_{IN}(NC/^{n}C)$, $PC_{IN/OUT}(VV/V)$

(35) Opacity improves on output-oriented PC

	NO-CODA	$PC_{OUT/IN}$ (N/∅)	PC_{OUT} (NC/^{n}C)	PC_{IN} (NC/^{n}C)	$PC_{OUT/IN}$ (VV/V)
Actual ☞ /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu:^{n}tu /mu:ntu/ → mu:^{n}tu /mu^{n}tu/ → mu:^{n}tu /mu:^{n}tu/ → mu:^{n}tu			* [mu:^{n}tu]	****	*****
No lengthening /mutu/ → mutu /mu:tu/ → mu:tu /muntu/ → mu^{n}tu /mu:ntu/ → mu:^{n}tu /mu^{n}tu/ → mu^{n}tu /mu:^{n}tu/ → mu:^{n}tu			**! [mu^{n}tu] [mu:^{n}tu]	**	

The actual scenario wins since it improves on the output-oriented PC_{OUT}(NC/^{n}C) constraint. In this scenario, there is only one output that corresponds to inputs distinct in pre-nasalization. This supports our observation that opacity reduces the number of outputs ambiguous in some property P. This is at the cost of incurring neutralizations of some other contrast in the system. In Luganda, the length contrast is neutralized to reduce the number of outputs ambiguous in prenasalization.

In conclusion, the Luganda case is admitted under PC theory, but this is not to say that any other case of multiple opacity would be allowed. Unless opacity improves on output-oriented PC or markedness, it should not take place. This is a restriction on what types of contrast transformations are possible under PC. This distinguishes the PC approach from other approaches to opaque process interactions like, for example, rule ordering.[12]

4.4.3 Contrast Preservation in Acquisition

In this section, the PC approach is investigated with respect to the acquisition of phonology. This is discussed on the example of cluster reduction.

Children often reduce consonant clusters in onsets (Gnanadesikan to appear, Pater 2002). Consider a case of cluster simplification in a sequence fricative *plus* nasal. The nasal is retained in the output while the fricative deletes (Pater 1997). In what follows, I am not going to discuss the pattern of deletion (see Pater 2002).

(36) Child mapping

inputs /snap/ vs. /nap/

↓ ↙

outputs [nap]

(37)

Adult gloss	*Child pronunciation*	*Age*
mommy sneeze	[mami+nis]	1;9.5
snake	[nek]	1;11.22
what (do) I smell?	[wʌs ai mɛʊ]	2;4.29

Formally, it must be the case that the child ranks markedness *CLUSTER above conflicting PC constraints. It is more important for the child to satisfy the high-ranking well-formedness constraint than it is to preserve contrast in presence versus absence of a segment, $PC_{IN/OUT}$(C/∅), where C stands for a consonant. The child ranking is given below.

[12] Another example of multiple opacity comes from Arabic. In some Arabic dialects (John McCarthy (p.c.)), epenthetic words are special with respect to stress and emphasis harmony (or even palatalization). Thus, contrast is doubly-preserved.

(38) Child ranking
*CLUSTER >> $PC_{IN/OUT}(C/\varnothing)$

Let us now move on to adult speech. In adult language, the ranking is the opposite. Markedness is demoted below conflicting PC constraints, such that deletion is blocked.

(39) Adult mapping

inputs /snap/ vs. /nap/

↓ ↓

outputs [snap] vs. [nap]

The ranking is given below.

(40) Adult ranking
$PC_{IN/OUT}(C/\varnothing)$ >> *CLUSTER

The relevant tableaux follow.

(41) Child language

			*CLUSTER	$PC_{IN/OUT}(C/\varnothing)$
a.	☞	/snap/→nap /nap/→nap		**
b.		/snap/→snap /nap/→nap	*!	

(42) Adult language

			$PC_{IN/OUT}(C/\varnothing)$	*CLUSTER
a.		/snap/→nap /nap/→nap	**!	
b.	☞	/snap/→snap /nap/→nap		*

This is parallel to markedness demotion in language acquisition within the OT model with standard faithfulness, see Tesar (1998), Tesar & Smolensky (1998), also Hayes (1999).

So far it has not been made explicit how children learn the way PC constraints interact in adult language. Not all forms included in the scenarios are the existing forms of the language. Thus, what is in the scenarios that children compile? In standard OT, children learn constraint interaction based on the actual forms of the language. I will assume that the same is true of the PC model. The learning process is based on the mappings for the actual forms of the language (as shown above, 43-44), and only then extended (hypothesized) to non-existent forms.

This concludes our discussion of PC predictions that have to do with (i) constraint permutations, (ii) satisfaction conditions of PC constraints, and (iii) the role of contrast in acquisition. The next section compares the PC approach with other OT approaches to contrast.

4.5 Comparison with Previous Approaches

In this section I will discuss the differences between PC and faithfulness (4.5.1) and compare PC theory with previous approaches to contrast in OT (4.5.2).

4.5.1 Faith in PC

In standard OT, the role of faithfulness is to demand identity between inputs and their corresponding outputs. When faithfulness outranks conflicting markedness, a phonological process is blocked. With the opposite ranking, a phonological process takes place. Let us take final devoicing in standard OT. When markedness against voiced obstruents word-finally outranks conflicting faithfulness, final devoicing takes place. With the opposite ranking, there is no devoicing. The following tableaux illustrate the two cases: a language with final devoicing in (43) and one without devoicing in (44). In each case, two types of inputs are considered: one with a voiced obstruent syllable-finally and one with a voiceless obstruent in the same position.

(43) Final devoicing

		/bu**d**/	*VOICEDOBS]$_\sigma$	IDENT(voice)
a.	☞	bu**t**		*
b.		bu**d**	*!	

		/bu**t**/	*VOICEDOBS]$_\sigma$	IDENT(voice)
c.	☞	bu**t**		
d.		bu**d**	*!	*

(44) No final devoicing

		/bu**d**/	IDENT(voice)	*VOICEDOBS]$_\sigma$
a.		bu**t**	*!	
b.	☞	bu**d**		*

		/bu**t**/	IDENT(voice)	*VOICEDOBS]$_\sigma$
c.	☞	bu**t**		
d.		bu**d**	*!	*

Let us consider forms with a voiced obstruent word-finally in both languages. Those are the top tableaux in each case, indicated here as (a-b). In the language with final devoicing, tableau (43), candidate (a) wins over candidate (b) since it satisfies high-ranked markedness. In a language with no final devoicing, on the other hand, tableau (44), candidate (b) is the winner. It does not change voicing specification and so satisfies high-ranked IDENT(voice). Let us now move to forms with a voiceless obstruent word-finally in both languages. Those are the bottom tableaux, indicated here as (c-d). In each case, it is the form with a voiceless obstruent word-finally, candidate (c), that wins. In consequence, in the language with final devoicing, there is neutralization of the voicing distinction on the surface. Inputs distinct in voicing word-finally, /bu**d**/ and /bu**t**/, map onto the same output. In the language with no final devoicing, on the other hand, the underlying voicing distinction is preserved on the surface.

PC theory takes those observations at face value and gives contrast preservation the status of an imperative in a phonological system. In PC, instead of input-output faithfulness constraints interacting with markedness constraints, neutralizations are accounted for by the relative ranking of markedness constraints and constraints on contrast. To evaluate constraints on contrast, in PC mappings are evaluated together as a system. Below I recall the PC rankings for languages with final devoicing and the lack of it (see also chapter 1, section 3). (Since in the following examples input and output-oriented PC constraints assign the same violation marks to each form, only input-oriented PC is shown in the tableaux.)

(45) Final devoicing

			*VOICEDOBS]$_\sigma$	PC$_{IN}$(VOICE)
a.	☞	/bu**d**/→bu**t** /bu**t**/→bu**t**		*
b.		/bu**d**/→bu**d** /bu**t**/→bu**t**	*!	

(46) No final devoicing

			PC$_{IN}$(voice)	*VOICEDOBS]$_\sigma$
a.		/bu**d**/→bu**t** /bu**t**/→bu**t**	*!	
b.	☞	/bu**d**/→bu**d** /bu**t**/→bu**t**		*

In the language with final devoicing, tableau (45), scenario (a) wins since it avoids voiced-obstruents word-finally, thus satisfying the high-ranked markedness constraint. This is at the cost of merging voicing. In the language with no final devoicing, on the other hand, tableau (46), scenario (b) is optimal since it does not merge the voicing contrast on the surface and thus satisfies the high-ranked PC constraint. This is at the cost of having a voiced obstruent word-finally.

Both standard OT and PC theory are able to account for cases of neutralization and the lack of it but the execution is different. In standard OT, neutralizations follow solely from the interaction of markedness and faithfulness constraints. In PC theory, they are a result of the relative ranking of markedness constraints and constraints on contrast preservation. That is, while in standard OT, contrast follows solely from the way constraints interact, in PC theory it is inscribed in the constraints themselves. There are constraints on contrast in the theory, called PC constraints. Constraint ranking in PC theory is a way of blocking or activating constraints on contrast.

The two approaches differ in the range of phenomena they cover. While they both account for cases of simple neutralization and the lack of it (transparent processes), they differ with respect to opaque alternations, such as chain shifts and derived environment effects. It has been shown here that chain shifts and derived environment effects, the two types of opaque alternations, are not admitted under standard OT, but PC admits them. Therefore, by formulating contrast preservation as an imperative in a phonological system, PC theory accounts for transparent and opaque processes in a uniform manner with no additional mechanisms required. This is crucially different from standard OT.

PC constraints are the core of PC theory but they are not enough to evaluate contrast. There is more than one way to preserve contrast on the surface and all PC constraints require is to preserve contrast in some way. Therefore, to effectively compare scenarios we need something other than PC in the theory. For example, in the simple case of no neutralization in (46), contrast between forms distinct in voicing can be preserved on the surface, as in the identity scenario, where inputs are identical to their outputs. But it can be also preserved by input-output permutations, as in the so-called permuted scenario (see chapter 1, section 3 for discussion). The permuted scenario is recalled below in (47b). As shown in the following tableau, the permuted scenario ties with the competing identity scenario on PC and markedness. I refer to this as the permuted scenario problem.

(47) Permuted scenario problem – a tie

			PC_{IN}(voice)	*VOICEDOBS$]_{\sigma}$
a.	identity	/bu**d**/→bu**d** /bu**t**/→bu**t**		*
b.	permuted	/bu**d**/→bu**t** /bu**t**/→bu**d**		*

The permuted scenario, scenario b, is like the identity scenario except that it switches the relation between inputs and their outputs. When compared to the identity scenario, in the permuted scenario, different outputs correspond to different inputs. The permuted scenario incurs the same markedness violations as the identity scenario since it contains the same outputs. It also satisfies contrast, just like the identity scenario (at least as far as PC(voice) goes). Therefore, it fares the same on PC and markedness as the identity scenario. But the two scenarios are clearly different.

In the permuted scenario, as opposed to the identity scenario, outputs and inputs are non-identical. However, PC constraints have nothing to say about this, unless it influences contrast preservation, which it does not in this case. Therefore, we need something else than PC to rule out the permuted scenario.

In PC theory this is the role of generalized faithfulness constraints that belong to stage 2 of Eval. Generalized faithfulness rules out unnecessary disparity between inputs and outputs in a scenario. In this particular case, it rules out the permuted scenario. This is illustrated below.

(48) The role of generalized faithfulness

			PC_{IN}(voice)	*VOICEDOBS]$_\sigma$	FAITH
a.	identity	/bu**d**/→bu**d** /bu**t**/→bu**t**		*	
b.	permuted	/bu**d**/→bu**t** /bu**t**/→bu**d**		*	**!

Generalized faithfulness chooses the identity scenario as optimal. In the permuted scenario, there are two violations of generalized faithfulness, since there is voicing disparity in both mappings in the scenario. Thus, each mapping constitutes a violation.

Generalized faithfulness in PC can be seen as a descendant of standard faithfulness since it evaluates individual input-output mappings. But it is different from standard faithfulness in two respects. First, unlike standard faithfulness, it lumps together every type of faithfulness violation for a given mapping in a scenario, not differentiating between types of input-output disparity. In other words, any change in property P between inputs and their corresponding outputs constitutes as a violation of this constraint. Generalized faithfulness, therefore, can be thought of as a constraint on minimizing distance between inputs and their corresponding outputs. It evaluates disparity for outputs of a certain type.

The other difference between faithfulness in PC (generalized faithfulness) and standard faithfulness is its place in the constraint hierarchy and consequently its role in constraint interaction. Faithfulness in PC is limited in its force. It is different from other OT constraints since it is a non-permutable constraint, ranked below all other constraints and activated only in case of a tie. This particular mode of activation of generalized faithfulness follows naturally from its placement in the constraint hierarchy. Generalized faithfulness, unlike other constraints, belongs to stage two of Eval.

The claim of PC theory is that PC constraints together with low-ranked generalized faithfulness subsume the role of standard faithfulness. They account for what standard faithfulness would and in addition cover more ground, thereby accounting for the full set of attested phenomena.

There are three types of PC constraints in the theory: input-oriented PC (also known as anti-neutralization PC), output-oriented PC and relational PC. To begin with, input-oriented PC constraints prohibit mergers of input contrasts in the output. They are satisfied even when an input contrast is realized as a different output contrast. Since input-oriented PC constraints are assigned a violation mark for any input pair distinct in property P that neutralizes in the output, they minimize the number of neutralizations in a scenario. Thus, overall, input-oriented PC constraints militate to retain underlying distinctions in some form on the surface.

Output-oriented PC constraints prohibit ambiguous outputs, by which they prohibit neutralizations (similar to input-oriented PC), but their primary role is to guard distribution of neutralizations in a scenario. Output-oriented PC constraints prefer a scenario where neutralizations are accumulated locally rather than distributed across outputs. This results in fewer ambiguous outputs. Under the assumption that fewer ambiguous outputs increase recoverability of a scenario, output-oriented PC constraints increase recoverability.[13]

The third type of PC constraints proposed in the theory is relational PC. Relational PC works to retain some correspondence between output and input contrasts. An output contrast of a particular type needs to correspond to at least one instance of an identical input contrast.

