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Vowel Reduction in Optimality Theory

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Linguistics

by

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1999

"Life belongs to the living, and he who
lives must be prepared for changes."
- GOETHE

This dissertation is dedicated to all the scholars who will develop better theories of vowel reduction.

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Tableaux, Illustrations, and Other Displays

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PUBLICATIONS AND PRESENTATIONS

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———. (1999) "Intra-Paradigmatic Homophony Avoidance in Two Dialects of Slavic," *UCLA Working Papers in Phonology*, Vol. 2 1999.

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———. (1997) "Cyclicity and Optionality in Chamorro Phonology,". *UCLA Working Papers in Phonology*, Vol. 1.

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ABSTRACT OF THE DISSERTATION

Vowel Reduction in Optimality Theory

by

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In many languages, the full set of vowels that occur in stressed syllables does not occur in unstressed syllables. This situation commonly results from vowel neutralizations in unstressed positions. For example, the vowels /e,o/ might occur in stressed syllables, but not unstressed syllables, being replaced with the corresponding high or low vowel when unstressed. Such stress-dependent vowel neutralizations are referred to as *vowel reduction*. This study is based on the examination of several languages with vowel reduction, and attempts to uncover universal cross-linguistic patterns in order to identify the motivations of vowel reduction. These motivations are taken as the basis for a formal analysis of the phenomenon of vowel reduction within the theoretical framework of Optimality Theory.

This survey demonstrates that vowel reduction phenomena neither operate in the same way nor produce the same results cross-linguistically. There are attested forms of vowel reduction which appear to be contradictory in behavior: Some languages will reduce unstressed /e,o/ via raising (to [i,u], respectively), while others utilize lowering of the same vowels (to [a], e.g.), or a combination of raising some vowels and centralizing or lowering others. Yet other attested vowel reduction patterns do not target the mid vowels at all, instead eliminating unstressed low vowels or unstressed high vowels.

The hypothesis advanced here is that vowel reduction is not a unitary process. Instead, there are at least two different types of stress-dependent vowel neutralization, each with its own motivation and formal analysis. Specifically, I posit a contrast-enhancing form of vowel reduction based on avoidance of poorly-contrastive vowel categories in unstressed positions, as well as a prominence-reducing form of vowel reduction based on avoidance of vowel qualities that favor longer articulation times (i.e., lower vowels) in positions that preferentially have short duration. This non-unitary approach to vowel reduction yields several beneficial results. For example, once the two types of vowel reduction are differentiated from one another, it becomes possible to identify certain cross-linguistic patterns and tendencies that occur in association with one or the other (but not both) of these types. Furthermore, differentiation of vowel reduction into two types is useful in predicting directions of vowel neutralizations and contexts where vowel reduction is fully or partially blocked.

Chapter 1 Introduction and Backgrounds

"I can stand what I know. It's what I don't know that frightens me."

–Frances Newton

1.0 Definition of Vowel Reduction

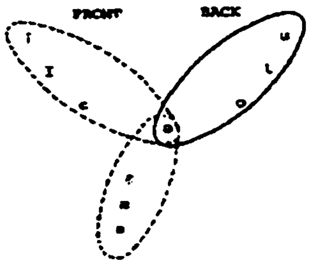
The term "vowel reduction" is often applied to a number of different linguistic phenomena. On one extreme, it can be used to refer to the wholesale deletion of unstressed vowels, while on the other extreme it is used to refer to non-neutralizing changes in the pronunciation of both stressed *and* unstressed vowels (usually tempo-dependent undershoot). For purposes of the present study, vowel reduction will be given a definition somewhere between these two extremes: I will examine cases where two or more underlying vowel qualities are neutralized in a stress-dependent fashion—here and throughout this study, the term "vowel reduction" will be used only in reference to this type of neutralization. Other phenomena traditionally described using this term will be referred to differently, such as "stress-dependent vowel deletion" or "stress-dependent vowel undershoot". This choice of terminology is not merely an expository simplification. One point that the present typology underscores is that vowel reduction (as defined here) does not have a uniform motivation—different vowel reduction processes can result from different motivating factors. In particular, two such factors (contrast enhancement and prominence reduction) will be discussed extensively (see Chapter 2). Once the point is illustrated that vowel reduction is not a unitary phenomenon, it becomes possible, and even probable, that other stress-dependent phenomena (such as deletion or non-neutralizing undershoot) result from formally distinct linguistic processes which, although superficially similar to vowel reduction and indubitably rooted in the same articulatory and perceptual circumscriptions shared by all human languages, should not necessarily be considered extensions of the formal mechanisms suggested in this work.

1.0.0 Comparison of Vowel Reduction and Non-Neutralizing Centralization:

To further illustrate the difference between vowel reduction and other vocalic phenomena that are sometimes referred to as "reduction", I will present some concrete data on two similar phenomena: vowel reduction and articulatory vowel undershoot. It will be shown that vowel reduction always involves a categorical quality change that is conditioned by phonological categories such as stress and or phonemic vowel length, but not by non-phonemic categories like speech tempo or register. On the other hand, vowel undershoot results in gradient changes in pronunciation that *can* be sensitive to tempo and/or register.

The traditional description of vowel undershoot centers on the idea that unstressed vowels centralize, becoming more and more like [ə] in certain contexts, such as under increases in speech tempo. For example, the following quotation and illustration are taken from a description of Ngarigu, a Victorian language described by Hercus (1986):

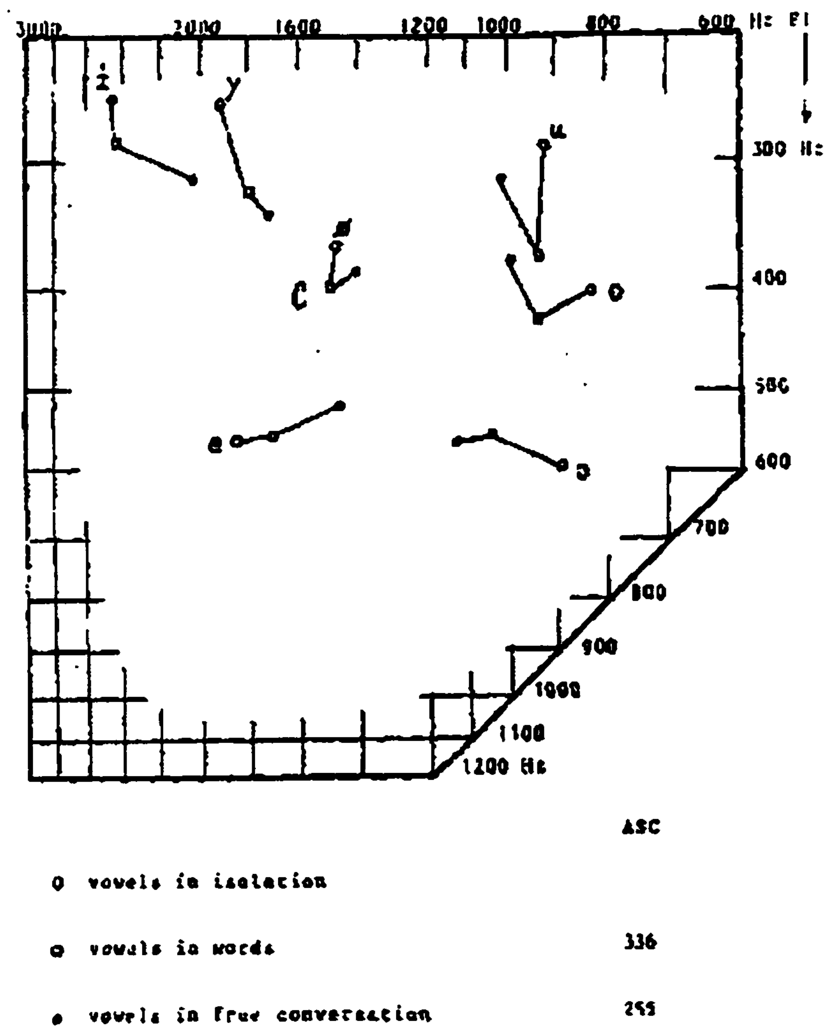
(1) Phonetic Vowel Reduction as Described by Hercus (1986) for Ngarigu



unaccented vowels in any syllable that follows the main tress can be reduced to the weak central vowel [ə]. The .istinctive quality of the vowel was maintained when the vord was repeated or pronounced very carefully. There is hus a gradation of phonetic values for each unaccented ·owel."

A more detailed description of this process has emerged from phonetic investigations on a number of languages. Two such are Koopmans-van Beinum (1980), who investigates Dutch vowels uttered in several different contexts, and de Graaf (1983), who examines vowels in Japanese, Hungarian, Finnish, and other languages. Representative results from de Graaf (for Hungarian short vowels) are shown in figure (2).