Overall, PC constraints increase similarity between sets of inputs and their corresponding outputs, and in this they can be compared to standard faithfulness. But while standard faithfulness evaluates input-output mappings in isolation, PC constraints are novel in that they evaluate contrasts for pairs of underlying and surface forms. Unlike standard faithfulness, PC constraints allow underlying contrasts to be transformed into distinct output contrasts. In this way they admit phonological processes that involve contrast transformation (i.e., chain shifts). This is true for both input- and output-oriented PC. Relational PC sets limits on what types of transformations can take place.

But PC does not fully subsume faithfulness. As has become apparent, we do need some faithfulness in the theory despite PC. It is proposed that in addition to PC constraints, there are low-ranked generalized FAITHFULNESS constraints that evaluate input-output disparity for each mapping in a scenario (see chapter 1, section 2). Those constraints are more general than standard faithfulness.

In the next section I will discuss previous approaches to contrast in OT.

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[13] The idea that opacity increases recoverability has been already discussed in the works of Gussmann (1976), Kaye (1974), (1975), Kisseberth (1976). Their understanding of recoverability is different from mine but the idea is similar.

4.5.2 Previous Approaches to Contrast in OT

PC theory developed in this work recognizes contrast as an imperative in a phonological system. It is formalized as constraints on contrast preservation. Phonological systems are accounted for by the relative ranking of constraints on contrast preservation and conflicting markedness constraints. There are also low-ranked generalized faithfulness constraints in the theory.

Previous work on contrast in Optimality Theory includes the *Dispersion Theory of Contrast* (Flemming 1995, 1996; Padgett 1997, 2000). Both PC theory and the *Dispersion Theory* propose that contrast is an imperative in a phonological system and needs to be stated formally as a family of constraints. It does not always follow from the interaction of markedness and standard faithfulness constraints, as this interaction does not admit some empirically attested phenomena. Both theories also recognize that to evaluate contrast, candidates must be sets and not singletons as in standard OT.

The primary difference between the PC approach to contrast and previous OT approaches relates to the types of contrast constraints and the structure of candidate sets. In previous work, contrast constraints evaluate surface inventories of segments. They are formulated as competing constraints on the maximization of the number of contrasts, maximization of the distinctiveness of contrasts and minimization of the articulatory effort, all evaluated at the surface.[14]

In PC theory, on the other hand, constraints on contrast aim to account specifically for phonological processes. Since phonological processes either neutralize a particular contrast in some environments (transparent processes) or preserve a particular contrast but express it in a different way than in the underlying form (opaque processes), PC theory proposes that constraints on contrast are really constraints on contrast preservation. These include anti-neutralization (input-oriented) PC, distribution (output-oriented) PC and relational PC. (See previous section for discussion.)

Since constraints on contrast are different in the two approaches, the structure of candidate sets is also different. In the *Dispersion Theory*, scenarios contain sets of possible outputs. In PC theory, on the other hand, scenarios contain sets of input-output mappings. The similarity here is that in both cases we are talking about possible words and not necessarily the existing words of the language. As for the size of scenarios, PC theory, unlike the *Dispersion The*ory, proposes that scenarios contain only a finite set of mappings, as only a finite set allows one to evaluate contrast.

4.6 Conclusions

This dissertation develops a theory of phonology in which phonological mappings are evaluated as a system and are accounted for by three distinct families of PRESERVE CONTRAST constraints (input-oriented PC, output-oriented PC and relational PC) interacting with conflicting MARKEDNESS constraints and low-ranked (non-permutable) FAITHFULNESS constraints.

The key observation is that an opaque phonological mapping, like a chain shift or a derived environment effect, involves *contrast transformation*. In an opaque mapping, a given underlying contrast is transformed into a different surface contrast at the cost of neutralizing some original instances of that surface contrast. In Finnish, an underlying

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[14] But see more recent work of Padgett (2000) for the analysis of historical change in terms of contrast.

length contrast is transformed into a surface rounding contrast at the cost of neutralizing some original instances of the rounding contrast.

In cases of contrast transformation, a given underlying contrast cannot be preserved on the surface in the same way as in the underlying form due to the application of some phonological process. But, at the same time, it is required that this particular contrast be preserved on the surface in some way. In consequence, some other process is activated to retain this contrast. In Finnish, for example, shortening takes place and so the underlying length contrast cannot be preserved on the surface in the same way as in the underlying form. However, there is a high-ranked requirement in the language to preserve the length contrast is some way despite shortening. In consequence, rounding takes place, and so the underlying length contrast is transformed into surface rounding contrast.

Often the process that is activated in cases of contrast transformation, e.g., rounding in Finnish, is not due to high-ranked markedness. Therefore, we need some other way to force it. PC theory admits such mappings, because it allows a phonological process to take place solely to preserve contrast, as long as there is another process that takes place higher-up in the shift. In Finnish, in particular, PC theory admits rounding, as long as there is shortening in the same environment. Thus, rounding is indirectly forced by shortening together with the requirement on preserving contrast between forms distinct in length. We no longer need high-ranked markedness against unrounded vowels to force rounding.

In PC theory contrast preservation is an imperative in the grammar. It is formalized as competing contraints on minimizing neutralizations of input contrasts on the surface (input-oriented PC), improving distribution of neutralizations in the system (output-oriented PC), and retaining correspondence between output and input contrasts (relational PC). Different aspects of contrast preservation take precedence in different languages.

Unlike standard faithfulness, preserve-contrast constraints allow one to retain contrasts in a way different than in the underlying form and thereby admit phonological mappings that involve contrast transformation. (This is true of both input and output-oriented PC.) The advantage of PC theory is that it accounts for both transparent and opaque processes (i.e., chain shifts) in a uniform manner with no additional mechanisms required.

CHAPTER 5

CASE STUDY: STRESS AND EPENTHESIS IN DIALECTS OF ARABIC

5.1 Statement of the Problem

Epenthesis has the potential to merge underlying contrasts on the surface. This takes place when identical epenthetic and non-epenthetic segments are found in the same environment and act the same with respect to various phonological processes. Thus surface words in which a given segment is present underlyingly are identical to those in which it is epenthetic. In Southern Palestinian Arabic, for example, (Davis 1995, McCarthy 1997), both epenthetic and underlying *i's* block spreading of rightward [RTR] harmony, underlying *i* (as in *Tiinak*), and epenthetic *i* as in (*baT**i**nha* from /baTn+ha/). Similarly, Spring (1994) shows that in Axininca Campa both underlying and epenthetic *t's* undergo palatalization.

But in many cases, identical words with epenthetic and non-epenthetic segments pattern differently with respect to phonological processes (Alderete 1995, 1996; Archangeli 1984, 1988; Archangeli and Pulleyblank 1994; Ito 1989; Kiparsky 1998; Steriade 1995). In Northern Palestinian Arabic (Herzallah 1990), unlike in Southern Palestinian, underlying and epenthetic vowels behave differently with respect to various segmental processes. For example, there is a process of r-de-emphaticization but only underlying *i's* trigger de-emphaticization. Epenthetic *i's* do not de-emphaticize. Similarly, underlying *i's* do not undergo dorsal assimilation while epenthetic *i's* assimilate.

In this chapter I will discuss the behavior of epenthetic and non-epenthetic vowels with respect to stress assignment in various dialects of Arabic (Broselow 1982, Farwaneh

1995). Arabic dialects vary on whether words with epenthetic and non-epenthetic vowels behave the same or different with respect to stress placement. (See also Michelson 1981, 1989 and Piggott 1995 for stress-epenthesis interaction in Mohawk. Piggott also discusses Iraqi Arabic.)

Dialects of Arabic can be divided into onset and coda dialects depending on the site of epenthesis (Selkirk 1981, Broselow 1982). In onset dialects epenthesis into a tri-consonantal cluster creates an open syllable (*ka-tab-t-lu* becomes *ka-tab-t**i**-lu*). In coda dialects, on the other hand, epenthesis into a tri-consonantal cluster creates a closed syllable (*ki-tab-t-la* becomes *ki-ta-b**i**t-la*). We will look at the following types of dialects:

(i) dialects in which words with epenthetic and non-epenthetic vowels behave the same with respect to stress in all environments: all onset dialects (Broselow 1992, Farwaneh 1995), some coda dialects – Omani (Shaaban 1977), Abu Dabi (Farwaneh 1995), and epenthesis into quadri-consonantal clusters in all dialects (both coda and onset)

(ii) dialects in which words with epenthetic and non-epenthetic vowels behave differently with respect to stress in all environments: coda dialects – Levantine (Farwaneh 1995, Kenstowicz 1981), Syrian (Cowell 1964)

(iii) dialects in which words with epenthetic and non-epenthetic vowels behave differently with respect to stress in case of epenthesis into word-final syllables but the same in case of epenthesis into word-medial syllables: coda dialect – Iraqi (Broselow 1982, Erwin 1963)

To account for the stress-epenthesis interaction, I will propose that when identical words with underlying and epenthetic vowels behave differently with respect to stress assignment, the underlying contrast in presence versus absence of a vowel (the V/∅ contrast) is preserved on the surface and realized as stress contrast. In other words, the underlying segmental contrast is transformed into a surface contrast in prosodic prominence. In cases when epenthetic and underlying vowels act the same with respect to stress assignment, on the other hand, the underlying V/∅ contrast is lost. Arabic dialects differ in ranking of the V/∅ contrast requirement and thus either preserve or neutralize this underlying contrast on the surface.

Contrast transformation is not admitted in classic Optimality Theory (Prince and Smolensky 1993), where the optimal mapping is chosen by the interaction of markedness constraints with standard faithfulness constraints. Standard faithfulness constraints require identity in the underlying-surface mapping and do not allow underlying properties to be transformed into different surface properties. As far as standard faithfulness is concerned, transforming the underlying property into a different surface property is equivalent to the loss of the underlying property altogether. Thus, I argue, phonological phenomena that involve contrast transformation, like contrast-preserving stress-epenthesis interaction in Arabic, require a framework where contrast transformation is captured formally and differentiated from the loss of contrast.

In this dissertation I have proposed such a framework. I call it Contrast Preservation Theory (PC theory for short). As we have seen, PC theory is a modification of Optimality Theory. Unlike standard OT, it admits phonological mappings that require an account in terms of preserving contrasts, like contrast-preserving epenthesis. Moreover, it explains such mappings in the same way in which it explains mappings involving the loss of contrast altogether in some environments (for example final devoicing, or non-contrast-preserving epenthesis). In traditional terms, mappings involving contrast transformation are known as opaque processes, whereas mappings involving the loss of contrast altogether are known as transparent processes. Thus, this account gives a uniform explanation for both. The next section gives an overview of the analysis of stress-epenthesis interaction in Arabic in PC theory.

5.2 Overview of the Analysis

As already noted, it will be proposed here that when words with and without epenthesis behave differently with respect to stress assignment, the underlying contrast between them is preserved on the surface but expressed differently than in the underlying form. Specifically, the underlying V/∅ contrast is transformed into a surface stress contrast.

To explain this particular contrast transformation, I will argue that the need to preserve contrast between words containing epenthetic and non-epenthetic vowels can alter the weight system of the language and consequently change main stress placement.

As has been proposed in the literature, coda consonants in Arabic dialects are moraic (see Hayes 1989, 1995, Farwaneh 1995, McCarthy and Prince 1990ab among others). Closed syllables count as heavy for purposes of stress assignment and for other processes sensitive to the moraic structure of a syllable. However, I will argue that in contrast-preserving dialects closed syllables with epenthetic vowels count as light. Therefore, I will propose that coda consonants of such syllables are non-moraic, unlike coda consonants of syllables with underlying vowels in the same dialect. The non-moraic status of coda consonants following epenthetic vowels often leads to a different foot structure of a word, and thus in many circumstances to different stress placement. (The evidence for my proposal comes from stress assignment, but I predict that the mono-moraic structure of syllables with epenthetic vowels would have consequences for other processes as well, were they sensitive to mora count.)

This proposal with some additional assumptions on mora continuity (see section 5.4) and a requirement on locality of contrast transformation (see section 5.6) makes correct typological predictions for Arabic dialects.

First, it predicts that there are both contrast-preserving and contrast-neutralizing dialects, as dialects differ in ranking of the contrast preservation requirement with respect to a constraint assigning a mora to a coda consonant. Thus, contrast is either lost or preserved on the surface, depending on the ranking.

Second, this account explains cases like those in Iraqi Arabic (Erwin 1963), where words with and without epenthetic vowels behave differently with respect to stress assignment, but only if they are in word-final syllables. Word-medially they act the same. In my proposal this amounts to saying that coda consonants of word-medial syllables need to be moraic, despite the loss of contrast, whereas coda consonants in word-final syllables can lack a mora and thus result in contrast being preserved.[1] To explain why a medial non-moraic coda is dispreferred to a final non-moraic coda, I will propose that a non-moraic coda medially disrupts continuity at the level of moras. Unlike a medial coda, a non-moraic coda word-finally does not violate moraic continuity and thus is preferred all else being equal. Here I follow Hyman (1985), Zec (1988) and Ito (1989) in assuming that each segment of a syllable is linked to a mora. Onset consonants share a mora with the following vowel. Thus, if a coda consonant lacks a mora medially in the string of segments, mora continuity is disturbed (see section 5.4).

In addition, this proposal makes correct typological predictions with respect to onset dialects (section 5.6.2) and epenthesis into quadri-consonantal sequences (section

[1] This idea is similar to final consonant extrametricality, which has been proposed in the past analyses of Arabic (Hayes 1982).

5.6.3), facts that remained puzzling under previous approaches to this phenomenon (rule ordering, underspecification; see section 5.8). As Farwaneh (1995) observed, epenthesis in onset dialects and epenthesis into quadri-consonantal sequences in all dialects are never contrast-preserving. Those two facts follow naturally from our analysis. Since there is no coda created by epenthesis in onset dialects, there is no possibility of differentiating the weight of the syllable with an epenthetic vowel from the one without an epenthetic vowel. Both syllables are light to begin with. The non-contrast-preserving nature of epenthesis into quadri-consonantal clusters is also predicted since, as we will see, changing the weight of the epenthetic syllable would not change footing and thus would be superfluous. And in Optimality Theory, given strict domination of constraints, we do not violate constraints if nothing is gained in the end.