(2) Vowel undershoot in Hungarian short vowels (de Graaf 1984)

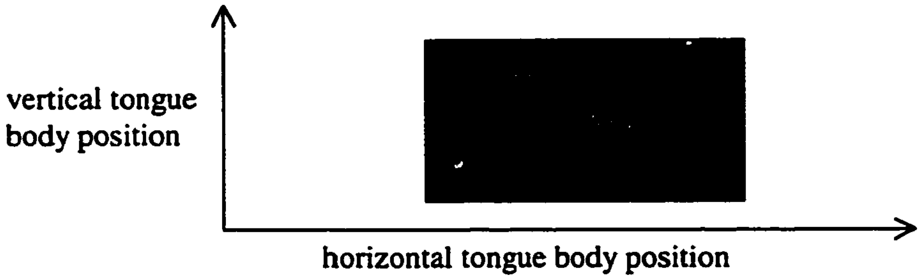


The Hungarian vowels seem to retain their distinctive qualities, but become much closer to one another in the vowel space. This type of phonetic centralization can be understood as shrinkage of the vowel space. That is, in certain contexts, vowels are made using extreme vowel articulations. In certain other contexts, the same type of articulations are used—they just do not reach their fullest realization, producing a more centralized result. The conditions where more extreme articulations are preferred include stressed syllables (Koopmans-van Beinum 1980), long vowels (de Graaf 1984), and slow or careful speech (Koopmans-van Beinum 1980, Moon and Lindblom 1994). As Lindblom (1963) puts it:

> "Although a vowel phoneme can be realized in a more or less reduced fashion, the talker's 'intention' that underlies the pronunciation of the vowel is always the same, independent of the contextual circumstances." (Lindblom 1963, p. 1778)

This effect has recently been modeled by Moon and Lindblom (1994) and Guenther (1995). Under the Moon and Lindblom approach, vowel undershoot is equated with contextual coarticulation between a vowel and the adjacent consonant(s); they model this process using a biomechanically motivated equation involving (1) a measure of articulatory distance between a vowel and surrounding consonants ("locus-target distance"), (2) articulatory effort (rate of formant frequency change), and (3) vowel duration. The basic idea embodied in the Moon and Lindblom approach is that a given vowel quality has a canonical articulation. In certain contexts (such as under stress, or in careful speech), the actual vocal tract configuration used by a speaker will match the canonical configuration fairly closely. In other contexts (such as unstressed syllables, fast speech tempos, etc.), the actual vocal tract configuration used for a given vowel quality will be displaced towards that of any adjacent consonant(s) due to coarticulatory factors. (In many cases, this type of consonantal displacement seems to cause centralization of the vowel, but this is not a necessary result.) In a similar approach, Guenther (1995) hypothesizes that a given vowel quality does not possess a *unique* canonical vocal tract configuration. Rather, a given vowel quality is associated with a *range* of acceptable vocal tract configurations, as shown in (3):

(3) **Tempo-Based Changes in Targets Regions for a Vowel** (based on Guenther 1995)

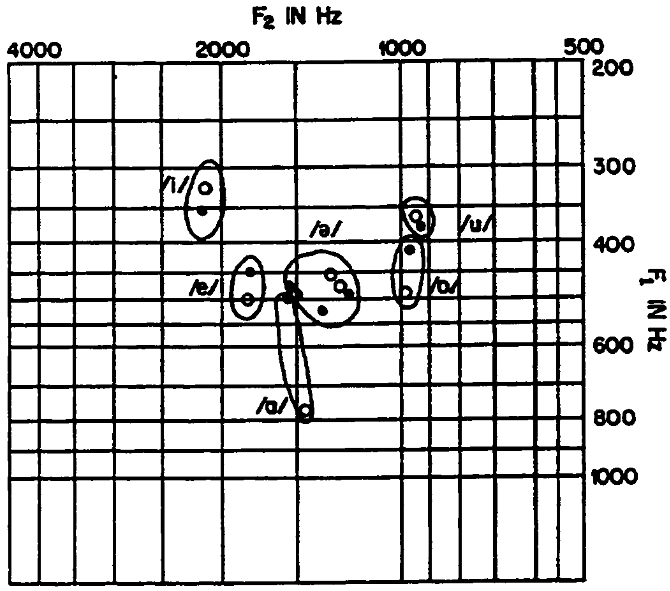


In slow, careful speech, the boundaries of the target range are drawn inwards towards the "canonical" or central area of the articulatory target region, which simultaneously allows less articulatory variability and demands higher articulatory precision; during fast or casual speech, the boundaries of the target region are extended, allowing speakers to use vocal tract configurations that lie in the more peripheral areas of the target region (Guenther 1995). Although these two approaches to vowel undershoot vary in their details, they are similar in characterizing vowel undershoot as a non-categorical process. That is, a given vowel quality is not *replaced* by another quality in unstressed and/or casual contexts; rather, unstressed and casual speech contexts allow less-canonical realizations of some qualitative category to be used, while stressed and/or careful contexts favor use of canonical realizations.

In phonological vowel reduction, however, a different picture emerges. Consider, for example, the following diagram for Bulgarian stressed and unstressed vowels (Lehiste

& Popov, 1970). Open circles indicate stressed vowel tokens, while filled circles indicate unstressed vowel tokens.

(4) Stressed and unstressed vowels in Bulgarian (Lehiste and Popov 1970) O = stressed vowel; ● = unstressed vowel



As shown in the diagram, the dialect of Bulgarian investigated by Lehiste and Popov is characterized by neutralization of unstressed /o/ and /u/ on the one hand, and unstressed /a/ and /ʌ/ on the other hand. (The vowel /ʌ/ is a phonemic vowel in Bulgarian, which can occur both stressed and unstressed.) Unstressed /e/, /i/, and /u/ do not reduce in this dialect, although /e/ does reduce in other variants of Bulgarian. Note that this vowel reduction process differs in two important respects from the vowel undershoot processes discussed above for Hungarian and Ngarigu: (1) the Bulgarian unstressed vowels do not centralize—in fact, the changes seen for Bulgarian unstressed vowels can best be described as raising; (2) these changes are categorical and, in fact cause neutralizations—at least some subset of the phonemic vowels become acoustically indistinguishable from one another. The same points can also be made concerning phonological vowel reduction in a number of other languages. (Additional instrumental data are discussed in section 4.1, where predicting patterns of neutralization is discussed.)

The neutralizing vs. non-neutralizing qualities of vowel reduction and vowel undershoot (respectively) seem to be not only measurable, but psychologically real. For example, the quality changes produced by vowel reduction are complete enough to affect poetic rhymes. It should be pointed out, however, that poetic rhyme is not always an unambiguous indicator of a complete neutralization. Manaster-Ramer (1996) has pointed out, for example, that final devoicing in German is used to form poetic rhymes, although German final devoicing is reported to be a case of incomplete neutralization. I would venture to suggest, however, that poetic rhymes formed on the basis of incomplete neutralizations would be felt to be inferior types of rhyme. Poetic rhymes in Russian based on vowel reduction are noted, however, even in verse written by authors who are otherwise well known for use of perfect rhymes and meters, such as Lermontov (see verses in text). In contrast, there are no good examples where phonetic (gradient) changes in vowel quality (i.e., vowel undershoot) serve as a basis for poetic rhymes.

As an example of poetic rhymes formed via vowel reduction, consider the following passages from Lermontov, where vowel reduction is used to form rhyme pairs (the relevant words are underlined). In the passage on the left, the words *skládki* 'folds' and *besporʲádke* 'disorder (locative)' are rhymed—these words are pronounced [sklátkʲi] and [bʲisparʲátkʲi], respectively. In the second passage, the words *velikána* 'giant (genitive)' and *ráno* 'early' are rhymed—these words are pronounced [vʲilʲikánə] and [ránə], respectively.

(5) Poetic Rhymes in Russian Using Vowel Reduction (exx. from Lermontov; in phonemic transcription)

I bʲéloj odʲéʒdi krasʲívije <u>skládkʲi</u>
Po plʲétʃʲam farʲísa vʲilʲísʲ v <u>bʲesporʲádkʲe</u>
(Lermontov, *Three Palms*)

Na grudʲí utʲósa-<u>vʲelʲikána</u>;
Útrom v pútʲ oná umtʃʲálasʲ <u>ráno</u>
(Lermontov, *The Cliff*)

<u>Comparison forms:</u>
[sklátkʲi]: 'folds' feminine noun w/ stem stress, here in nominative plural; cf:
  [daskʲí]: 'boards' same gender and case as above, but with end stress

[v bʲisparʲádkʲi]: 'disorder' fem. noun w/ stem stress; here in locative due to *v* 'in'; cf:
  [v daskʲé]: 'board' (loc). same gender and case, but with end stress

[vʲilʲikánə]: 'giant' masc. noun w/ stem stress; here in genitive singular; cf:
  [gəvəruná]: 'chatterbox' (gen.) same gender and case, but has end stress

[ránə]: 'early' adverb with stem stress; cf.:
  [lʲixkó]: 'easily' adverb with end stress

The same is true of Bulgarian. Consider, for example, the following passages from Botev. Both passages show examples of unstressed /i/ rhymed with unstressed /e/ (which is pronounced [i]).[1]

[1] In the passage on the left, the unstressed /e/ at the end of the vocative form *slʌ́nce* does not reduce, and this word therefore rhymes with *sʌrcé*, which ends with a stressed /e/. Vocatives are generally immune to reduction in Bulgarian.