To capture locality of contrast transformation, I will propose a locality constraint on contrast preservation (see section 5.6) - by which only the coda consonant of the syllable with an epenthetic vowel can be moraless. The weight of adjacent syllables is never altered to preserve contrast. In addition, as we will see, the "altered syllable" needs to be incorporated into the main-stressed foot.

Since the surface contrast is a result of a non-moraic coda, I propose here that a structural expression of contrast, the mora-less coda, can be distinct from the surface contrast expression, the locus of prominence. That is, the underlying contrast in presence versus absence of a vowel is transformed into surface stress contrast via a structural change at the level of moras. This distinction between structural and surface contrast expression will be important in the discussion of locality in section 5.6. As we will see, locality holds with respect to both the structural and surface contrast expression.

Another important consequence of this observation is that for contrast to be preserved, it is crucial that the surface contrast expression is distinct for contrasting word pairs. A structural change that does not result in a surface distinction does not preserve contrast (see section 5.6.1).

The difference in the moraic structure between syllables with epenthetic and with non-epenthetic vowels has been previously proposed in the literature by Piggott (1995) primarily on the basis of the analysis of Mohawk and some discussion of Iraqi Arabic. In Piggott's proposal, epenthetic syllables that behave exceptionally to stress assignment are represented as empty segmental slots, thus weightless, at the stage when stress rules apply. The empty slots are filled in at the later stages of derivation and thus, surface with a vowel. This explains why open syllables can be exceptional to stress rules. Closed syllables, the ones that concern us here, are problematic under Piggott's proposal because, according to the so-called Closed Syllable Condition formulated by Piggott, a closed syllable with a moraic coda cannot have an empty nucleus. Therefore, Piggott represents closed syllables with epenthetic vowels that do not count for stress as sequences of two syllables (for example the syllable *b**i**t* as in *ki.ta.b**i**t.la* is realized as *b**i**.t∅*). The surface coda consonant is realized as an onset consonant of the second syllable in the sequence (here *t∅*). This second syllable contains an empty nucleus at the stage when stress assignment takes place and thus is weightless. The syllable with an epenthetic vowel, the first syllable in the sequence (here *b**i***), is assigned a vowel with a mora under the so-called Proper Government Condition, to avoid a sequence of two empty nuclei. Consequently, surface closed syllables count as light for purposes of stress rules.

Despite the shared observation concerning the weight of closed epenthetic syllables in contrast-preserving languages, Piggott's account differs from my proposal in many respects. In section 5.3.3 I will argue that Piggott's proposal does not account for stress-epenthesis interaction in a surface approach to phonology, because it is not able to force epenthesis based on the well-formedness of the surface form alone. If we explain the light quality of the epenthetic syllable by allowing its coda consonant to form its own syllable, then there is no cluster within a syllable, and thus nothing forces epenthesis. The markedness constraint that drives epenthesis is satisfied with no repair. The surface form *ka.tab.t∅.la*, with no epenthesis, is optimal. The account also makes different predictions with respect to locality of contrast transformation discussed in section 5.6.

In the next section I present an analysis of dialects which preserve and neutralize contrasts in all environments.

5.3 Contrast Preserving and Contrast Neutralizing Dialects

In this section I discuss two coda dialects: Syrian (Cowell 1964), which preserves contrast in all environments (5.3.1), and Omani (Shaaban 1977), which neutralizes contrast in all environments (5.3.2). I then develop an analysis of both cases in (5.3.3).

Both dialects have Latin stress. As described in Hayes (1981, 1995), in Latin we stress the rightmost heavy syllable, otherwise the antepenult with the additional assumption that final syllables are not stressed (except, of course, in monosyllables). Some examples are given below:

(1) Latin stress

a.	a(mí:)kus	rightmost heavy (=penult)
b.	do(més)tikus	rightmost heavy (=antepenult)
c.	(símu)la:	antepenult

Hayes (1995) proposes that this is a moraic trochee system with final syllable extrametricality and feet assigned from right to left. Main stress falls on the rightmost foot in the Prosodic Word. Degenerate feet are banned absolutely (see also Mester 1994).

In OT terms, to account for Latin stress I will propose that FOOTFORM constraints are undominated. This results in a well-formed moraic trochee, which, according to Hayes, consists of two light syllables with initial prominence, (LL), or a single heavy syllable, (H).

Since in Latin, the final syllable is never stressed, I will assume that a foot cannot be final in a Prosodic Word. I will call this constraints *FINALFOOT. Both FOOTFORM and *FINALFOOT dominate PARSE-SYLLABLE since satisfying foot well-formedness and foot non-finality may leave syllables unparsed. This is represented in the following tableau:

(2) FOOTFORM, *FINALFOOT >> PARSE-SYLLABLE

/ami:kus/	FOOTFORM	*FINALFOOT	PARSE-SYLLABLE
a. ☞ a(mi:)kus			(*)*
b. a(mi:)(kus)		*!	(*)
c. (ami:)kus	*!		(*)

Candidate (a) wins as it satisfies foot well-formedness and foot nonfinality. It does so at the cost of leaving two syllables unparsed but since FOOTFORM and *FINALFOOT both dominate PARSE-SYLLABLE, this multiple violation of parsing is rendered irrelevant.

A note on exposition: In my proposal candidates are sets of mappings and not just individual mappings, but since stress and syllabification are non-contrastive in the input, in the discussion of stress in this section, I present candidates as singletons, that is in a traditional way. To put it differently, by non-contrastive stress assignment, no meaningful contrasts are merged.[2]

In addition to the ranking in (2), both FOOTFORM and *FINALFOOT dominate a constraint on main stress placement, demanding that the main-stressed foot be rightmost in a Prosodic Word, ALIGN(Hd(Ft), R; PrWd, R). This is shown below, where only the main-stressed foot is indicated:

(3) FOOTFORM, *FINALFOOT >> ALIGN(Hd(Ft), R; PrWd, R)

/domestikus/	FOOTFORM	*FINALFOOT	HD(Ft)-R
a. ☞ do(mes)tikus			**
b. domesti(kus)		*!	
c. domes(ti)kus	*!		*

Candidate (a) satisfies foot well-formedness and foot nonfinality and thus is chosen as optimal. In this candidate, the main-stressed foot is not aligned with the right edge of the Prosodic Word but since the alignment constraint is ranked lower than FOOTFORM and *FINALFOOT, we accept its violation.

To explain why final super-heavy syllables are stressed, despite high-ranking *FINALFOOT, I follow McCarthy and Prince (1990ab) in assuming that final super-heavy syllables consist of two syllables, the first heavy, the second 'incomplete', and thus can receive stress when final in a Prosodic Word. When a superheavy syllable is stressed, stress falls on the first syllable in the sequence, the non-final syllable, and thus *FINALFOOT is satisfied. This is represented in the diagram below. The super-heavy syllable is *talt.*

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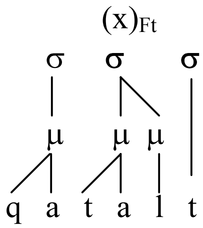
[2] Formally, this means that a constraint on preserving the stress contrast, PC(stress), is low-ranked. By meaningful contrasts, I refer to contrasts that surface in some forms of the language.

(4) Super-heavy syllables as double syllables



‘I killed’ (Omani, Shaaban 1977)

Finally, to account for the right to left foot alignment, I propose that a constraint ALIGN FT-R outranks ALIGN FT-L. In addition, ALIGN FT-R is dominated by PARSE-SYLLABLE as footing more syllables and thus erecting more feet leads to a bigger violation of alignment.

(5) PARSE-SYLLABLE >> ALIGN FT-R

/katabitla/	PARSE-SYLLABLE	ALIGN FT-R
a. ☞ (ka.ta.)(bit.)la	(*)	(*)**
b. ka.ta.(bit.)la	(*)*!*	(*)

In summary, the ranking is as follows:

(6) Constraint ranking for Latin stress
FTFORM, *FINALFT >> HD(Ft)-R, PARSE-SYLL >> ALIGN FT-R >> ALIGN FT-L

Dialects of Arabic that will be discussed in sections 5.3 and 5.4 show the same stress pattern as Latin. We now have the tools to analyze those dialects.[3]

5.3.1 Contrast is Preserved Across the Board

In Syrian *ə* is epenthesized to break up clusters of consonants that cannot form a sequence (for example *l-ktāb* → *ləktāb* ‘the book’, *laḥm-baʔar* → *laḥəm-baʔar* ‘beef’). Since there are other sources of schwa in the same environments, epenthesis can potentially merge the underlying V/∅ contrast.

[3] In the analysis, I assume the theory of Generalized Alignment by McCarthy and Prince (1993). For a different conception of alignment, see McCarthy (2002).

Some other sources of schwa, according to Cowell (1964), are:

(i) underlying schwas in some dialects (this can be heard in the phrase *ʔí̱za ʔə̱́za* 'if he comes', where the two vowels are distinct for some speakers of Syrian),

(ii) short *e* and *o* both become *ə* when accented (*ʔə́nṣo̱l* 'consul' but *ʔənṣə̱́lna* 'our consul'),

(iii) high vowels *i* and *u* freely alternate with *ə* in some dialects (*bə̱tḥə̱́ṭṭ* = *bi̱tḥú̱ṭṭ*)

(iv) in a closed syllable unaccented *a* changes to *ə* (*ba̱rṭált* → *bə̱rṭált*)

It is claimed that epenthetic schwas and schwas that come from other sources are pronounced the same (Cowell 1964:28).

As we will see, both in cases of epenthesis into medial clusters and into final clusters, words with epenthetic vowels and words with underlying vowels behave differently with respect to stress assignment.

Let us start with medial epenthesis. In Syrian, words with underlying vowels stress a heavy penult (unless there is a final super-heavy syllable - see the previous section). This is shown below:

(7) Penultimate stress

a.	da(ráb)ha	'he hit her'
b.	sak(kə́r)ha	'close it'
c.	da(rás)tu	'I studied'

When there is no heavy penult, stress is on the antepenultimate syllable:

(8) Antepenultimate stress

a.	(dára)bo	'he hit him'
b.	(báda)lo	'his substitute', 'instead of him'
c.	(fáru)ha	'her fur, pelt'

Interestingly, when a closed penult is formed by epenthesis, it behaves as if it were a light syllable. Stress is antepenultimate and not, as expected, penultimate. (The epenthetic vowel is in bold type.)

(9) Medial epenthesis – antepenultimate stress

a.	(ʔát**ə**l)to	'she killed him'	*ʔa(t**ə́**l)to
b.	(mə́š**ə**m)še	'an apricot'	*mə(š**ə́**m)še
c.	(bə́ḥ**ə**m)lo	'I'll carry it'	*bə(ḥ**ə**m)lo

Under the assumption that in Syrian degenerate feet are banned (in OT terms FOOTFORM constraints are high-ranked), it follows that the epenthetic syllable and the preceding syllable in the examples in (9) must belong to the same foot. To ensure that it is a licit moraic trochee, the syllable with an epenthetic vowel must be light even though it is a closed syllable and therefore expected to be heavy. Thus, we have a (LL) moraic trochee.

Let us now discuss epenthesis into final clusters. As in word-medial epenthesis, a syllable with an epenthetic vowel behaves differently with respect to stress from a syllable with an underlying vowel in the same environment.

In Syrian, when there is a light penult, stress is on the antepenultimate syllable:

(10) Antepenultimate stress

a.	(bára)ke	'blessing'
b.	(dára)že	'degree, step'
c.	(stáʔ)balu	'they welcomed'

Interestingly, when a light penult is followed by a syllable with an epenthetic vowel, it receives stress. Thus, in such case stress is penultimate and not antepenultimate, as expected:

(11) Final epenthesis – penultimate stress

a.	sa(dáʔət)	'you told the truth'	*(sáda)ʔət
b.	sta(šárət)	'I consulted'	*(stáša)rət
c.	xa(láṣəṭ)	'you finished'	*(xála)ṣəṭ

As in word-medial epenthesis, with FOOTFORM high-ranked, since stress is on a penultimate light syllable, the following epenthetic syllable must be incorporated into the main-stressed foot. But it can only be incorporated into the foot and form a licit moraic trochee if it is a light syllable. Again, it is a closed syllable and so we expect it to be heavy.

To explain why the epenthetic syllable counts as light, even though it is a closed syllable, I propose that the coda consonant of the epenthetic syllable is non-moraic, unlike other coda consonants in the same dialect. In addition, in word-final epenthesis, by admitting the final syllable into the foot, foot non-finality is violated, as the foot is now final in the Prosodic Word. Thus, I will assume that to preserve contrast, violation of foot non-finality can be forced.

The stress pattern of epenthetic and non-epenthetic forms in Syrian is represented schematically below (the epenthetic vowel is ə):

(12) Medially – different stress

Non-epenthetic	/CVCVC-CV/	→	cv(cv́c_μ)cv penultimate stress
Epenthetic	/CVCC-CV/	→	(cv́cəc)cv antepenultimate stress

(13) Finally – different stress

Non-epenthetic	/CVCVC-VC/	→	(cv́cv)cvc_μ antepenultimate stress
Epenthetic	/CVCVC-C/	→	cv(cv́cəc) penultimate stress

In both cases, the syllable with an epenthetic vowel counts as light despite the coda consonant. In final epenthesis, in addition, foot non-finality is violated. Consequently, forms containing identical epenthetic and underlying vowels contrast on the surface by different stress placement. The same is true of other coda dialects, such as Levantine (Farwaneh 1995, Kenstowicz 1981) and Libyan (Owens 1984), except that in Libyan words with underlying long vowels behave differently (see Farwaneh 1995:140-41).

There are, of course, other imaginable prosodic analyses of these forms. But none is as good as (12-13) when the full analysis is considered. One alternative would be to assume that the final consonant in *kitábit* constitutes its own syllable outside of the main stressed foot. We would then have footing as in *ki.(tá.bi.)t* with the final consonant unparsed and foot non-finality satisfied. However, if *t* constituted its own syllable, then there would be no cluster within a syllable to be broken up by the epenthetic vowel and thus epenthesis would not be motivated.

In the discussion so far, I have assumed that constraints on FOOTFORM (FOOTBINARITY, WEIGHT–TO-STRESS-PRINCIPLE) are obeyed at the expense of weight, and not the other way around. That is, we always strive to have a licit moraic trochee (a bimoraic foot) by incorporating the epenthetic syllable into the main-stressed foot. To do so, the weight of the epenthetic syllable is altered so that it is a light syllable. However, another alternative would be to assume that weight is obeyed at the expense of FOOTFORM. This would mean that in epenthetic forms, the final consonant retains its mora but feet are degenerate or excessive, mono- or tri-moraic. An example of a monomoraic foot would be with the epenthetic syllable outside of the main-stressed foot as in *ki(tá)b**i**t*$_{\mu}$, whereas an example of a tri-moraic foot would be with the epenthetic syllable incorporated into the main stressed foot as in *ki(táb**i**t*$_{\mu}$*)* or *ki(táb**i**t*$_{\mu}$*)la*.

However, following Broselow (1982), I assume that in Arabic FOOTBINARITY is undominated. Evidence comes from a strict minimal word requirement by which words have to be minimally bimoraic. Therefore, I do not adopt the monomoraic foot alternative. Formally, since FOOTBINARITY is undominated, it outranks WBP, and so we prefer to violate WBP (see (21)) than to create monomoraic feet.

Trimoraic feet as in *ki.(tá.bit)*, in turn, violate the WEIGHT–TO-STRESS-PRINCIPLE (WSP) as heavy syllables do not receive stress. I take WSP as part of the FOOTFORM constraints. Evidence for undominated WSP comes from epenthesis into onset dialects, which is never contrast-preserving. If we allow trimoraic feet, then epenthetic *bin*$_{\mu}$***ti**na* in Egyptian should come out as (*bín*$_{\mu}$***ti**)na* with antepenultimate stress, thereby preserving contrast with a non-epenthetic form where stress is penultimate. (See section 5.6.3 for discussion.)

We have seen, then, that additional approaches to the prosodic structure of epenthetic syllables are not as satisfactory as (12-13). Additional evidence for my proposal of limiting the weight of epenthetic syllables and against the degenerate foot alternative comes from the typological predictions my proposal makes with respect to quadri-consonantal clusters, and also from hybrid cases as in Iraqi Arabic (see section 5.4).

5.3.2 Contrast is Merged Across the Board

In this section I contrast Syrian with another coda dialect - Omani (Farwaneh 1995, Shaaban 1977), where words with epenthetic and non-epenthetic vowels behave the same with respect to stress assignment in all environments, both medially and finally. In Omani the high vowel *i* is epenthesized to break up clusters that violate sonority of the syllable.[4]

Examples of medial epenthesis are given in (14) and (15). In all cases shown here, epenthesis is into the penultimate syllable and the final syllable is either heavy or light. We expect stress to fall on the penult and it does so in both epenthetic and non-epenthetic words:

(14) Medial epenthesis

a.	ʔa(k**í**l)hum	'their (m.) food'	/ʔakl+hum/
b.	qa(b**í**r)he	'her grave'	/qabr+ha/
c.	qa(b**í**l)ne	'before us'	/qabl+na/

(15) Corresponding non-epenthetic words

a.	(gár)rak	'he dragged you-m'
b.	mix(tíl)fa	'different (f.)'
c.	ma(lík)ne	'our King'

Let us now look at final epenthesis. All forms shown here are two syllables long with a final heavy syllable. Thus, we expect main stress to fall onto the penult. This is true of both epenthetic and non-epenthetic forms:

(16) Final epenthesis

a.	gís**i**m	'body'	/gism/
b.	ʔák**i**l	'eating'	/ʔakl/
c.	láħ**i**n	'tune'	/laħn/

(17) Corresponding non-epenthetic words

a.	málik	'king'
b.	ṣā́ħib	'friend'
c.	qálit	'he said'

4 For a detailed discussion of conditions for epenthesis, see chapter 3 in Shaaban (1977).

Schematically, this is represented below. In both medial and final epenthesis, epenthetic and non-epenthetic words are stressed the same.

(18) Medial epenthesis – penultimate stress

Non-epenthetic	/CVCVC-CVC/	→	cv(cv́c$_{\mu}$)cvc$_{\mu}$
Epenthetic	/CVCC-CVC/	→	cv(c**v́**c$_{\mu}$)cvc$_{\mu}$

(19) Final epenthesis – antepenultimate stress

Non-epenthetic	/CV-CVCVC/	→	(cv́cv)cvc$_{\mu}$
Epenthetic	/CV-CVC-C/	→	(cv́cv)c**v**c$_{\mu}$

In terms of contrast, there is surface neutralization of the underlying contrast between epenthetic and non-epenthetic words. The next section presents the proposal.

5.3.3 The Proposal

When contrast is preserved, coda consonants of syllables with epenthetic vowels count as light:

(20) Syrian recalled (cf. (12))

Non-epenthetic	/CVCVC-CV/	→	cv(cv́c$_{\mu}$)cv
	L(H)L penultimate stress		
Epenthetic	/CVCC-CV/	→	(cv́c**v**c)cv
	(L**L**)L antepenultimate stress		

Thus I propose that in case when contrast is preserved, coda consonants of syllables with epenthetic vowels are non-moraic, unlike other codas in the language.

Formally, contrast is preserved by means of violating an otherwise high-ranked requirement in the language, by which each coda consonant is assigned a mora, WEIGHT-BY-POSITION (Hayes 1989, 1992, Hyman 1985, Zec 1988). In OT terms:

(21) WEIGHT-BY-POSITION (WBP)
A coda consonant must bear a mora, and this mora belongs exclusively to this consonant (i.e., it is not shared with a vowel).

WEIGHT-BY-POSITION is violated to preserve contrast between words that differ underlyingly in presence versus absence of a vowel. The contrast preservation constraint that compels violation of WBP is defined below.[5]

(22) $PC_{IN}(V/\varnothing)$ (see chapter 1, (15), for a definition)
For each pair of inputs, in_1 and in_2, contrasting in $V/\varnothing$, where in_1 has V and in_2 lacks V in the same position in a string, that map onto the same output, assign a violation mark.
"Words that differ underlyingly in the presence/absence of a vowel must be distinct on the surface (not necessarily in $V/\varnothing$)."

This constraint is violated by vowel deletion or vowel insertion in one of the inputs.

In contrast-preserving dialects, the PC constraint outranks WEIGHT-BY-POSITION:

(23) Contrast-preserving dialects
$PC_{IN}(V/\varnothing) >> WBP$

With this ranking, WBP is violated to preserve contrast.

As explained in chapter 1, in the PC proposal candidates are sets of mappings, called scenarios. Scenarios in a candidate set are of the same size. In a tableau only a subset of mappings from a scenario is shown. The mappings included in the following tableaux are minimally contrastive in presence vs. absence of the vowel in the input.

In the tableau below, I compare a contrast-preserving scenario to a contrast-neutralizing scenario. The relevant contrast dimension is presence versus absence of a vowel in the input. In each of the mappings, the main-stressed syllable is underlined. The epenthetic vowel is in bold type.

5 Forms that violate $PC_{IN}(V/\varnothing)$ also violate $PC_{OUT}(V/\varnothing)$. Since the role of input- and output-PC is the same here, in the tableaux in this chapter I will only include input-oriented PC, $PC_{IN}(V/\varnothing)$.

(24) Medial epenthesis – contrast is preserved

Scenarios		PC_{IN}(V/∅)	WBP
A. Contrast is preserved ☞ (Syrian)	/CVCC-CV/ → (cv́c**v**c)cv /CVCVC-CV/ → cv(cv́c_{μ})cv		*
B. Contrast is merged (Omani)	/CVCC-CV/ → cv(c**v́**c_{μ})cv /CVCVC-CV/ → cv(cv́c_{μ})cv	*!	

In scenario A, contrast is preserved at the expense of violating WBP. In scenario B, on the other hand, contrast is lost but WBP is satisfied. Scenario A wins in Syrian as it preserves the contrast between epenthetic and non-epenthetic vowels.

With the opposite ranking, WBP >> PC_{IN}(V/∅), scenario B would be the winner as in Omani. It would be more important to satisfy WBP than to preserve contrast. For final epenthesis to be contrast-preserving, we also need to assume that *FINALFOOT is ranked lower than PC. Thus, to ensure that final epenthesis is contrast-preserving the ranking is as follows: PC_{IN}(V/∅) >> WBP, *FINALFOOT.

(25) Final epenthesis – contrast is preserved

Scenarios		PC_{IN} (V/∅)	WBP	*FINAL FOOT
A. Contrast is preserved (Syrian) ☞	/CVCVC-C/ → cv(cv́c**v**c) /CVCVC-VC/ → (cv́cv)cvc_{μ}		*	*
B. Contrast is merged (Omani)	/CVCVC-C/ → (cv́cv)c**v**c_{μ} /CVCVC-VC/ → (cv́cv)cvc_{μ}	*!		
C. Contrast is merged (harmonically-bounded)	/CVCVC-C/ → (cv́cv)c**v**c /CVCVC-VC/ → (cv́cv)cvc_{μ}	*!	*	

Scenario A is the winner because it preserves contrast. The other two scenarios are ruled out on the preserve-contrast constraint. In scenario B, as in Omani, stress is antepenultimate and so contrast is merged with comparable words that contain non-epenthetic vowels in the same environment. Scenario C can never come out optimal. In scenario C, contrast is also merged and in addition the coda consonant is deprived of a mora, thus both PC and WBP are violated.

This example raises a question of the difference between structural (purely phonological) vs. surface (phonetic) contrast expression. I assume that the PC constraint is satisfied only when the distinction between words is realized phonetically in the output. Thus, it is a prediction of PC theory that the mere presence/absence of a μ in the output, without visible effect on stress, as in scenario C, is not enough to preserve contrast. Candidate C violates the PC_{IN}(V/∅) constraint.

With the opposite ranking, WBP >> PC_{IN}(V/∅), codas would be required to be moraic at the cost of losing contrast. Scenario B would win, as in Omani:

(26) Final epenthesis – contrast is merged

Scenarios		WBP	PC_{IN} (V/∅)	*FINAL FOOT
A. Contrast is preserved (Syrian)	/CVCVC-C/ → cv(cv́c**v**c) /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$	*!		*
B. Contrast is merged ☞ (Omani)	/CVCVC-C/ → (cv́cv)c**v**c$_{\mu}$ /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$		*	
C. Contrast is merged (harmonically-bounded)	/CVCVC-C/ → (cv́cv)c**v**c /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$	*!	*	

Scenarios A and C are ruled out on WBP.

Also, if *FINALFOOT dominated PC, even with PC dominating WBP, we would not deprive the final coda consonant of a mora since nothing would be gained by it, as the following tableau shows. Therefore, in Syrian it is important that *FINALFOOT is ranked lower than PC.

(27) Final epenthesis - contrast is merged

Scenarios		*FINAL FOOT	PC_{IN} (V/∅)	WBP
A. Contrast is preserved (Syrian)	/CVCVC-C/ → cv(cv́**cvc**) /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$	*!		*
B. Contrast is merged ☞ (Omani)	/CVCVC-C/ → (cv́cv)**cvc**$_{\mu}$ /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$		*	
C. Contrast is merged (harmonically-bounded)	/CVCVC-C/ → (cv́cv)**cvc** /CVCVC-VC/ → (cv́cv)cvc$_{\mu}$		*	*!

Scenario A is ruled out as it violates foot non-finality. Scenario C violates WBP unnecessarily. It deprives the final consonant of a mora but does not preserve contrast. Scenario B is the winner. It satisfies foot non-finality and WBP.

Under Richness of the Base (ROTB), inputs show multiple stress patterns that neutralize onto the actual stress pattern in the output. Since in Arabic in most cases stress is predictable, stress contrasts are neutralized in many instances. Formally, PC(stress) is ranked lower than constraints regulating stress assignment. Due to low-ranking of PC(stress), stress seems like a good choice to represent other contrasts and epenthesis takes advantage of it. The contrast in presence vs. absence of a vowel is manifested as surface stress contrast. Furthermore, transforming the V/∅ contrast into surface stress contrast is predictable since Arabic is weight-sensitive. Stress assignment correlates with mora-hood, which in turn correlates with the presence vs. absence of a vowel.

There is another possible scenario that comes out optimal given PC theory. In the discussion so far, I have assumed that in a scenario, the non-epenthetic form always receives regular stress, and it is the epenthetic form that surfaces with irregular stress to preserve contrast. This is by no means assured. The reason is that there is a possible contrast-preserving scenario in which inputs and outputs are permuted, and it is otherwise identical to the contrast-preserving scenario in (27a). For discussion see section 5.7.

Contrast could also be preserved by simply not epenthesizing a vowel. To rule it out, I will assume that in all dialects you have to epenthesize. In OT this means that a constraint forcing epenthesis, *CLUSTER (avoid sequences of consonants), dominates PC_{IN}(V/∅). Otherwise, we could preserve the V/∅ contrast by simply not epenthesizing a vowel. In addition, to ensure that we do not satisfy the *CLUSTER constraint by deleting a consonant, we need a high-ranking PC_{IN}(C/∅) constraint. By deleting a consonant we would avoid a cluster but we would also merge a contrast with a comparable word that does not have the cluster in the underlying form.

(28) Epenthesis is required
*CLUSTER, PC_{IN}(C/∅) >> PC_{IN}(V/∅)

Let us take an example from a contrast-neutralizing dialect, Omani, /ʔakl+hum/→ ʔak**i**lhum 'their food'.