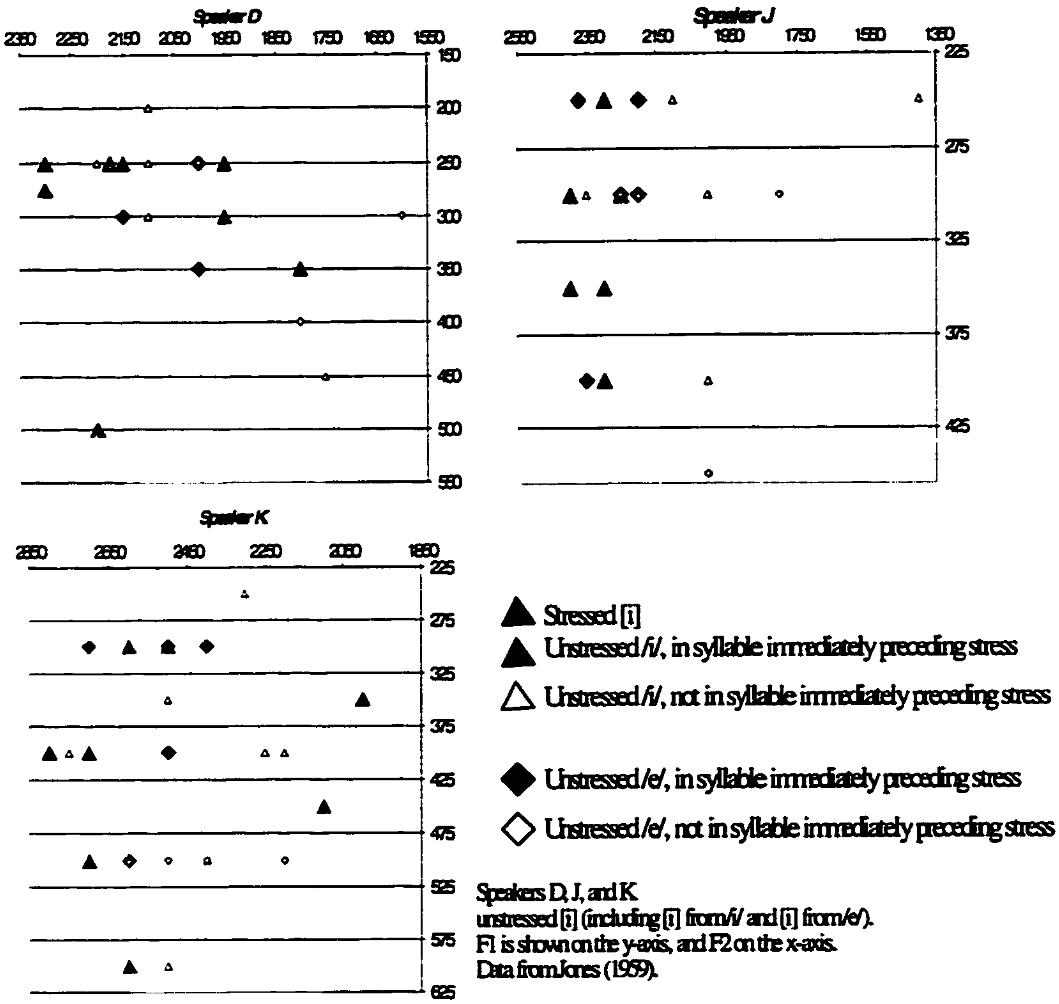
(6) Poetic Rhymes Using Vowel Reduction in Bulgarian (exx. from Botev):

ʒʌ́tva e segá… Péjte, <u>robíni,</u>
tez tʌ́ʒni pésni! Grej i ti, slʌ́nce,
v taz róbska zemjá! ʃte da <u>zagíne</u>
i tója junák… No mlʌkní, sʌrcé.

dénem mu sjánka pázi orlíca
i vʌlk mu krótko ránata <u>blíʒe</u>;
nad négo sokól, junáʃka ptíca,
i tja se za brat, za junák <u>gríʒi</u>.
(Botev, *Chadzhi Dimitur*)

Languages such as Russian and Bulgarian can be contrasted with vowel undershoot in terms of tempo-dependence as well. In Russian and Bulgarian, the appropriate vowel reductions are mandatory at all speech tempos. For example, when a Russian word is spoken very slowly and in isolation, unstressed vowels still undergo the appropriate vowel reduction changes (provided that the word is not spoken in a syllable-by-syllable manner, where each syllable is treated as a separate stress domain). This can be verified by listening to any popularly-available instructional audio tape produced using a native speaker, such as Dover Books' *Listen and Learn Russian*. In this type of audio tape, words are spoken slowly and in isolation for the benefit of a non-native language learner. In *Listen and Learn Russian*, vowel reduction changes are, if anything, produced in a slightly exaggerated manner. This contrasts markedly with Hercus' observations about Ngarigu, where phonetic vowel centralization is blocked in the careful speech elicited for benefit of a non-native speaker. Of course, it is an open question as to whether the Ngarigu and Russian speakers are *consciously* suppressing or emphasizing vowel reduction, respectively. However, the point is clear that Ngarigu and Russian speakers differ with respect to their conceptualization of "normative" pronunciation: Russian normative pronunciation includes vowel reduction, and Ngarigu normative pronunciation does not.

The survey will focus on those vowel processes which are categorical in nature and obligatory at all speech tempos, such as those outlined above for Russian and Bulgarian. This type of vowel process will be referred to as vowel reduction. Superficially similar cases which are not neutralizing or which do not occur at all speech tempos will not be considered cases of vowel reduction (as the term is defined here), and will not be of central importance in this study. This differentiation is important, since some languages possess both types of process. This is the case, for example, in Contemporary Standard Russian (CSR). Consider, for example, the following vowel plots based on measurements published in Jones (1959). The speakers Jones used in this study were all born in Moscow, either in 1895 or 1910. The occupations of speakers are: Speaker K, housewife; Speaker D, actor, formerly of the Moscow Art Theater; Speaker J, university professor. The plots shown in (7) are for surface [i], which results both from underlying /i/ and /e/ (which reduces to [i]).



(7) Vowel Plots for Pronunciation of Stressed and Unstressed [i]

(The illustration provided here distinguishes between unstressed vowels that immediately precede the stress and those that occur elsewhere, since Russian vowel reduction is sometimes sensitive to this difference. However, note that it does not seem to play a role here.[2])

Note that the unstressed [i] tokens in (7) have a much wider distribution than the stressed [i] tokens. Indeed, this difference in distribution causes a noticeable effect on the pronunciation of unstressed [i], which tends to be lower and somewhat more central than stressed [i]. However, this is not the case for 100% of the tokens: for example, several of the unstressed tokens are just as high and as front as the stressed tokens. In fact, the distribution of the unstressed tokens wholly overlaps that of the stressed tokens. This sort of gradient centralization is consistent with articulatory undershoot: the vowels occur within the same general region of articulatory space, but the stressed variants seem to fall within a narrower area, more representative of the canonical quality for [i]. However, absolutely no difference in distribution is noted in a comparison between the tokens that derive from underlying /e/ and underlying /i/. For example, it is not the case that the unstressed tokens whose phonemic category is /e/ have a lower distribution than do those unstressed tokens whose phonemic category is /i/. In other words, it is *not* the case that the unstressed /e/'s in these data are simply "sloppy", non-canonical instantiations of the [e] quality. Rather, it seems as though both unstressed /e/ and unstressed /i/ are completely neutralized to a high front vowel, although the articulation of this quality in

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[2] According to Avanesov (1984), Russian unstressed [i] found in the syllable immediately preceding the stress is longer in duration when compared with other unstressed [i]'s, but does not differ in quality. This seems consonant with the data presented here.

unstressed syllables may be less similar to a canonical [i] than would be the case in a stressed syllable. In this study, I will not consider subtle, non-neutralizing modifications to the articulation of vowels such as those just discussed for CSR stressed [í] vs. unstressed [i]. This decision has not been made arbitrarily: as mentioned earlier, different types of vowel reduction seem to have different etiologies. The type of quality changes that are excluded here (i.e., gradient, non-neutralizing quality changes) might best be analyzed in the manner suggested by Guenther (1995) and Moon and Lindblom (1994). Although such approaches can likely be formalized using the same theoretical framework adopted in the current study (Optimality Theory, Prince and Smolensky 1993, McCarthy and Prince 1993), it seems clear that such an analysis would be formally distinct from that offered here for non-gradient, neutralizing vowel reduction.

1.1 Myths About Vowel Reduction

Over the years, many generalizations have been made about vowel reduction—some of which have appeared in publication and some of which are implicit "common knowledge". Many of these generalizations do not hold up under closer scrutiny, especially in cross-linguistic perspective. Some are based on language-specific patterns which are contradicted by vowel reduction phenomena in other languages, and some are based on the misassumption that all stress-dependent vowel phenomena represent a unitary process (thus assuming that generalizations about stress-dependent vowel undershoot also apply to phonological vowel reduction, for example). Some of these myths include:

Myth #1: Vowel Reduction Equals Vowel Centralization

It is often assumed that vowel reduction processes strive to "simplify" vowel articulation in unstressed positions. In this case, simplification means the minimization of articulatory gestures—avoiding large, effortful movements and instead opting to remain as close to the "neutral" tongue position as possible. Typically, the neutral tongue position is defined as the position used for pronunciation of schwa. So, in Miller's (1972) theory of vowel reduction, schwa is formally represented as having a [-] specification for all features; [+] feature specifications represent deviations away from the neutral position—the two main features she uses are [palatal] and [labial]. Therefore, vowel reduction is formally represented as the deletion of (a subset of) [+] feature specifications, making unstressed vowels more similar in quality to [ə] in at least some relevant parameter.