(29) Epenthesis takes place

Scenarios		*CLUSTER	PC_{IN} (C/∅)	PC_{IN} (V/∅)
A. Epenthesis ☞	/ʔakl –hum/ → ʔak**i**lhum /ʔakil-hum/ → ʔakilhum /ʔak –hum/ → ʔakhum			*
B. Identity	/ʔakl –hum/ → ʔaklhum /ʔakil-hum/ → ʔakilhum /ʔak –hum/ → ʔakhum	*!		
C. Deletion	/ʔakl –hum/ → ʔakhum /ʔakil-hum/ → ʔakilhum /ʔak –hum/ → ʔakhum		*!	

The epenthetic scenario, scenario A, is the winner. Scenario B, the one without epenthesis and without deletion, satisfies both PC constraints but violates the high-ranking *CLUSTER markedness constraint. Scenario C, the one with deletion, satisfies *CLUSTER but violates the high-ranking PC_{IN}(C/∅) constraint. The ranking of PC_{IN}(C/∅) over PC_{IN}(V/∅) is a central property of Arabic – vowels come and go, but consonants abide.

An alternative explanation for why a coda consonant does not count as moraic would be to assume that the coda consonant of an epenthetic vowel does not belong to a syllable. For example, we could assume that it is directly adjoined to a prosodic word node (see Rubach 1996, Rubach and Booij 1990) or to a foot. This alternative, however, would not explain why epenthesis takes place at all since if a consonant is not in a syllable, then there is no violation of the *CLUSTER constraint that forces epenthesis. Similarly, Piggott (1995) proposes that the coda consonant forms its own syllable and thus is not part of the syllable with an epenthetic vowel. Again, the same problem arises. If it belongs to a separate syllable, no cluster is formed and so nothing forces epenthesis (Piggott 1995:313).

It is possible that a dialect will preserve one contrast but neutralize another contrast, both of which could be preserved in the same way. For example, Omani neutralizes the contrast in presence versus absence of the vowel. Words with and without epenthesis have the same stress. However, in Omani the underlying contrast between geminates and singletons, unlike the V/∅ contrast, is preserved and realized as different stress placement (Shaaban 1977:80). The form with an underlying geminate surfaces with final stress (/saKat+t/→saKát ‘I was silent’), while the form with an underlying singleton has penultimate stress (/saKat/→sáKat 'he was silent'). Thus the underlying geminate/singleton contrast is manifested as surface stress contrast.

I will assume that the form with an underlying geminate is footed *sa(Kát$_\mu$)*, and the form without a geminate is footed as *(sáKat)*, both violating *FINALFOOT. Since I have argued that degenerate and apparently excessive feet are not allowed in Arabic, I will propose that the final consonant in *(sáKat)* is non-moraic to satisfy FTFORM. Thus, FTFORM outranks WBP and *FINALFOOT (FTFORM >> WBP, *FINALFOOT). It can force violations of both constraints.

The geminate/singleton contrast is preserved by footing fewer syllables in the form with an underlying geminate. In OT, the fact that in Omani the underlying geminate/singleton contrast is preserved on the surface, but the underlying V/∅ contrast is merged in the same position follows from the difference in ranking of those two PC constraints with respect to PARSE-SYLLABLE. The PC_{IN}(geminate/singleton) constraint outranks PARSE-SYLLABLE, whereas the constraint PC_{IN}(V/∅) is dominated by it. The ranking is as follows: PC_{IN}(geminate/singleton) >> PARSE-SYLL >> PC_{IN}(V/∅). (PC_{IN}(V/∅) is also dominated by WBP (see (27)).) A tableau for the geminate/singleton contrast is given below:

(30) Geminate contrast is preserved

		PC_{IN} (gem/singleton)	PARSE-SYLL
A. Contrast is preserved ☞	/saKat-t/ → sa(Kát$_\mu$) /saKat/ → (sáKat)		*
B. Contrast is merged	/saKat-t/ → (sáKat) /saKat/ → (sáKat)	*!	

This provides support for the proposal that PC constraints are relativized to different input properties. Various contrasts are of different importance in a language, and only certain contrasts compel violation of a particular markedness constraint.

In the next section I will discuss a dialect where the same contrast compels violation of markedness but only under certain conditions. The example comes from Iraqi Arabic.

5.4 Contrast is Preserved Only Word-Finally: Iraqi Arabic

In this section we will look at a coda dialect Iraqi Arabic (Erwin 1963, Broselow 1982) in which epenthesis is contrast-preserving only word-finally. That is, epenthetic vowels behave the same with respect to stress assignment as non-epenthetic vowels in word-medial epenthesis (see (31)) but they contrast in epenthesis into word final syllables (see (32)). Consider medial epenthesis:

(31) Epenthesis into non-final clusters – regular stress

a.	(kita)(b**í**t)la	'I wrote to him'
b.	ki(tab)(t**í**l)ha	'I wrote to her'
c.	(**í**d)rus	'study!'
d.	**i**č(láab)	'dogs'

As expected, in examples (31a-c), stress is on the rightmost heavy syllable, which is penultimate in all the cases shown here, and in (31d) it falls on the final super-heavy syllable.

Let us now look at stress in words with epenthesis into word-final clusters. In those forms, stress consistently falls on the penultimate syllable, even though it is light:

(32) Epenthesis into final 2-consonant clusters – penultimate stress

a.	tar(jám**i**t)	'you M/I translated'
b.	dar(rás**i**t)	'you M/I taught'
c.	fti(kár**i**t)	'you M/I thought'
d.	xaa(bár**i**č)	'he phoned you F'
e.	qa(lám**i**č)	(variation on this one)

This is different from comparable words with underlying vowels in word-final position, where stress is as expected. In all examples below, stress is antepenultimate as the penultimate syllable is light:

(33) Underlying vowels

a.	(ʔába)dan	'never'
b.	(mád)rasa	'school'
c.	mu(sá:)ɛada	'assistance'

Summarizing, the V/∅ contrast is merged in word-medial epenthesis (shown in (31)), but preserved in word-final epenthesis (shown in (32)-(33)).

In my proposal the V/∅ contrast is preserved on the surface by creating a mora-less coda consonant, which affects the foot structure of a word and, consequently, main-stress placement. Since in Iraqi contrast is preserved word-finally but not word-medially, we need to explain why a mora-less coda is permitted word-finally but banned from a word-medial position. If a mora-less coda is not permitted word-medially in the string of segments, contrast cannot be preserved in case of epenthesis into word-medial syllables. Conversely, if a mora-less coda is admitted word-finally, contrast can and is preserved in case of word-final epenthesis. Thus, there must be a difference in well-formedness of segmental strings with mora-less codas medially as opposed to at the edges of a string.

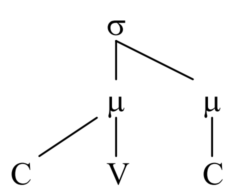
It has been observed that prosodic constituents (i.e., segments, syllables, feet) at the periphery of a prosodic or a morphological domain (i.e., prosodic word, stem, phrase) have special status. They can be deficient in structure or different in affiliation from identical constituents trapped within a string. This special property of edge-most constituents is captured in the theories of incomplete syllabification (McCarthy and Prince 1990ab), extrametricality (Liberman and Prince 1977, Hayes 1982, 1995, Kager 1995) or extrasyllabic consonants (Rubach and Booij 1990). Prince and McCarthy (1990), for example, propose that edge-most consonants in Arabic, unlike medial consonants, can form incomplete syllables. Rubach (1996), Rubach and Booij (1990) observe that in Polish word-initial extrasyllabic consonants behave differently from non-initial consonants with respect to segmental processes, i.e., final devoicing, voice assimilation, degemination. They capture this difference formally by proposing separate PrWd-adjunction processes for word-initial versus non-word-initial consonants. Since the two adjunction processes can occur at different stages of the derivation process, segments are predicted to behave differently with respect to segmental processes depending on their position in a PrWd. For other accounts of extrasyllabicity see Halle and Vergnaud (1987), Ito (1982), Borowsky (1986).

In a number of accounts 'incomplete' or deficient prosodic constituents are universally only admitted at the edges of a string (see the McCarthy and Prince (1990) for a discussion). But some researchers (Rubach 1996, Rubach and Booij 1990) observe that both medial- and edgemost- deficient constituents are admitted under certain circumstances, though it is necessary to distinguish between the two. Thus, based on this research, we can conclude that medial incomplete constituents are marked, but they do occur, and we should be able to capture this fact formally.

We have already seen that mora-less codas are allowed both finally and medially in Syrian but only finally in Iraqi. To capture this observation, I propose a constraint called MORACONTINUITY that does not allow word-medial mora-less codas, as such consonants disrupt continuity at the level of moras. Like other OT constraints, moraic continuity is a violable constraint and thus mora-less codas are permitted when compelled by higher-ranked constraints.

Following Hyman (1985), Zec (1988) and Ito (1989), I assume that in weight-sensitive languages each segment of a syllable bears a mora. Onsets share a mora with the following vowel. Thus, a CVC syllable in a weight-sensitive language has the following moraic structure:

(34)



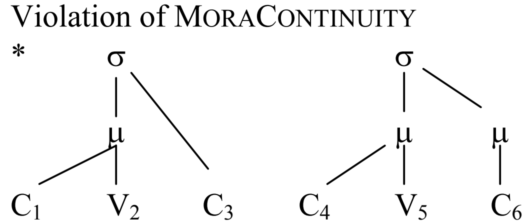
This structure finds motivation in tonal processes (Hyman 1984), language games where onsets act as constituents (Katada 1990), and in the theory of epenthesis (Ito 1989).

Assuming the above syllable structure, MORACONTINUITY is defined as follows:

(35) Def. of MORACONTINUITY
In $\alpha\beta\delta$, if $\alpha \in \mu$ and $\delta \in \mu$, then $\beta \in \mu$.

Informally, this constraint enforces moraic continuity over continuous strings of segment. It is violated whenever continuity is disrupted, as illustrated below:

(36) Violation of MORACONTINUITY



In (36), there is a mora-less coda, C_3, medially in the string of segments, and so continuity is disrupted.

If MORACONTINUITY outranks PC_{IN}(V/∅), the weight of a medial syllable with an epenthetic vowel cannot be altered to preserve contrast. Thus, under this ranking, word-medial epenthesis is non-contrast-preserving as in Iraqi:

(37) No medial epenthesis
MORACONTINUITY >> PC_{IN}(V/∅)

This is illustrated in the following tableau:

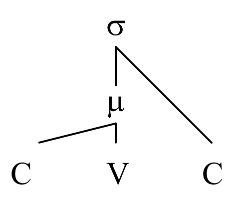
(38) Contrast is merged word-medially

		MORA CONTINUITY	PC_{IN} (V/∅)	WBP
A. Non-moraic coda (Syrian)	/CVCC-CV/ → (cv́c**v**c)cv /CVCVC-CV/ → cv(cv́c_μ)cv	*!		*
B. Moraic coda (Iraqi) ☞	/CVCC-CV/ → cv(c**v́**c_μ)cv /CVCVC-CV/ → cv(cv́c_μ)cv		*	

Scenario B is the winner as it satisfies moraic continuity, even though it merges the V/∅ contrast on the surface.

Given the definition of MORACONTINUITY, a non-moraic coda word-finally does not violate moraic continuity, as it is edge-most in the string of segments.

(39) No violation of MORACONTINUITY



Thus, provided that *FINALFOOT is low-ranked and PC dominates WBP, word-final epenthesis is still contrast-preserving, even when MORACONTINUITY is high-ranking. This is illustrated in the following tableau.

(40) Contrast is preserved word-finally

Scenarios		MORA CONTINUITY	PC_{IN} (V/∅)	WBP
A. Non-moraic coda (Iraqi) ☞	/CVCVC-C/ → cv(cv́**cvc**) /CVCVC-VC/ → (cv́cv)cvc_{μ}			*
B. Moraic coda (Omani)	/CVCVC-C/ → (cv́cv)**cvc**$_{\mu}$ /CVCVC-VC/ → (cv́cv)cvc_{μ}		*!	

Scenario A is the winner as it preserves contrast. Continuity is not violated.

In the next section I summarize the rankings obtained so far.

5.5 Rankings

So far I have accounted for cases where (i) contrast is merged across the board as in Omani, (ii) contrast is preserved across the board as in Syrian, and (iii) contrast is preserved word-finally but merged word-medially as in Iraqi.

To account for cases where contrast is merged across the board, I proposed that WBP outranks PC. As a result, preserving contrast cannot compel having a non-moraic coda consonant.

(41) Contrast is merged ATB (Omani)[6] (section 5.3.2)
WBP >> PC_{IN}(V/∅)

To explain cases where contrast is preserved across the board, the opposite ranking has been established. Thus, contrast preservation is satisfied at the expense of having a non-moraic coda consonant.

(42) Contrast is preserved ATB (Syrian) (section 5.3.1)
PC_{IN}(V/∅) >> WBP, *FINALFOOT, MORACONTINUITY

6 And there is no higher-ranked constraint that forces violation of WBP.

To account for Iraqi Arabic, where contrast is preserved only finally, a high-ranked constraint on moraic continuity outranks PC, and thus medial non-moraic codas are ruled out:

(43) Contrast is preserved only finally (Iraqi) (section 5.4)
*MORACONTINUITY >> PC_{IN}(V/∅) >> WBP, *FINALFOOT

There is one more case that has not been found so far but is possible, given ranking permutations of the constraints proposed so far. This is the case when final epenthesis is non-contrast-preserving, but medial epenthesis preserves contrast. A case like this would be obtained when *FINALFOOT outranked PC, thus not allowing for a final foot, but MORACONTINUITY was ranked lower than PC, thus allowing for medial non-moraic codas:

(44) Contrast is preserved only medially (not found so far but possible)
*FINALFOOT >> PC_{IN}(V/∅) >> WBP, MORACONTINUITY

This argument holds only under the assumption that there is no other way to satisfy both PC and *FINALFOOT at the same time in word-final epenthesis.

5.6 Locality of Contrast Preservation

To explain stress-epenthesis interaction in contrast-preserving dialects, I proposed that the underlying V/∅ contrast (contrast in presence vs. absence of a vowel) is preserved on the surface by creating a mora-less coda in the epenthetic syllable. This alters the foot structure of a word and thus has an effect on main stress placement. In this proposal the surface contrast expression (i.e., stress placement) is mediated via a structural change (i.e., a mora-less coda).

Both the structural and surface contrast expression is subject to locality. We can make the following observations concerning locality in contrast-preserving dialects in Arabic.

(45) Locality in Arabic

(i) In epenthetic forms, main stress always falls on the syllable preceding the epenthetic syllable (it is local to the site of epenthesis).

(ii) To preserve contrast, we always alter the weight of the syllable with an epenthetic vowel and never the weight of adjacent syllables.

(iii) In all cases, the syllable with an epenthetic vowel is incorporated into the main stressed foot.

This section will account for those observations formally.

Since in Arabic epenthesis takes place, the underlying V/∅ contrast cannot be expressed on the surface in the same way as in the underlying form. Instead, it is transformed into surface stress contrast and dislocated in the string of segments. I observe that in all cases contrast dislocation is minimal. Stress falls on the syllable preceding the epenthetic vowel and never further away from the site of epenthesis. For example, in penultimate epenthesis, an underlying form /katab-t-la/ maps onto *ka(t**á**b**i**t)la* with stress on the antepenult. This preserves contrast with a minimally distinct non-epenthetic form /katab-it-la/ that surfaces as *(kata)(bít*$_{\mu}$*)la* with penultimate stress.

However, another way to preserve contrast would be to move stress further away from the site of epenthesis without altering the weight of the epenthetic syllable. For example, the epenthetic form /katab-t-la/ could surface as *(k**á**ta)(b**i**t*$_{\mu}$*)la,* with pre-antepenultimate stress. Yet, this does not happen and our account should predict this result. (A similar problem arises in word-final epenthesis.)

To account for minimal contrast dislocation, I will propose a locality constraint demanding that the surface expression of the underlying V/∅ contrast, that is stress placement in Arabic, is located as close to the original locus of contrast as possible. In effect, the underlying contrast is signaled locally. This will be formulated as a correspondence constraint between minimally contrasting input-output word pairs, PC-LOCAL.

In addition, I will discuss epenthesis in onset dialects and in quadri-consonantal sequences in all dialects. As observed in Farwaneh (1995), those two types of epenthesis are never contrast-preserving in Arabic. This fact has not received a principled explanation under previous approaches to stress-epenthesis interaction, but I will show that my account together with a locality constraint on contrast expression predicts this result.

Since in onset dialects epenthesis creates an open syllable, there is no coda in the epenthetic syllable to deprive of a mora. Therefore, under the assumption that we can only alter the weight of the epenthetic syllable, stress is not altered and contrast is not preserved. In quadri-consonantal sequences, on the other hand, I will show that depriving the coda consonant of the epenthetic syllable of a mora does not lead to a different foot structure of a word and so would be superfluous.

But in both onset dialects and in quadri-consonantal sequences, to preserve contrast we could alter the weight of some other syllable than the epenthetic syllable. Since this possible repair does not take place, I will take it as evidence for another locality constraint, PC-DOMAIN. This constraint demands that the structural expression of a given underlying contrast, a non-moraic coda in Arabic, is contained within the domain of the original contrast, that is, in the same syllable as the epenthetic vowel. When ranked above general PC, this constraint requires that contrast not be moved out of the original domain. Again, this will be formulated as a correspondence constraint between contrasting input-output word pairs. PC-DOMAIN, when high-ranked, makes correct typological predictions with respect to onset dialects and quadri-consonantal sequences.

5.6.1 Local Dislocation

In this section I discuss contrast preservation in longer words. Such cases provide a strong argument for the locality constraint on contrast preservation.

Consider epenthesis into word-final clusters. In contrast-preserving dialects, as we have seen, stress in epenthetic words is penultimate, thus the epenthetic syllable is incorporated into the final foot (Syrian, Iraqi). Stress in non-epenthetic words, on the other hand, is antepenultimate with the final syllable unparsed.

(46) Word-finally (Iraqi)

Epenthetic	/CVCVC-VC-C/	→	(cvcv)(cv́**v**c)
Non-epenthetic	/CVCVC-VCV-C/	→	cv(cv́cv)cvc$_{\mu}$

This has been accounted for by ranking the PC constraint above WBP and *FINALFOOT. In other words, contrast preservation enforces violation of WBP and foot nonfinality.

(47) Contrast is preserved word-finally
$PC_{IN}(V/\varnothing)$ >> WBP, *FINALFOOT (cf. (25))

But under this ranking, there is another scenario that comes out optimal. This is a scenario that satisfies all of the constraints in (47). It preserves contrast by moving main stress leftwards, without depriving the coda consonant of a mora and without violating foot nonfinality. In this scenario, stress in the epenthetic word is pre-antepenultimate. This is shown in (48).

(48) Optimal but incorrect scenario

Epenthetic	/CVCVC-VC-C/	→	(cv́cv)cvc**v**c$_\mu$
Non-epenthetic	/CVCVC-VCV-C/	→	cv(cv́cv)cvc$_\mu$

The following tableau shows the problem formally:

(49) Incorrect result

Scenarios		PC$_{IN}$(V/∅)	*FINAL FOOT	WBP
A. Actual ☞	/CVCVC-VC-C/ → (cvcv)(cv́c**v**c) /CVCVC-VCV-C/ → cv(cv́cv)cvc$_\mu$		!*!	!*!
B. Incorrect ☜	/CVCVC-VC-C/ → (cv́cv)cvc**v**c$_\mu$ /CVCVC-VCV-C/ → cv(cv́cv)cvc$_\mu$			

Both scenarios preserve contrast. The incorrect scenario comes out optimal as it satisfies all of the above constraints.

To choose the actual scenario as optimal, we need a constraint ranked higher than *FINALFOOT and WBP so that violations of those two constraints are rendered irrelevant. This constraint needs to prefer scenario A to scenario B.

I propose that it is a constraint on locality, which prefers local displacement of contrast to a non-local one and thus favors the actual scenario. This constraint compares pairs of mappings whose inputs contrast minimally in P. It requires that if two inputs are distinct in P, and their corresponding outputs are distinct in Q, then Q is local to P in the corresponding string of segments (contrast is signaled locally).

This is similar to traditional faithfulness constraints. However, to locate the P and Q properties, mappings are compared against each other. First let us recall the definition of correspondence (McCarthy & Prince 1995):

(50) Correspondence (McCarthy & Prince 1995)
Given two strings S_1 and S_2, correspondence is a relation $\Re$ from the elements of S_1 to those of S_2. Segments $\alpha \in S_1$ and $\beta \in S_2$ are referred to as correspondents of one another when $\alpha\Re\beta$.

As first approximation, we can formulate the locality constraint as follows:

(51) PC-LOCAL(P)

Let there be two inputs, In_1 and In_2, that are minimally distinct in P. Then In_1 = /…in-seg_i…/ ($seg_i \in P$) and In_2 = /…in-seg_j…/ ($seg_j \in \neg P$). Let $In_1 \rightarrow Out_1$ and $In_2 \rightarrow Out_2$. If Out_1 and Out_2 are distinct in some property Q (so Out_1 = /…out-seg_k…/ ($seg_k \in Q$) and Out_2 = /…out-seg_z…/ ($seg_z \in \neg Q$), and in-seg_i $\Re$ out-seg_i, then k=i (for $In_1 \rightarrow Out_1$). Assign one violation mark for each segment intervening between out-seg_k and out-seg_i (same for out-seg_z and out-seg_j).

That is, one violation is assigned for each segment intervening between the output segment that bears the Q property and the output correspondent of the input segment that bears the P property. The P and Q properties referred to in the definition of this constraint can be positive, indicating the presence of a property, as well as negative, indicating the lack of it.[7]

In Arabic, we compare inputs minimally contrastive in the presence versus absence of a vowel. The constraint requires that stress fall as close to the site of epenthesis as possible. I will assume here that stress is affiliated with a segment, and thus locality of stress can be evaluated in a segmental string.

In scenario A, as was shown in tableau (49), PC-LOCAL is violated minimally, as stress is dislocated by one segment from the site of epenthesis (we only take into account segments that can bear stress). This is recalled below:

(52) PC-LOCAL(P) is violated minimally (*)

$/k_1\ a_2\ t_3\ a_4\ b_5 - \varnothing_6\ t_7 - l_8\ u_9/ \longleftrightarrow /k_1\ a_2\ t_3\ a_4\ b_5 - i_6\ t_7 - l_8\ u_9/$

$k_1\ a_2\ (t_3\ \acute{a}_4\ b_5\ \ i_6\ t_7)\ \ l_8\ u_9 \longleftrightarrow k_1\ a_2\ t_3\ a_4(\ b_5\ \ \acute{\imath}_6\ t_{\mu 7}\ )\ l_8\ u_9$

In comparison, scenario B violates this constraint twice, as contrast is dislocated from its original locus by two segments that provide a legitimate locus for stress:

(53) PC-LOCAL(P) is violated twice (**)

$/k_1\ a_2\ t_3\ a_4\ b_5 - \varnothing_6\ t_7 - l_8\ u_9/ \longleftrightarrow /k_1\ a_2\ t_3\ a_4\ b_5 - i_6\ t_7 - l_8\ u_9/$

$(k_2\ \acute{a}_2\ t_3\ a_4\ )\ b_5\ \ i_6\ t_7\ \ \ l_8\ u_9 \longleftrightarrow k_1\ a_2\ t_3\ a_4(\ b_5\ \ \acute{\imath}_6\ t_{\mu 7}\ )\ l_8\ u_9$

We assume that the non-epenthetic form has regular stress (see discussion in section 5.9).

The constraint ranking in a contrast-preserving dialect is as follows:

(54) $PC_{IN}(V/\varnothing)$ >> PC-LOCAL(V/∅) >> *FINALFOOT

The following tableau illustrates the role of locality in word-final epenthesis:

[7] This constraint evaluates inputs that are minimally distinct in P but it does not require that their outputs are minimally distinct. That is, outputs corresponding to minimally distinct inputs may differ in more than one property. For now, I will assume that this constraint assigns violation marks for any Q property by which outputs are differentiated that is displaced from the original P position. That is, if outputs are distinct in more than one Q property, and each of them is displaced from the original locus of P, then for each of them the constraint assigns violation marks. In the examples discussed in this chapter, this question does not arise as outputs as well as inputs are minimally distinct, but it is crucial to PC theory and will be further investigated in this dissertation.

I will also assume that Q refers to the surface contrast between outputs, like stress assignment. The notion of surface contrast needs to be encoded formally in the theory. For now I assume that Q is what makes the two outputs phonetically distinct.

(55) The role of PC-LOCAL

Scenarios		PC_{IN} (V/∅)	PC-LOC (V/∅)	*FINAL FOOT
A. Actual ☞	/CVCVC-VC-C/ → (cvcv)(cv́**cv**c) /CVCVC-VCV-C/→ cv(cv́cv)cvc_μ		*	*
B. Non-local	/CVCVC-VC-C/ → (cv́cv)cvc**v**c_μ /CVCVC-VCV-C/ → cv(cv́cv)cvc_μ		**!	
C. Merger	/CVCVC-VC-C/ → cv(cv́cv)c**v**c_μ /CVCVC-VCV-C/ → cv(cv́cv)cvc_μ	*!		

Scenario C is ruled out as it merges the contrast between words with epenthetic and non-epenthetic vowels. Scenario B, the incorrect scenario, loses on locality. In this scenario, contrast is dislocated too far in the string of segments from the site of epenthesis. Scenario A is the winner - contrast is dislocated only minimally.

Consider now word-medial epenthesis. In contrast-preserving dialects (Syrian), stress is antipenutimate in epenthetic words and penultimate in non-epenthetic words.

(56) Actual scenario

Epenthetic	/katab-t-lu/	→	ka(tábi**i**t)lu	antepenultimate
Non-epenthetic	/katab-it-lu/	→	kata(bít$_\mu$)lu	penultimate

But we could also move stress further away from the epenthetic syllable onto the pre-antepenult. Contrast would then be preserved without making the coda consonant of the epenthetic syllable non-moraic.

(57) Hypothetical scenario

Epenthetic	/katab-t-lu/	→	(káta)b**i**t$_\mu$lu
Non-epenthetic	/katab-it-lu/	→	kata(bít$_\mu$)lu

As in word-final epenthesis, the scenario in (57) is ruled out by LOCALITY of contrast preservation. The contrast property is dislocated too far away in the string of segments from its original locus.

(58) Locality in medial epenthesis

Scenarios		PC_{IN}(V/∅)	PC-LOCAL(V/∅)	WBP
A. Actual ☞	/katab-t-lu/ → ka(tábi**i**t)lu /katab-it-lu/ → kata(bít$_{\mu}$)lu		*	*
B. Non-local	/katab-t-lu/ → (káta)b**i**t$_{\mu}$lu /katab-it-lu/ → kata(bít$_{\mu}$)lu		**!	
C. Merger	/katab-t-lu/ → kata(bít$_{\mu}$)lu /katab-it-lu/ → kata(bít$_{\mu}$)lu	*!		

The actual scenario incurs a minimal violation of locality and thus is chosen the winner.

In word-medial epenthesis, the non-local scenario is also non-optimal on stress constraints. It violates WBP (weight by position) and WSP (the weight to stress principle). Thus, in some cases, the effect of locality can be also achieved by constraints on stress placement as long as they are ranked lower than PC (see the stress ranking in (6)).

In the discussion so far, I have implicitly assumed that to preserve contrast, mappings in a scenario need to be pronounced differently. It is not enough for them to be distinct in phonological structure only to preserve contrast. As for epenthesis into word-final clusters, I have not considered scenarios where stress would be on the same syllable in both mappings but mappings would be different structurally. For example, we could have a pair of mappings where stress is antepenultimate, as expected, but the final consonant in one of the mappings lacks a mora. Thus, we would have cv(cv́cv)c**v**c_{μ} and cv(cv́cv)c**v**c as outputs of non-epenthetic and epenthetic strings. My assumption is that contrast preservation is satisfied only when the structural distinction is realized overtly on the surface.

In the next section I will show how my proposal explains the fact that epenthesis in onset dialects is never contrast-preserving unlike epenthesis in coda dialects.