Although the description of vowel reduction as effort-avoiding centralization may be applicable to stress-dependent undershoot, it is probably not an accurate description of phonological vowel reduction—a number of languages have phonological vowel reduction phenomena that contradict this formalization. For example, one of the most common types of vowel reduction seen cross-linguistically is the raising of unstressed mid vowels: /e,o/ > [i,u]. This pattern is seen, for example, in Standard Bulgarian

(Lehiste & Popov 1970, Scatton 1984, Pettersson & Wood 1987a, 1987b; Groen 1987), Luiseño (Munro and Benson 1973), and Greek dialects of Asia Minor (Dawkins 1916), to give a few examples. Articulatorily speaking, the high vowels represent a greater deviation from the neutral tongue position than do the mid vowels, contrary to the idea that vowel reduction equals vowel centralization.

Myth #2: Patterns of Vowel Neutralization are Universal

A widespread belief is that languages "get rid of" undesirable vowels in unstressed positions and replace them with better ones, and that this process is governed by universal standards of vowel "desirability" (a.k.a. markedness). Under this view, the substitutions that are made in unstressed syllables might be assumed to be a matter of course, and might not even be included in a description of the vowel reduction process itself. For example, a vowel reduction process may be described as reducing a typical five-vowel inventory (i,u,e,o,a) to a three-vowel inventory (i,u,a) in unstressed syllables, without any mention of the neutralizations that achieve this change (cf., for example, the brief description of vowel reduction in Bortzerrieta Basque in Hualde 1991, p. 174). A similar view might be seen in Alderete's (1995) analysis of vowel reduction. In his analysis, all vowel articulations are considered to be marked to some degree. When not protected by the presence of stress, the most marked vowels (i.e., the mid vowels) are replaced by less marked vowels according to a universal hierarchy of vowel markedness.

This conception of vowel reduction is most often found in language-specific works, where patterns from other vowel reduction languages are not available for comparison. For example, to someone familiar with (standard) Catalan (Recasens 1991, Mascaró 1978), the neutralization of /e/ to [ə] seems so commonplace as to go without explanation, but to a speaker of Standard Bulgarian (Lehiste & Popov 1970, Scatton 1984, Pettersson & Wood 1987a, 1987b; Groen 1987) or Standard Russian (Avanesov 1984, Bondarko 1977, Bulanin 1977, Zubkova *et al.* 1985), it seems almost unnatural (Standard Bulgarian and Russian replace unstressed /e/ with [i][3]). On the other hand, someone familiar with Russian would view the reduction of /o/ to [ə] as something to be taken for granted, although Bulgarian and Catalan speakers find this reduction unusual (Bulgarian and Catalan replace unstressed /o/ with [u]). The idea of a universal pattern of vowel substitutions is especially problematic for the Standard Russian and Catalan patterns, where the mid vowels reduce asymmetrically (Catalan e>ə, o>u; Russian e>i, o>ə, also see fn. 3).

Myth #3: Certain Vowels Are Always More Vulnerable to Reduction

One implicit and widespread assumption about vowel reduction is that certain vowels—specifically, the mid vowels—are always the first to be targeted for

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[3] It is sometimes mistakenly supposed that the Russian pattern /e/ > [i] is due to the interference of a preceding palatalized consonant. However, at least in the standard dialect, /e/ > [i] also occurs independently. Compare: [ékspərt] '*export*' (noun) and [ikspartʲírəvətʲ] '*to export*'.

neutralization. Although it is true that the mid vowels are numerically the most oftenly-reduced vowels cross-linguistically, it is important to note that this is **not** part of an implicational hierarchy. For example, it would be easy to (incorrectly) assume that if a language has vowel reduction, the mid vowels will definitely be targeted, possibly along with some other set of additional vowels. If this scenario were an accurate representation, you would not expect to find languages where vowel reduction affects non-mid vowels while leaving the mid vowels intact. However, although this type of pattern is rare, it is nonetheless attested. For example, in Sri Lankan Portuguese creole (Smith 1978), low and mid vowels are contrastive under stress, but unstressed low vowels raise to the corresponding mid vowels when unstressed: /æ/ > [e], for example. Similarly, in colloquial Slovene (Lencek 1982), short high vowels undergo reduction, while mid vowels do not.

A similar assumption is that the high vowels only rarely undergo reduction, and then only if all lower vowels also reduce (for example, in English, where all vowels are subject to reduction to [ə] under appropriate conditions). In other words, the high vowels are seen as cross-linguistically least likely to undergo reduction. Again, although this generalization is *usually* the case, it is not a hard universal. For example, in some southern dialects of Italian (Maiden 1995), all vowels *except /a/* undergo reduction to [ə] in pretonic unstressed syllables—representing a case where high vowels undergo reduction before a lower vowel does. The case of colloquial Slovene (just mentioned) is another counterexample to this generalization.

Myth #4: Different "Degrees" of Vowel Reduction are Aspects of a Single Process

In some vowel reduction phenomena, different patterns of neutralization occur in different environments. Typically, a moderate pattern of reduction holds in certain environments, while a more extreme pattern of neutralization is seen elsewhere. For example, in the southern Italian dialects just mentioned, all vowels *except /a/* reduce to [ə] pretonically, and all vowels (including /a/) reduce to [ə] posttonically. In most dialects of Brazilian Portuguese (Redenbarger 1981, Dukes 1993), only a moderate degree of reduction is seen in prevocalic unstressed syllables—/e/ & /ɛ/ neutralize to [e], and /o/ & /ɔ/ neutralize to [o]; however, posttonically all mid vowels raise to the corresponding high vowel, and /a/ is realized as [ə]. The standard assumption about such two-pattern vowel reduction systems is that the "moderate" and "extreme" neutralizations are different aspects of a single process—a process which is more aggressive in certain environments. This is particularly the case for the southern Italian and Brazilian Portuguese cases just mentioned—in these cases, the "extreme" neutralizations involve the same type of change seen in the "moderate" neutralizations. For example, in southern Italian, the same centralization process is simply extended to apply to a larger class of vowels. In Brazilian Portuguese, both the moderate and extreme neutralizations involve raising; the only differences are that a larger set of post-tonic vowels undergo raising, and they raise more than pre-tonic vowels do.

Based on these examples and others like them, it is easy to assume that this type of two-pattern system employs a single type of vowel reduction, which has varying degrees of success in reaching its fullest realization. However, this conclusion is contradicted by other attested two-pattern vowel reduction systems. For example, in the two-pattern systems found in Rhodope Bulgarian (Miletich 1936) and certain southern Russian dialects (Avanesov & Orlova 1965, Stroganova 1965, Meshcherskii 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989), the neutralizations seen in the moderate and extreme reduction environments are opposite in action. For example, in Rhodope Bulgarian, unstressed /o,e/ reduce to [a] pretonically, but reduce to /i,u/ (respectively) posttonically. A similar pattern is seen in many southern Russian dialects, where /e,o/ reduce to [a] in the syllable immediately preceding the stress, but reduce to [i,ə] (respectively) in other unstressed syllables (in cases where unstressed /o/ is not preceded by a palatalized consonant, that is). Finally, a similar sort of "reversal" in the direction of reduction is also seen in the north-eastern variety of Brazilian Portuguese (Brakel 1985, Perrone and Ledford-Miller 1985). In these dialects, the mid vowels reduce pretonically via *lowering*: /e/ & /ɛ/ neutralize to [ɛ], and /o/ & /ɔ/ neutralize to /ɔ/. The same *raising* pattern found in standard Brazilian Portuguese posttonic syllables is also found posttonically in north-eastern Brazilian Portuguese: front mid vowels reduce to [i] and back mid vowels reduce to [u]. This type of two-pattern vowel reduction system will be discussed in greater detail in Chapter 3. The approach adopted here will treat this type of two-pattern reduction as the intersection of two different types of reduction.

Myth #5: Stressed Vowels are Immune to Vowel Reduction

Finally, and perhaps the most surprisingly, it is not the case that vowel reduction only strikes unstressed syllables. In some languages, such as standard Italian (Flemming 1995), Slovene (Lencek 1982), and perhaps some dialects of Chamorro (Topping 1969, Topping, Ogo, and Dungca 1975), vowel reduction strikes a subset of stressed vowels (such as vowels bearing secondary stress, or stressed vowels that are monomoraic), as well as unstressed vowels. More interesting, in some dialects of Slovene (Rigler 1963), vowels carrying primary stress are targeted for neutralization. In these dialects, short high vowels and short mid vowels are distinctive in unstressed positions, but not under stress. Under stress, the short high vowels lower to the corresponding mid vowel. Given the definition of vowel reduction assumed for this survey—i.e., all stress-conditioned vowel neutralizations—this dialectal Slovene pattern qualifies as a type of vowel reduction. Interestingly, the same pattern in also seen in Chamorro (for analysis, see Crosswhite 1999), where high vowels lower to the corresponding mid vowel in stressed, closed syllables—however, since mid vowels only occur allophonically in Chamorro, this is not a neutralizing change. The formal devices used in this survey to analyze the more traditional forms of vowel reduction easily extend to account for these and similar cases.