5.6.2 Onset Dialects

It has been observed that in onset dialects words with epenthesis behave the same with respect to stress assignment as words with no epenthesis (Farwaneh 1995). In terms of contrast preservation, onset dialects merge the V/∅ contrast in all environments. Egyptian (Broselow 1976, Harrell 1957) provides an example. As shown below, in Egyptian epenthetic and non-epenthetic words behave the same with respect to stress placement:

(59) Egyptian - contrast is merged

	Epenthetic words	
a.	(bin)(tína)	'our daughter'
b.	(ʔar)(Día)	'our land'
c.	ka(tab)(tílu)	'I wrote to him'
	Non-epenthetic words	
d.	(mad)(rása)	'school'
e.	ka(táb)na	'we wrote'

Egyptian has a different stress pattern from dialects discussed so far. As described in Hayes (1995), it is a moraic trochee system with feet assigned from left to right. Main stress is located in the rightmost foot and the final mora is extrametrical. Some other examples of onset dialects are Sudanese (Trimingham 1946, Hamid 1984), Saudi (Abu-Mansour 1987).

I will now explain how my account captures the fact that epenthesis is non-contrast-preserving in all onset dialects. When discussing contrast-preserving coda dialects, I have proposed that the coda consonant of the syllable with an epenthetic vowel is non-moraic and therefore it counts as light for purposes of stress placement. But in onset dialects epenthesis creates an open syllable (Selkirk 1981, Broselow 1982), as in /katabt+lu/→ ka-tab-t**i**-lu 'I wrote to him'. Since in onset dialects there is no mora consonant in the syllable with an epenthetic vowel, it is not possible to change the weight of the epenthetic syllable so that foot assignment and thus stress placement in words with epenthesis would be different from that of non-epenthetic words. There is no coda to deprive it of a mora.

However, we could change the weight of an adjacent syllable and thus change stress placement, thereby satisfying PC. Given the Egyptian stress pattern, if the preceding syllable was a closed syllable, we could force its coda consonant to be monomoraic. Stress would then move leftwards onto the antepenult and contrast would be preserved. An example is given below:

(60) Contrast-preserving scenario

Epenthetic	bint-na	→	(bínt**i**)na
Non-epenthetic	bint-i-na	→	(bin$_{\mu}$)(tína)

So how do we rule it out?

To rule out non-local contrast dislocation, in the previous section I have assumed locality of contrast preservation, by which you prefer to realize the surface contrast property locally rather than non-locally. But LOCALITY of surface contrast expression does not rule out the above scenario, as long as it is dominated by PC. In other words, the above scenario violates LOCALITY of stress placement, but only minimally. Such violation of locality can be explained by a high-ranking PC constraint.

Therefore, to rule out the above scenario, I propose that in addition to a locality constraint on surface contrast expression, we need some other constraint dominating PC that would only allow for cases where it is the coda consonant of the epenthetic syllable that loses a mora.

I propose a constraint on the locality of structural contrast expression. It demands that the structural expression of contrast be represented in the same domain as the original locus of contrast. I call it PC-DOMAIN(P). Its effect is to allow a non-moraic coda only in the same syllable as the epenthetic vowel. This constraint works similarly to the constraint formulated in the previous section (see (49)). The primary difference between the two is that the domain constraint guards locality of the structural expression of contrast, mora-hood, as opposed to the surface contrast expression, stress placement. Thus, the domain constraint is evaluated with respect to a prosodic domain. The domain constraint is defined below (as a first approximation):

(61) PC-DOMAIN(P)
Let there be two inputs, In_1 and In_2, that are minimally distinct in P. Then In_1 = /…in-seg_i…/ ($seg_i \in P$) and In_2 = /…in-seg_j…/ ($seg_j \in \neg P$). Let $In_1 \rightarrow Out_1$ and $In_2 \rightarrow Out_2$. If Out_1 and Out_2 are distinct in some property Q (so Out_1 = /…out-seg_k…/ ($seg_k \in Q$) and Out_2 = /…out-seg_z…/ ($seg_z \in \neg Q$)), and in-seg_i $\Re$ out-seg_i, then out-seg_k is contained in the same prosodic domain to which out-seg_i belongs (same for out-seg_z).
"Do not move a contrast out of its domain."

That is, the output segment that bears the Q property and the output correspondent of the input segment that bears the P property are contained in the same domain. The domain is the smallest prosodic domain relevant for a particular contrast expression. As for mora-hood, the smallest relevant domain is the syllable.

I propose that in Arabic, PC-DOMAIN outranks general PC:

(62) PC-DOMAIN(P) >> PC_{IN}(P)

Since domain locality dominates PC, a non-local structural change is not allowed. Any candidate with a non-moraic coda in a non-epenthetic syllable violates the domain constraint.

(63) Violation of PC-DOMAIN

/kitab$_1$-t∅$_2$-la/ ↔ /kitab$_1$-ti$_2$-la/ P = V/∅

ki(táb$_1$ti$_2$)la ↔ kitab$^{\mu}{}_1$(ti$_2$la) Q = moraic/non-moraic coda

In the example above, the structural locality constraint (called PC-DOMAIN) is violated, as the mora-less coda consonant is in a different syllable than the epenthetic vowel.

(64) The role of PC-DOMAIN

Scenarios		PC-DOMAIN	PC$_{IN}$(V/∅)
A. Actual ☞	/bint-na/ → (bin$_\mu$)(tína) /bin-t-na/ → (bin$_\mu$)(tína)		*
B. Contrast-preserving (=(63))	/bint-na/ → (bínt**i**)na /bin-t-na/ → (bin$_\mu$)(tína)	*!	

Scenario B is ruled out. It preserves contrast but the structural change takes place outside of the epenthetic syllable domain, which is not allowed.

5.6.3 Quadri-consonantal Clusters

As Farwaneh (1995) observed, "epenthetic vowels in medial quadriconsonantal sequences are systematically stressed in all dialects". That is, in case of epenthesis into a four-consonant cluster, there is no difference in the stress pattern between words with and without epenthetic vowels. Some examples are given below:

(65) Quadri-consonantal epenthesis

/katab+t+l+ha/	→	ka(tab)(tíl)ha	'I wrote to her'
/ʔamal+t+l+ha/	→	ʔa(mal)(tíl)ha	'I did for her'

This is true of all dialects. In the rest of this section, I will show that my account predicts this result.

Let us consider ways in which we could preserve contrast in quadri-consonantal sequences but which are not allowed, given the high-ranking constraint on domain locality, PC-DOMAIN.

To preserve contrast, we could change the weight of both the epenthetic syllable and the preceding non-epenthetic syllable. This would give us a L**L**L sequence of syllables, with the epenthetic syllable in bold font. In Eqyptian, this would make a difference to stress assignment. Due to this change, stress would be on the antepenult ($\underline{\text{L}}$L)L, and not on the penultimate syllable, as in identical non-epenthetic words (see section 5.6.2 for Eqyptian stress). This scenario is illustrated below:

(66) Not attested (assume Eqyptian stress)

Epenthetic	/CVCVC+C+C+CV/	→	cv(cv́cc**v**c)cv
Non-epenthetic	/CVCVCCVCCV/	→	cv(cvc$_\mu$)(cv́c$_\mu$)cv

Even though contrast is preserved, this scenario is ruled out by domain locality. One of the "altered syllables" is not the epenthetic syllable.

To preserve contrast, we could also move stress leftwards, onto the antepenult, without altering the weight of any syllable.

(67) Not attested

Epenthetic	/CVCVC+C+C+CV/	→	cv(cv́c$_\mu$)(c**v**c$_\mu$)cv
Non-epenthetic	/CVCVCCVCCV/	→	cv(cvc$_\mu$)(cv́c$_\mu$)cv

In this scenario, there is no mora-less coda, and so PC-DOMAIN, as formulated in the previous section, is satisfied. But in this scenario, the surface expression of the underlying contrast, main stress, is not contained in the same foot to which the epenthetic vowel belongs. In other words, the main-stressed foot, and the foot with the epenthetic vowel are distinct. If we assume that feet are also in a sense a structural expression of contrast, then this scenario is ruled out by high-ranking PC-DOMAIN. The epenthetic vowel does not belong to the main-stressed foot.

This scenario could be also ruled out in some languages by adequate ranking of prosodic well-formedness constraints. For example, if HD-FT-R dominated PC, this scenario would be non-optimal, as stress is not located in the rightmost foot. But assuming that in contrast-preserving dialects, PC dominates *FINALFOOT, by transitivity it also dominates HD-FT-R (see (6)), and so prosodic well-formedness alone cannot explain why the above scenario is not attested in Arabic.

Summarizing, in this section we have seen that my proposal of altering the weight of the epenthetic syllables, together with high-ranked PC-DOMAIN, explains why epenthesis in quadri-consonantal sequences in never contrast-preserving. I have also entertained the possibility that PC-DOMAIN may have to be extended to the foot domain.

5.7 Symmetric Violation of PC: The Role of the Learner or OO-Correspondence

In all contrast-preserving dialects it is the mapping with an epenthetic vowel that behaves irregularly to stress assignment. The mapping with an underlying vowel acts regularly. But given the formulation of PC, there is nothing that ensures this result. PC only requires that contrast be preserved in a system and does not determine which mapping should violate markedness to preserve contrast. So why is it the word with an epenthetic vowel that is exceptional to stress assignment? How do we make sure that the other situation does not occur?

One possibility is to say that the child first learns stress assignment of non-epenthetic forms and only then the epenthetic ones. Therefore, from the two, only the epenthetic forms can be exceptional. This would allow the child to figure out the constraint ranking for a system of mappings, but it may run into problems when we want the constraint ranking itself to be able to generate the optimal scenario. A permuted scenario may be generated.

Another possibility is to assume OO-faithfulness to moraic affiliation of segments, OO-Ident-Mora. This proposal stems from the observation that the coda consonant of the syllable with an epenthetic vowel is never in a coda position outside of the epenthetic environment. But the coda consonant of the syllable with a non-epenthetic vowel is a coda in a variety of morphological forms and thus as a coda bears a mora in those forms. The OO-Ident-Mora constraint would prohibit coda consonants in words with non-epenthetic vowels from losing a mora but would not be violated if coda consonants of syllables with epenthetic vowels lack a mora. Informally, this constraint encodes the "coda" status of a consonant in a paradigm.

5.8 Comparison with Previous Approaches

In this section I compare my account to other approaches to stress-epenthesis interaction proposed in the literature. Rule-based accounts are discussed in (5.8.1), and other OT proposals in (5.8.2).

5.8.1 Rule-based Approaches

In contrast-preserving dialects (Syrian, Levantine, Libyan, Iraqi), the interaction of stress and epenthesis is opaque. That is, the way stress is assigned is inconsistent with the normal pattern. To recall, in word-medial epenthesis into the penult, in epenthetic forms stress is antepenultimate (*ki.tá.b***i***t.la*) and not penultimate (**ki.ta.bít.la*), as expected. Similar, in word-final epenthesis, stress is penultimate (*ki.t**á**.b**i**t*) and not antepenultimate (**k**í**.ta.b**i**t*), as expected.

A standard approach to opaque processes in rule-based theory is rule ordering (Kiparsky 1973, Kenstowicz and Kisseberth 1979, Rubach 1984). By rule ordering, in contrast-neutralizing dialects, epenthesis precedes stress assignment, and thus words with and without epenthesis have the same stress pattern. In contrast-preserving dialects, on the other hand, stress precedes epenthesis, and thus words with and without epenthesis have different stress.

The rule-ordering approach is problematic for several reasons. To begin with, in this approach, it is difficult to explain cases like Iraqi Arabic, where epenthesis is contrast-preserving but only word-finally. Word-medially contrast is merged. In the rule-ordering approach, we either preserve or neutralize contrast depending on the ranking of epenthesis with respect to stress.

This problem has been already pointed out by Broselow (1982), who observes that one way to avoid it is to assume distinct epenthesis rules, one for word-final- and the other for word-medial-epenthesis, and to order them differently with respect to stress assignment. Specifically, word-medial epenthesis would precede stress assignment, and thus contrast would be merged word-medially. Word-final epenthesis, on the other hand, would follow stress assignment, and thus contrast would be preserved between epenthetic and non-epenthetic words in case of word-final epenthesis. But, as discussed in Broselow (1982), epenthesis into word-final and word-medial clusters has the same characteristics (Selkirk 1981), and so splitting of the epenthesis rule into two distinct processes is uncalled for. To solve this problem, rule-based accounts usually adopt an additional assumption of consonant extrametricality. With this assumption, epenthesis in word-final and word-medial positions will be one and the same process, but final consonants will be extrametrical at the point when stress applies. As a result, stress will precede word-final epenthesis. Post-lexically, extrametricality will be revoked and so final epenthesis will apply. But stress will have been assigned by then and thus epenthesis will be contrast-preserving word-finally. However, as shown in Prince and Smolensky (1993), formal extrametricality is problematic and should not be treated as a formal device. P&S argue that properties ascribed to formal extrametricality, such as nonexhaustivity, constituency, peripherality, edge markedness and uniqueness, often encode some more general phonological tendencies and should be recognized as such (see pp. 44-47).

In addition, the rule-ordering approach cannot explain the generalization that quadri-consonantal clusters are always contrast-neutralizing. In this approach, they should be either contrast-preserving or contrast-neutralizing depending on the ranking that holds in a particular dialect.

Another generalization that is missed under the rule-based approach concerns onset dialects. It remains a mystery why all onset dialects are contrast-preserving in Arabic, unlike coda dialects, which are divided into contrast-preserving and contrast-neutralizing types. In rule ordering, this means that only one ordering of rules, epenthesis before stress assignment, is permitted for onset dialects. But why it should be so remains unexplained.

Broselow (1982) takes a different approach to stress-epenthesis interaction. She proposes that the way stress interacts with epenthesis is dependent on the internal organization of the grammar. In Arabic, epenthesis results in a well-formed syllable structure, that is, by epenthesis, clusters of consonants are avoided. Thus, epenthesis in Arabic refers to the level of syllabic constituents. Since syllables are contained within feet (see Selkirk 1984, 1995), in a serial model, syllables are constructed before feet are built. As argued by Broselow, it follows that most cases of syllable-conditioned epenthesis will be contrast–neutralizing, as epenthesis applies before stress is assigned. In this way, Broselow accounts for dialects where the contrast between epenthetic and non-epenthetic words is neutralized across the board.