1.2 Phonetic Background: Vowel Production and Perception

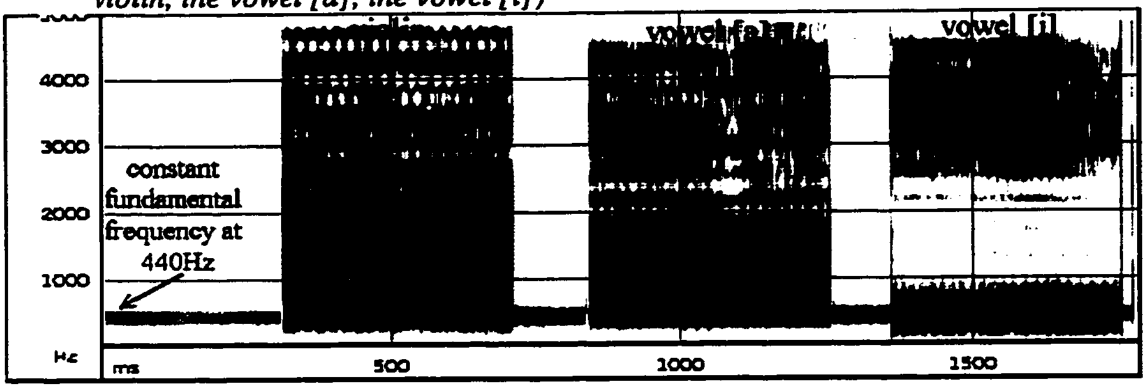
In the chapters that follow, vowel reduction phenomena will be discussed with respect to their impact on vowel articulation and vowel perception. Therefore, before proceeding any further, I review some basic concepts concerning the production and perception of vowels—especially those concepts that will be useful in subsequent chapters. This section is provided as background material.

1.2.0 Vowel Perception

1.2.0.0 Basic Concepts: Quality and Formant Structure

Acoustically, a vowel is a complex sound consisting of many different frequency components—a similar type of sound is produced when a violin string is sounded: The string as a whole vibrates at one frequency and produces one component of the overall sound, each ½ of the string vibrates at a higher frequency producing another component of the overall sound, each 1/4 of the string vibrates at an even higher frequency and produces yet another component of the overall sound, and so on. These frequency components are referred to as *harmonics* or *overtones*. In contrast, a pure tone has no harmonics or overtones—this type of sound is produced, for example, by a tuning fork. For both vowels and violins, there are groups of harmonics that are louder than their immediate neighbors, producing a local amplitude maximum centered around some frequency—these local maxima are referred to in speech as *formants*, and their location is determined by the resonance qualities of the vocal tract (for vowels) or the instrument body (for a violin). This situation is illustrated in the following picture:

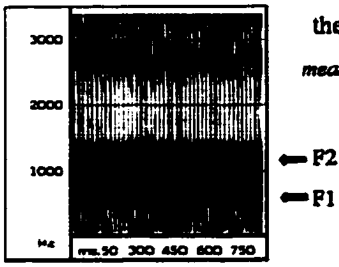
(8) *Sounds produced with a fundamental frequency of about 440 Hz (tuning fork, violin, the vowel [a], the vowel [i])*



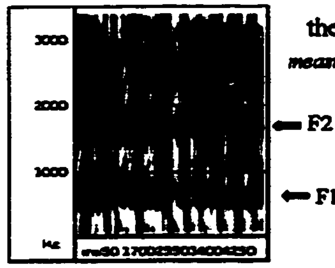
This diagram was produced from a sound file created by splicing together portions of various noises, including an A-440 tuning fork, a violin playing A-440, and the vowels [a] and [i] sung on the pitch of A. Portions of the tuning-fork file were inserted between the various other sounds to visually separate them in the spectrogram. As shown, there is a constant band (sometimes rather light in color) at about 440 Hertz. In the first portion of the display, the 440-Hz component is the only component—this represents a pure tone as recorded from the tuning fork. In other areas, the 440-Hz component is accompanied by bands (harmonics) at higher frequencies: these bands occur at about even intervals in the portions labeled "violin", "[a]" and "[i]", but the patterns of dark bands (formants) and light bands in these areas are different. It is this type of pattern that gives the percepts of different instrumental qualities (violin, recorder, piano) and different vowel qualities ([a], [i], [e]). For example, notice that the vowel [a] has formants at about 800Hz and

1300Hz—this is typical for a low central vowel. The formant patterns (or formant *structures*) for several vowels are displayed below. For each vowel, its first formant (F1) and second formant (F2) are labeled with arrows, and measured values for these formants are also noted.

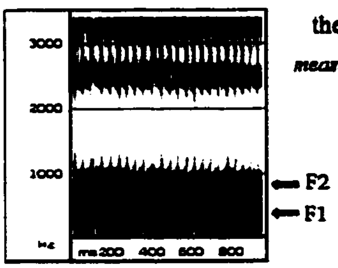
(10) Formant Structures for Six English Vowels



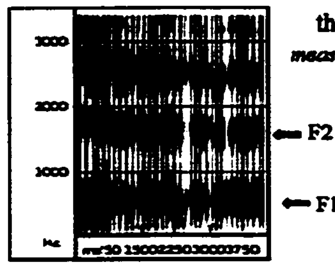
the vowel [a]
measured F1,F2 values: 702, 1188



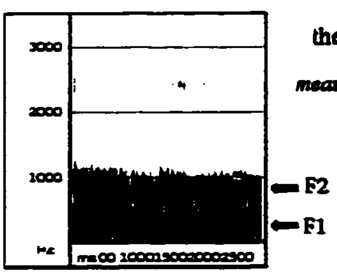
the vowel [æ]
measured F1,F2 values: 712, 1742



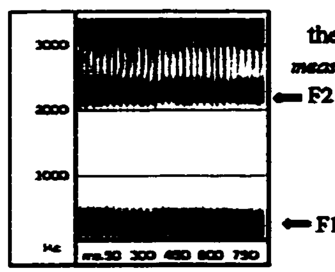
the vowel [o]
measured F1,F2 values: 453, 911



the vowel [e]
measured F1,F2 values: 584, 1638



the vowel [u]
measured F1,F2 values: 263, 932

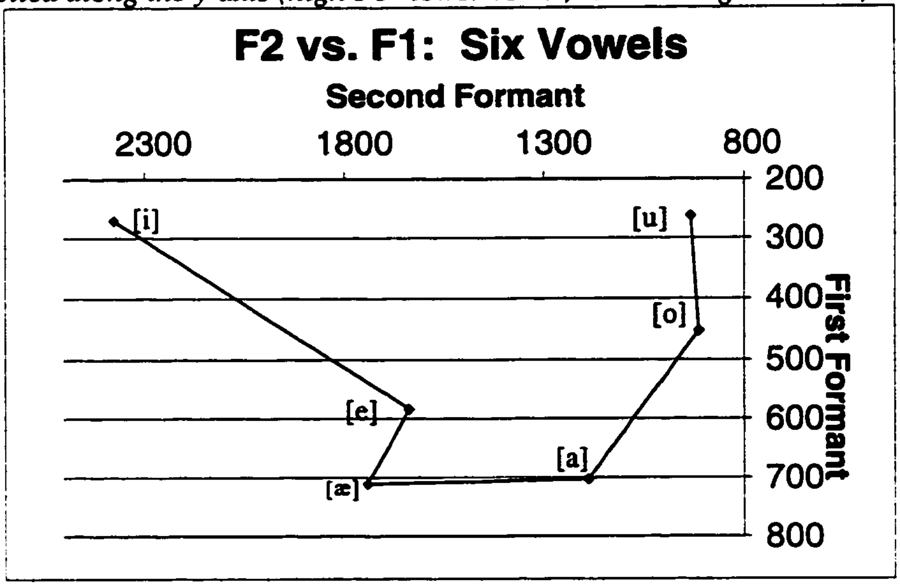


the vowel [i]
measured F1,F2 values: 269, 2375

Notice that the position of the formants is different for different vowel qualities—in order to identify the quality of a vowel, you need to identify the vowel's formants and their frequency positions. The formant structures associated with different vowel qualities are not randomly assigned: The frequency of the first formant corresponds roughly to vowel height (the higher a vowel's articulation, the lower the position of F1 will be; the lower a vowel's articulation, the higher F1 will be). The frequency of the second formant corresponds in large part to a vowel's advancement (the fronter a vowel is, the higher its value for F2 and the backer a vowel is, the lower its value for F2).[4] This relationship makes it possible to convert formant measurements into a graphical illustration of a vowel's position within the vowel space, as shown in illustration (11).

[4] The frequency value for F2 is also affected by lip rounding.

(11) Graph using measured F1,F2 values from illustration (10) *F2 is plotted along the x-axis (high F2=fronter vowel, low F2=backer vowel), and F1 is plotted along the y-axis (high F1=lower vowel, low F1=higher vowel).*



Here, F2 is plotted along the x-axis, and F1 is plotted along the y-axis. The values are plotted in reverse numerical order (the origin for the chart is in the upper right corner), which means the "front" of the vowel space is towards the left margin, and the "bottom" of the vowel space is towards the bottom margin. For example, from (11), we can see that on this occasion the speaker produced an [e] that is lower in articulation than the corresponding back vowel [o].

1.2.0.1 Factors Affecting Vowel Quality Identification

Given the description of vowel quality just discussed, it may seem that identifying a vowel's quality is a simple matter: For example, simply translate any F2 value of 1800Hz or higher into [+front], any F1 value above 700Hz into [+low], etc., etc.

However, things are not quite this easy. In this section, I will present some of the factors that can affect the identification of a vowel's quality.

Duration

In order to identify a vowel, first you have to (1) identify that there *is* a vowel in the speech stream to be identified, and (2) determine where its formants are. Both of these tasks can be thwarted in vowels with short duration. For example, Chistovich *et al.* (1976) find that a vowel in any consonantal context must have a duration of above approx. 40 ms. in order for a listener to reliably identify the *presence* of a vowel at that point in the speech stream, and must have a duration above approx. 70 ms. in order for its *quality* to be identified reliably. The importance of vowel duration for quality identification has two main bases. First, quality identification requires a certain minimum stimulus—if a listener does not have an adequate amount of vowel, he/she simply might not have enough information to identify where the vowel's formants lie. Second, the quality of a vowel can be perturbed by various factors, including most significantly it's consonantal environment. As mentioned earlier, Lindblom (1963) and Moon and Lindblom (1994) hypothesize that vowel undershoot is caused by displacement of a vowel's articulation towards that of surrounding consonants—contextual vowel-consonant coarticulation causes a vowel to become "colored" by adjacent consonants. For example, Bondarko (1979) reports that Russian native speakers can correctly identify the quality of a stressed vowel excised from the speech stream just about 100% of the time, even when the vowel quality has been strongly influenced by neighboring palatalized consonants. On the other hand, she reports that the corresponding accuracy rate for identification of the (surface[5]) quality of excised unstressed vowel qualities varies from 20% to 40%.

Vowel Quality

The actual quality of a vowel can also affect its identification. In particular, the peripheral vowel qualities [i,u,a], which inhabit the corners of the articulatory vowel space, seem to be more readily identified than non-peripheral vowel qualities. For example, the formant structures associated with these vowels show *extremes* in formant location, which makes their formant structure describable in terms that don't depend on actual frequency values: the quality [i] always has the first two formants maximally separated, [u] has the first two formants close together and low, and [a] has the first two formants close together and high. These can be important cues to quality, since actual formant frequency values for different vowels vary from person to person.

In addition to their distinctive formant patterns, the peripheral vowels [i,u,a] also benefit in terms of perceptibility from their actual locations within the vowel space. For example, in a typical 5-vowel system, the vowels [i,u,a] are directly in contrast with only two other vowels: [i] directly contrasts with its immediate neighbors [e,u], [u] contrasts with [i,o], and [a] contrasts with [e,o]. In contrast, the non-peripheral vowels enter into a

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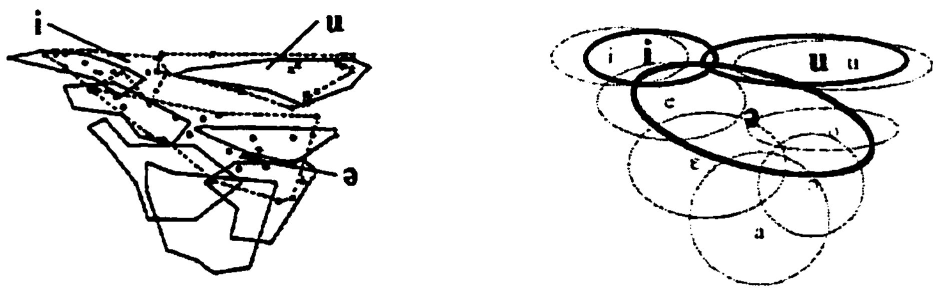
[5] Subjects were not expected to guess the underlying phonemic category of the unstressed vowel, since for

higher number of direct contrasts: [e] contrasts with its immediate neighbors [i,o,a]; [o] contrasts with [u,e,a]. Since the non-peripheral vowels enter into more contrasts, they also enter in more *possible confusions*. This is an important point, since the distribution of vowel qualities within the vowel space often overlaps. Consider, for example, the following vowel plot of Catalan stressed vowels. (The figure on the left is from Recasens (1986), and the figure on the right was produced by superimposing ellipses over the original figure.)

(12) Catalan Stressed Vowels—*Left: Measured Values (Recasens 1986), Right: Distributions as Ellipses (approximate)*



Note, in particular, that the peripheral vowels (especially [i] and [u]) are easily separated out—their distributions are fairly distinct from those of other vowels. In contrast, the distributions of the mid vowels [e,o,ɛ,ɔ] are more congested and overlapping. Lindblom (1986) has referred to the idea that vowels prefer not to overlap using the idea of *dispersion*: the vowels of a language will tend to space themselves out in the vowel space in a manner that maximizes the minimum distance between any pair of vowels in the

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example, both underlying /e/ and /i/ give rise to surface [i].

system. A three-vowel system consisting of the peripheral vowels /i,u,a/ displays *maximal dispersion*, since the acoustic distance between the vowels of this system is limited only by physiological constraints (the size of the articulatory vowel space).

Featural Enhancement

Formant structure can be affected by characteristics other than vowel height and fronting. For example, lip rounding and tongue root advancement/retraction are two factors which can also affect formant frequency: Lip rounding causes lowering of F2 (and F3), while tongue root advancement causes lowering of F1. In general, combinations of gestures that have the same or similar effect on formant frequencies are preferred, while combinations of gestures with opposing acoustic correlates are dispreferred. For example, front round vowels like [y] are dispreferred, since fronting raises F2, but rounding lowers it; high tense vowels are preferred since both tongue root advancement and high tongue posture lower F1. These relationships are sometimes referred to as *acoustic enhancement*: the combination of features with similar acoustic correlates reinforces their perceptual salience. For example, a back round vowel sounds backer than a back non-rounded vowel, and a high tense vowel sounds higher than a high lax vowel.

1.2.0.2 Summary: Vowel Perception

The main points made in this section are that vowels are identified by their formant structure, that accurate identification of vowel quality is enhanced by increased duration and by featural combinations that are mutually enhancing, and that peripheral vowels are less confusable than non-peripheral vowels.

1.2.1 Vowel Production

The articulators that are the most important for producing different vowel qualities are the tongue, the lips, and the jaw. These articulators execute the gestures necessary for the correct implementation of lip rounding, tongue raising or lowering, and tongue advancement. In particular, changes in the position of the lips producing rounding, changes in the position of the tongue produce fronting and backing, and changes in both tongue position and jaw position jointly affect tongue height. However, when it comes to the articulation of vowels, not all of these articulators behave in a similar manner. In this section, we will look at the behavior of the jaw in the articulation of vowels in particular.

1.2.1.0 The Jaw and Inherent Duration

As mentioned above, changes in tongue height can be effected by a combined effort of the tongue and the jaw. That is, the tongue can be raised/lowered either actively or passively. The muscles that make up the tongue can cause changes in its height—this type of lowering/raising is an active change in tongue height. Since the tongue is attached to the jaw, raising or lowering the jaw will also raise or lower the tongue (all else being equal)—this causes passive changes in tongue height. For example, in a description of

Standard Bulgarian, Pettersson and Wood (1987a, 1987b) report that high vowels and schwa are produced with a non-lowered jaw and that mid and low vowels are produced with a lowered jaw. At the same time, the high and mid vowels are reportedly produced with a raised tongue while low vowels and schwa are not. According to their discussion, the terms "high" and "low" originally referred to (active) tongue raising or its absence, while "open" and "close" originally referred to jaw lowering or its absence. However, in modern usage, the terms "high", "mid", and "low" are used simply to refer to absolute tongue position, without reference to the type of articulatory gesture used to achieve it, and the terms "open" and "close" are largely unemployed.

The use of jaw opening to achieve a low tongue position has an effect on both the duration and amplitude of a vowel. As reported by Lehiste (1970), it is purportedly a surface-true generalization that low vowels have greater inherent duration than mid vowels, and that mid vowels in turn have a greater inherent duration than high vowels. Lehiste suggests that the basis for this is physiological: The articulation of lower vowels is simply allowed to take more time. Presumably, this is linked to the fact that lower vowels are normally produced with more jaw opening than are higher vowels. This observation seems to be tied to the idea of the phonological sonority hierarchy, in which lower vowels are more sonorous than higher vowels and vice versa.