To explain hybrid cases like Iraqi Arabic, she proposes that languages choose different orderings between re-syllabification and stress assignment (that is foot building). When re-syllabification follows stress, then stress is contrast-preserving word-finally, as in Iraqi. At the stage when stress applies, in word-final epenthesis, the penult is still heavy despite epenthesis. In effect, stress is penultimate (*ka.tab._t* > by stress *ka.táb._t* > by resyllabification *ka.tá.b**i**t*). Word-medially, regardless of re-syllabification, epenthetic syllables are heavy and so behave with respect to stress like heavy syllables with underlying vowels. Thus, we have a hybrid case. Word-finally epenthetic vowels do not count for stress, but word-medially they do. In contrast-preserving coda dialects, the ordering would be the opposite, that is, resyllabification would precede stress.

But this account does not seem to generalize to those dialects in which contrast is preserved across the board, like Syrian, Levantine and Libyan (see section 5.3.1). If we order stress before re-syllabification, then we get Iraqi (a hybrid case), and with the opposite ranking we arrive at Omani (a contrast-neutralizing case). Syrian (a contrast-preserving dialect) presents a problem.

Broselow (1992) proposes a different account of the same phenomena. She proposes that unsyllabified consonants are assigned the status of a monomoraic syllable in coda dialects (*ki.tab.*t_μ*.la*) and the status of an onset with an empty mora position in onset dialects (*ki.tab.t_.la*). In onset dialects the empty mora position is then filled with a vowel. This rightly predicts that words with and without epenthesis in onset dialects behave the same. In coda dialects, however, no vowel insertion is required. Therefore, words with and without epenthesis will have different stress. For example, when epenthesis is into the penult, where the antepenultimate syllable is heavy, it is the antepenult that receives stress (*ki.táb.*t_μ*.la*). Subsequently, epenthesis and resyllabification take place and so stress assignment contradicts surface facts (epenthetic *ki.tá.b**i**t.la* versus non-epenthetic *ka.táb.tu*). This explains cases like Syrian, where stress in words with and without epenthesis is distinct.

Under this approach, contrast-neutralizing dialects like Omani seem problematic. That is, we need to explain why in some coda dialects epenthetic vowels count for stress.

Another problem is to explain what forces epenthesis in this proposal. If the extrasyllabic consonant forms its own syllable, then there is no cluster within a syllable to be broken up by an epenthetic vowel. We need some additional assumptions to force epenthesis. (With regard to the same problem, see the discussion of Piggott (1995) in section 5.2.)

Farwaneh (1995) provides a solution. In her proposal, unlike Broselow (1982), epenthetic syllables count as light in coda dialects until nucleus formation is invoked. Nucleus formation takes place iff the epenthetic syllable has an onset. She furthermore proposes that languages choose an option of either assigning an onset to the epenthetic syllables (*ka.ta.b_t.l*a) or keeping the potential onset consonant in the coda of the preceding syllable (*ka.tab._t.la*). She captures this formally by allowing languages to choose either the so-called onset or weight-by-position parameter. Languages that choose the onset parameter merge the contrast between words with epenthetic and non-epenthetic vowels. Languages that choose the weight-by-position parameter, retain the contrast. This can be seen in relation to resyllabification. That is, the onset parameter means that resyllabification takes place at the point when stress applies, whereas the weight-by-position parameter implies that resyllabification has not yet taken place. Since onsetless syllables do not have a nucleus when stress is assigned, this distinguishes between contrast-preserving and contrast-neutralizing dialects, a problem that Broselow's account faces.

This account does not seem to predict cases like Iraqi Arabic, where contrast is merged word-medially but preserved word-finally. Since contrast is merged for word-medial epenthesis, Iraqi would choose the onset parameter word medially, thus surface *ki.ta.bít.la* would be syllabified *ki.ta.b_t.la* at the stage when stress applies (with the nucleus filled). By choosing the onset parameter, syllabification is the same as on the surface, and stress is assigned in the same way as to underlying vowels in the same position. But in word-final position, the onset parameter wrongly predicts antepenultimate stress, **kí.ta.b_t*, instead of the actual penultimate stress which is consistent with the WBP parameter, *ki.táb._t*. By choosing the WBP parameter, the penultimate syllable is heavy and thus receives stress. To account for cases of this type, we need to assume that a language can choose parameters depending on the site of epenthesis. In case of Iraqi, the onset parameter is chosen word-medially, but the WBP parameter word-finally. Unless there is some principled way of explaining this difference in the choice of the parameter, it should be avoided. Epenthesis is one process in Iraqi and should be formally captured as such. (But see a discussion of Libyan versus Levantine in Farwaneh 1995:142-151).

A similar problem arises in the approach to epenthesis developed by Michelson (1989), modifying Archangeli (1984). On the example of Mohawk epenthesis, Michelson proposes that in cases when words with epenthesis behave differently with respect to stress assignment than words without epenthesis: epenthetic vowels are invisible to stress. The invisibility is achieved by proposing that in those cases epenthesis inserts segmental features without accompanying V-slots. V-slots give vowels the status of a nucleus. Thus, at the point when stress applies, epenthetic vowels do not have the status of a syllabic nucleus and so do not count for stress. In languages where epenthetic words behave the same as non-epenthetic words with respect to stress, on the other hand, V-slots are supplied before stress assignment takes place.

Just like the proposal in Farwaneh (1995), the invisibility hypothesis does not account for hybrid cases like Iraqi Arabic, unless we allow for separate V-slot rules depending on the environment of the epenthetic segment. This again brings us back to the general problem with the rule-ordering hypothesis described at the beginning of this section, which is that epenthesis in those dialects is one and the same process, and so should be treated as such under any formal account of those facts.

The proposal developed by Michelson (1989), moreover, does not give a principled explanation for why epenthesis into quadri-consonantal sequences is never contrast-preserving. Again, in languages that choose to insert V-slots after stress assignment, epenthesis in quadri-consonantal sequences should be contrast-neutralizing just like epenthesis into other clusters in the same language.

Furthermore, under the invisibility proposal onset dialects are left unexplained. That is, we expect onset dialects to either preserve or neutralize the underlying contrast on the surface depending on the ordering of V-slots insertion with respect to stress assignment. Yet, they are all contrast-preserving. This would mean that in all onset dialects, V-slots assignment precedes stress. This seems accidental. Onset dialects present a problem for a number of rule-ordering accounts, as has been described in this section.

Finally, in cases where epenthesis improves syllable structure, as in Arabic, if V-slots are not present at the point when epenthesis takes place, then there is no reason for epenthesis. Vowels inserted without V slots do not improve the syllable structure and thus there seem to be no reason for inserting them. Therefore, this account finds it problematic to explain epenthesis in languages where it is syllable-driven.

5.8.2 OT Proposals

To account for stress-epenthesis interaction, Alderete (1995) proposes a constraint HEAD-DEPENDENCE, by which only underlying vowels can receive stress. Like other OT constraints, this is a violable constraint, and therefore epenthetic vowels will receive stress under the compulsion of constraints ranked higher than HEAD-DEP. Thus, this account predicts both contrast-preserving and contrast-neutralizing dialects depending on the ranking of the constraint HEAD-DEP. To illustrate this proposal, assume that the epenthetic syllable is non-moraic, as proposed in this chapter - epenthetic *kitab**i**tla* is footed as *ki(tábit)la.* In comparison, an identical non epenthetic form is footed as *(kita)(bít*$_{\mu}$*)la.* Those two forms differ on WBP (Weight-By-Position), and also on PARSE-

SYLLABLE. Therefore, for the contrast-preserving mapping to be optimal, HEAD-DEP must outrank the two conflicting constraints, thereby forcing a violation of them.

(68) The role of HEAD-DEP

	/kitab-t-la/ 'I wrote to him'	HEAD-DEP	PARSE-SYLL	WBP
a. Contrast-preserving ☞	ki(tábit)la		**	*
b. Contrast-neutralizing	(kita)(bít$_\mu$)la	*!	*	

With the opposite ranking, WBP >> HEAD-DEP, or PARSE-SYLL >> HEAD-DEP, epenthesis would be contrast-neutralizing (provided that no other higher-ranked constraint forces a violation of WBP or PARSE-SYLL).

This account finds it problematic to explain cases where epenthesis is contrast-preserving but for reasons other than avoiding the HEAD-DEP violation. These are cases where stress in words with and without epenthesis is distinct, but the epenthetic vowel would not be stressed anyway, even if epenthetic words received regular stress. Since the epenthetic vowel would not be stressed anyway, there is no violation of HEAD-DEP, and thus something else must be forcing the irregular stress of epenthetic words. Word-final epenthesis in Iraqi Arabic provides an example. Neither the contrast-preserving form *ki(tábit)* nor the contrast-neutralizing form *(kíta)bit* violate HEAD-DEP. Thus, something else must decide in favor of the contrast-preserving form in this dialect.

Kiparsky (2000ab) develops a different proposal for stress-epenthesis interaction based on the Lexical Phonology Model of OT (LPM-OT). Like Broselow (1992), Kiparsky posits a special structure for epenthetic syllables at the lexical (word) level in contrast-preserving dialects. It is proposed that in those dialects stray consonants are licensed as semi-syllables at the word level, directly adjoined to a PrWd node rather than a syllable node. Consequently, there is no need for epenthesis at that level since there are no consonant clusters. This structure is then readjusted postlexically by epenthesis. But stress has already applied at the word level. As a result, epenthetic vowels are opaque to stress. To take an example, underlying */fihm-na/* 'our understanding' maps onto word-level *(fíh)m-na* with no epenthesis. Stress applies at this level but does not see epenthetic syllables since they are not there. Subsequently, the same structure maps onto post-lexical *fíh**i**m-na* with epenthetic *i* and stress carried over from the word stratum. Thus, in those dialects epenthetic vowels are opaque to stress. This is achieved by positing distinct constraint rankings for word and post-lexical levels of representation by which in contrast-preserving dialects semi-syllables exist at the lexical level, as ***m*** in *(fíh)**m**-na*, and are repaired at the post-lexical level by epenthesis, as in *fíh**i**m-na*. In contrast-neutralizing dialects, on the other hand, semi-syllables are not allowed and so epenthetic vowels count for stress. Thus, in this account of Arabic opacity follows from the ordering of levels and special assumptions about epenthetic syllables. In this chapter, I develop a very different approach from Kiparsky's to stress-epenthesis interaction, based on a parallel model of OT, and see where it leads.

5.9 Conclusions and Extensions

In this chapter I have provided an analysis of stress-epenthesis interaction in dialects of Arabic. In some dialects words with epenthetic vowels behave differently with respect to stress assignment from words with non-epenthetic vowels. I have explained this difference in terms of contrast preservation, by observing that the underlying V/∅ contrast is transformed into surface stress contrast.

To capture this observation formally, I have proposed that a PC constraint militating against the loss of the V/∅ contrast, PC_{IN}(V/∅), can force violation of WBP so that the coda consonant in the syllable with an epenthetic vowel lacks a mora. The non-moraic status of the coda consonant leads to a different foot structure of a word and consequently different stress placement. Arabic dialects differ in the ranking of the PC constraint with respect to WBP and thus either preserve or neutralize contrasts (see section 5.3).

To explain cases where contrast is preserved only finally but not medially (see section 5.4), I have proposed a high-ranking constraint against discontinuity at the level of moras. This constraint, when ranked higher than PC, does not allow for a mora-less coda medially in the string of segments.

In section 5.6 I have discussed locality of contrast preservation. I have formulated locality constraints on structural and surface contrast expression. Constraints on locality can be seen as aiding recoverability of the underlying form (for a discussion of recoverability see Kaye 1974, 1975, Kisseberth 1976). Locality explains why contrast is only dislocated minimally in the string of segments. It also provides a principled explanation for why epenthesis in onset dialects and into quadri-consonantal sequences in all dialects is never contrast-preserving.

In Arabic the underlying V/∅ contrast is transformed into surface stress contrast. Whenever an underlying contrast is transformed into a different surface contrast, some instances of the original surface contrast are lost. So, in this particular case, some instances of the original stress contrast are lost, because it now represents another contrast. Stress is a good choice to represent other contrasts, as it is itself non-contrastive on the surface, that is various input stress patterns neutralize onto the actual stress pattern anyway, with or without compulsion from the high-ranked $PC_{IN}(V/\varnothing)$ constraint. In PC theory, this means that PC_{IN}(stress) is low-ranked.

PC theory makes a prediction with respect to epenthesis that is confirmed by the facts. Epenthetic segments are often not found outside of the epenthetic environment in the same language. In the rule-based theory, this is known as non-structure preserving epenthesis (Steriade 1995). In OT, this means that markedness constraints against such segments are high-ranked, but $PC_{IN}(V/\varnothing)$ forces a violation of them. Marked segments are then utilized to preserve contrasts between words with and without epenthesis. Under the contrast preservation approach, this fact is explained because such segments do not neutralize meaningful underlying distinctions on the surface. They never surface outside of the epenthetic environment, and thus by epenthesizing them no contrasts between words with and without epenthesis are merged. On the other hand, if an epenthetic segment is the one that surfaces in some other environments in the language, epenthesis has the potential to merge underlying distinctions on the surface, and languages need to resort to some other means to preserve such distinctions. Arabic dialects provide an example.

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Abbreviations:

BLS	=	(Proceedings of the) Berkeley Linguistics Society
CLS	=	(Proceedings of the) Chicago Linguistics Society
LI	=	Linguistic Inquiry
NELS	=	(Proceedings of the) Northeast Linguistics Society
NLLT	=	Natural Language and Linguistic Theory
ROA	=	Rutgers Optimality Archive (http://ruccs.rutgers.edu/roa.html)
WCCFL	=	(Proceedings of the) West Coast Conference on Formal Linguistics

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