It has been suggested that jaw position can be used to account for sonority in general (i.e., in consonants as well as vowels). Under this hypothesis, highly-sonorant consonants like /j,w/ or /l,m/ would be predicted to have a lower jaw position than low-sonority consonants like /s/ or /k/. However, investigations of the jaw position of consonants (cf. Keating 1983, Malsch and Fulcher 1989) disconfirm these predictions. Nathan (1989) suggests that sonority in general is actually a multivariate phenomenon (i.e., that sonority is affected by amplitude, duration, absence vs. presence of formant structure, etc.). However, whatever the case is *in general*, in the particular case of vowels, jaw position seem to correspond well to the traditional idea of sonority. (This would explain why [ə], sometimes considered a mid vowel, is at the low end of the sonority hierarchy: It has a close jaw position.)

1.2.2 Phonetic Cross-Linguistic Variation

Finally, it should be noted that different languages vary with respect to the degree they do or do not instantiate the patterns described above. For example, a survey of phonetic vowel reduction by de Graaf (1987) demonstrates that not all languages show the same amount of vigor in realizing vowel qualities in faster speech tempos. Similarly, a discussion of phonetic vowel inventories in Lindblom (1986) demonstrates that although dispersion is a universal tendency cross-linguistically, it is not given the same priority in all languages. Finally, data cited in Lehiste (1970) (from a variety of researchers) shows that although inherent duration patterns are apparently universally observed, the relative ratio of the duration of different vowel qualities is not constant cross-linguistically. This is parallel to the cases of phonetic (i.e., gradient) consonant lenition discussed by Kirchner (1997): Although many (perhaps all) languages possess some degree of consonant lenition intervocalically, languages vary with respect to the extent this phenomenon is realized. Some languages may have rampant phonetic, gradient consonant lenition at all speech tempos, while others might show significant lenition only in fast speech. Kirchner proposes to account for this fact by positing that phonetic (gradient) phenomena are computationally governed. In other words, different languages place different values on the opposing desiderata of accuracy of articulation and ease of articulation, and children acquiring a specific language must adjust their computational phonetic mechanism to properly generate the patterns of the ambient language. Kirchner's computational phonetic system relies on a series of transparent constraints on ease of production and accuracy of articulation. In the following chapters, we shall see how the same two principles can also be used to account for phonological vowel reduction phenomena. A child who knows something about one (fairly transparent) area of language can use this information to figure out a less-transparent area. In the case of the acquisition of phonology, a child can use her understanding of phonetic universals to account for more opaque, language-specific phonological processes.

1.3 Theoretical Background

1.3.0 Optimality Theory

The theoretical framework that I use for analyzing vowel reduction is Optimality Theory (McCarthy and Prince 1993, Prince and Smolensky 1993). This section presents an overview of Optimality Theory for those readers who are unfamiliar with this framework.

Optimality Theory (OT) is a non-rule-based approach to phonology. As in other generative approaches to phonology, a linguistic form in OT has an *underlying representation* and a *surface representation*. The underlying representation must be inferred by each language-learner through contact with other speakers of the language; the surface representation is generated from it by the speaker—this is the process that phonological analyses try to model. In OT, the underlying representation is referred to as the *input*, and the surface representation is referred to as the *output*. In a rule-based theory of phonology, the input (underlying) form is converted to an output (surface) form by the application of specific procedures, often ordered with respect to one another. In OT, no specific procedures are necessary. Instead, an input form is subjected to any and all imaginable sound substitutions or alterations, in various permutations.[6] This generates a pool of *candidate outputs*. Within this pool of candidate outputs, there is one—the *optimal candidate*—which will actually be chosen as the correct surface form. When discussing OT analyses for specific sound patterns, only those candidate outputs that are considered relevant are explicitly considered in the text (i.e., candidate outputs that obviously don't have a chance are not considered). For example, with respect to vowel reduction, the candidate pool to be considered would contain variations where an underlying unstressed vowel quality is replaced with any and all possible alternative vowel qualities. This is demonstrated below for a hypothetical underlying form /tobát/:

Input:	/tobát/	Candidate Outputs:	[tobát]
			[tubát]
			[tabát]
			[tɔbát]
			[tebát]
			[tibát]
			[təbát]
			[tɯbát]
			[bəbát]
			... etc. ...

Of course, not all of these candidates are reasonable—in an analysis of an actual language where /tobát/ occurs underlyingly, the final candidate listed—[bəbát]—would probably not be mentioned, because it is uninteresting to explain *why* the initial /t/ should not

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[6] Actually, this is a expository simplification. It is now usually assumed that a pre-generated pool of candidate outputs already exists, and that this pool contains all imaginable phonological strings. The same pre-generated pool is used each time.

change to [b]. Similarly, the second-to-last candidate—[tɯbát]—would probably only be mentioned if the language in question actually utilizes the vowel [ɯ].

Once the candidate pool is identified, the optimal candidate is chosen by a series of ranked *constraints*. A constraint can be thought of as a distilled phonological ideal—a "motivating factor" for some sound change or other. Typically, a constraint is stated in terms of what an ideal surface form *should* be like. This is why OT lacks rules—instead of specifying what you should *do* to a form, OT simply specifies what the end result should *sound like*. Once the constraints that are necessary for a given language are identified, each candidate output is evaluated with respect to each constraint. If a given candidate is in accord with the demands of a constraint, no action is taken and evaluation simply continues. If a given candidate is not in accord with the demands of the constraint, it is assigned a violation mark ("*") for that constraint, and evaluation continues. The standard assumption is that the evaluation of all the candidates in the pool happens simultaneously, so that all violation marks are assigned at the same time.

Once the violation marks have been assigned, various candidate outputs are eliminated from consideration until a single candidate remains. This candidate is deemed optimal, and is chosen as the correct surface form. Elimination occurs in accordance with *constraint ranking*. That is, all the constraints of a given language are arranged into a linear order, referred to as a ranking. Part of the analysis for a given phonological phenomenon is establishing the correct ranking for the constraints, based on observed output forms. Evaluation occurs as follows: for the constraint under consideration, only the best candidate(s) is/are retained—the rest are eliminated. If **all** non-eliminated candidates equally pass or equally violate a constraint, none are eliminated and evaluation simply moves on to the next constraint. Evaluation is usually graphically displayed using a *constraint tableau*, as shown below. In a constraint tableau, the candidate outputs to be considered are listed down the left-hand side of the tableau. Constraints are listed, in rank order, across the top of the tableau. The highest ranking constraint is shown at the left edge, and the lowest at the right. The underlying form is often listed in the upper left-had corner of the tableau. (N.B.—the constraints illustrated here ad-hoc inventions for expositional purposes only.)

input: /tobát/	NO UNSTRESSED MID VOWELS.	NO UNSTRESSED LOW VOWELS.	NO SCHWA.	NO UNSTRESSED HIGH VOWELS.
☞ [tubát]				*
[təbát]			*!	
[tabát]		*!		
[tobát]	*!			

In a tableau, the symbol "☞" indicates the optimal candidate, in this case [tubát]. As mentioned above, a "*" indicates that a candidate has violated a given constraint. In addition, the symbol "*!" indicates a fatal violation—a violation that causes a candidate to be eliminated from consideration. Note that the successful candidate violates the lowest-ranked constraint. However, since it is the last surviving candidate by that point, it is not a fatal violation. Shading in a tableau indicates that the cell in question is irrelevant for determining the optimal output (i.e., the candidate that belongs with that cell has already been eliminated).

It is assumed that all constraints are universal, but that their ranking varies language-specifically. These language-specific variations in ranking produce different phonological patterns—a grammar therefore consists of a language-specific ranking of universal constraints. For example, the constraint ranking shown in the tableau above derives the vowel reduction pattern /o/ > [u]. However, simply by reversing the ranking of the last two constraints, a different (and attested) pattern of vowel reduction is generated: /o/ > [ə], as shown below:

input: /tobát/	NO UNSTRESSED MID VOWELS.	NO UNSTRESSED LOW VOWELS.	NO UNSTRESSED HIGH VOWELS.	NO SCHWA.
☞ [təbát]				*
[tubát]			*!	
[tabát]		*!		
[tobát]	*!			

In the text of an analysis, the statement "Constraint A outranks Constraint B" may be written "Constraint A » Constraint B". This means that the ranking of constraints depicted in the tableau immediately above could also be represented as follows:

NO UNSTRESSED » NO UNSTRESSED » NO UNSTRESSED » NO SCHWA

MID VOWELS LOW VOWELS HIGH VOWELS

Also, it should be noted that it is possible for a candidate output to violate a constraint more than once if the candidate possesses more than one environment that is relevant for the constraint. For example, in a form with two unstressed syllables, it is possible to violate the constraint "NO UNSTRESSED MID VOWELS" two times—for example, the hypothetical form [totobát] would get two violation marks in the column for "NO UNSTRESSED MID VOWELS". In cases like this, only the form which violates the constraint the fewest times will be retained. Such a case is represented below:

input form	CONSTRAINT A	CONSTRAINT B	CONSTRAINT C
☞ Candidate 1	*	*	**
Candidate 2	*	**!	*
Candidate 3	*	**!	*
Candidate 4	*	**!*	*

In this case, all the candidate outputs equally violate Constraint A, so none of them are eliminated (none of them is "best" with respect to Constraint A). All the candidates also violate Constraint B—however, Candidate 1 violates it the fewest times, so it is retained and all the others are eliminated. Also note that Candidate 1 violates Constraint C more times than any other candidate. However, by this point, all the other candidates have been eliminated, so this does not affect the choice of the optimal output form.

When considering the phonology of a real language, quite a number of constraints are usually necessary. Oftentimes, it is not possible to determine the ranking of all the constraints with respect to each other. In such cases, it is assumed that all the constraints are ranked with respect to one another (producing a *linear* ordering of the constraints), but that we phonologists are only able to discern some subset of the rankings (meaning that phonologists will often model a phonological process using a *partial* ordering of constraints). In such cases, you might see a statement such as "Constraint A, Constraint B » Constraint C". This statement indicates that Constraint A is ranked above Constraint C, and Constraint B is ranked above Constraint C, but no ranking can be determined between Constraints A & B (meaning that changing the ranking between Constraints A & B will not alter the selection of the correct output form). In a constraint tableau, such a situation is often signaled by placing a dashed line between constraint columns if no ranking can be discerned between those two constraints. If constraints in adjacent columns *are* ranked with respect to one another, this is signaled by placing a solid line between those two constraint columns. This is demonstrated in the following tableau:

input form	CONSTRAINT A	CONSTRAINT B	CONSTRAINT C
☞ Candidate 1			**
Candidate 2	*!		
Candidate 3		*!*	

In this tableau, we know that both Constraint A and Constraint B must dominate Constraint C. This is so because the optimal candidate violates Constraint C, but it wins anyway. If Constraint A or Constraint B were ranked differently with respect to Constraint C, a different candidate would have emerged as the winner. However, we do not know the ranking between Constraints A and B. This is shown in the tableau by the dashed line separating the columns for Constraints A and B. It should be noted that additional data from the language in question might shed light on the ranking between Constraints A and B, making it possible to establish a ranking at some future point. But it is also possible that some constraints simply never conflict in such a way as to reveal a ranking—for example, a phonologist might be hard pressed to determine any ranking between the constraints NO UNSTRESSED MID VOWELS and NO EJECTIVE CONSONANTS IN THE CODA, simply because such constraints don't interact very much. In cases such as this where the data necessary to establish a ranking is missing, the ranking is said to be ***unlearnable***, and it is assumed that language learners are free to assume either ranking—resulting in a situation where two speakers of the same language might have grammars that are trivially different from one another. In such cases, the phonological analysis should be constructed in such a way as to mirror this fact—the selection of the correct output form should result from either possible ranking.

1.3.1 Commonly-Used Constraints

At this point in the history of Optimality Theory, quite a number of constraints have been identified, and many of these are standardly used and will be encountered in a number of analyses by various researchers. For the benefit of those who may be unfamiliar with the OT literature, a brief explanation of some of the most widespread constraints and constraint families will be given in this section, especially concentrating on three families of constraints which will be used in this survey: Faithfulness constraints, Output-Output Correspondence Constraints, and enhancement constraints.

Faithfulness Constraints: The Faithfulness constraint family is a group of constraints that all embody the idea that the output form should be similar to the input form. For example, Faithfulness constraints would militate against inserting, deleting, or modifying segments that occur in the input. Faithfulness constraints also ban changing the linear order of input segments (metathesis) and reducing or increasing the number of distinct input units (coalescence and dipthongization, respectively). Some standard names for Faithfulness constraints are as follows (based on McCarthy and Prince 1994, 1995, shown here with slightly different wordings):

MAX(segment): No segments should be deleted.
("max" is short for "maximality"—based on the idea that the output should contain the maximum possible number of input segments)

DEP(segment): No segments should be inserted.
("dep" is short for "dependence"—based on the idea that an output segment is similar to the dependent variable in a mathematical function, and as such may not occur unless it corresponds to some independent variable from the input)

LINEARITY: The segments of the input and the output should occur in the same linear order. (i.e., no metathesis)

UNIFORMITY: There should be a uniform number of distinct segments in the input and the output (i.e., no coalescence or dipthongization).

IDENT(feature F): An output segment and its correspondent in the input should have identical specifications the feature [F].
("ident" is short for "identity")

It should be noted that multiple IDENT constraints can occur in the same analysis, each one based on a different feature. For example, an analysis might use both IDENT(high) and IDENT(low). Also, it has been argued by Zoll (1996) that the MAX and DEP constraints need to be able to refer to feature specifications. In this view of feature-based faithfulness, IDENT constraints are not used. Instead, a featural change, such as the change of a [+high] specification to a [-high] specification is seen as two constraint violations—a violation of MAX[+high] (because an underlying [+high] has been deleted) followed by a violation of DEP[-high] (because an underlying [-high] has been inserted). For example, in a process where targetless, unspecified vowels are a possibility, MAX and DEP constraints for features may be required to correctly represent the fact that an underlying feature specification has been deleted, and not replaced with anything.

Output Correspondence Constraints: The Faithfulness constraints discussed above are actually couched in more technical terms within the OT literature. Technically, a *correspondence relation* is set up between the segments of the input and the output. For example, for the input/output pair from English /kæt/~[kʰæt] '*cat*', the following *correspondents* are identified: (k_{input},k^h_{output}), ($æ_{input}$,$æ_{output}$), (t_{input},t_{output}). So, a Faithfulness constraint like IDENT(voice) would compare the pair (k_{input},k^h_{output}) to make sure that both members of the pair have the same voicing status, which they do. (The same would be done for (t_{input},t_{output}).) If they did not have the same voicing status, a "*" would be assigned for the constraint IDENT(voice). For this reason, Faithfulness constraints are sometimes referred to as Input~Output Correspondence constraints.

A similar group of constraints—termed Output~Output Correspondence constraints—can also operate on the candidate set. In this case, however, the constraints do not compare a candidate output form with the input, but with a morphologically-related word. This type of constraint has been extensively used to model so-called cyclicity effects (see, for example, Benua 1995, 1997, Steriade 1996, and Kenstowicz 1995, among others). As an example, in Iberian Portuguese, certain unstressed vowels in *derived* words are immune to vowel reduction. More specifically, if the vowel is stressed in the simplex form of a verb, the same vowel is immune to vowel reduction in a related derived form, even if the vowel is no longer stressed. In other words, vowel reduction is blocked in order to mimic a quality of the *surface* form of a closely-related word. This particular phenomenon could be modeled using either of the following constraints (which are based on Steriade's and Benua's formalization for such constraints, respectively):

PU(vowel height): Members of a verbal paradigm should have similar surface realizations with respect to [vowel height]. (**PU** stands for "Paradigm Uniformity", Steriade 1996)

Ident-OO(vowel height): The output segment α (a segment in a candidate surface form) should have the same specification for [vowel height] as does its correspondent β (a segment in a morphologically-related surface form). (**Ident-OO** stands for "Identity-Output/Output", Benua 1997)

Enhancement Constraints: A number of different constraints have been proposed by different researchers that can be classed together under the description "enhancement constraints". These are constraints that favor the combination of features that acoustically enhance each other. For example, the features [back] and [round] have the same (or similar) acoustic correlates—therefore, it is mutually beneficial to both features if they co-occur, thus reinforcing one another's phonetic cues. Such featural-enhancement constraints have been proposed, for example, by Flemming (1997). An entire system of enhancement constraints has been developed by Archangeli and Pulleyblank (1993), who refer to them as *grounding conditions*: a constraint that seeks to combine phonetically similar elements or to disunite phonetically dissimilar elements is phonetically grounded. (Note that although Archangeli and Pulleyblank focus on articulatory grounding—i.e., the preferential combination of features that have similar gestural components and the dispreference for combining sounds with articulatorily opposing gestures—they also allow for perceptually-motivated grounding conditions.)

Another sort of enhancement constraint is embodied in the so-called Prominence Alignment constraints discussed by Prince and Smolensky (1993) and others. Although prominence-alignment constraints are not usually thought of as an enhancement constraint, they fit neatly under this rubric. A prominence-alignment constraint favors the combination of two categories (which can be segmental, prosodic, or suprasegmental) that both exhibit some sort of prominence. Traditionally, prominence alignment has been used to express the idea that segmentally prominent segments make good carriers of prosodic prominence (where segmental prominence equals sonority and prosodic prominence equals stress, syllabicity, or some similar concept). For example, Prominence Alignment is used by Prince and Smolensky in an analysis of Imdlawn Tashlhiyt Berber, where the relevant phenomenon involves the idea that low vowels make better syllable nuclei than do mid vowels, and mid vowels make better syllable nuclei than do high vowels, etc. Prominence Alignment has also been used by Kenstowicz (1994) to embody the idea that low vowels make better carriers of main stress than do non-low vowels, etc. (this was *apropos* the analysis of languages where sonorous vowels attract stress). The prominence alignment constraints used by these authors are written as follows, where "syllable margin" means a syllable onset or coda, and "syllable peak" means syllable nucleus.

*M/a: The vowel quality [a] does not make a good syllable margin.
*P/t: The consonant [t] does not make a good syllable peak.

These constraints are organized into inherently-ranked constraint families, based on the relative prominence of the segments involved. For example, the ranked constraint family shown below expresses the idea that [a] is the worst syllable margin possible, while segments of decreasing sonority make increasingly better syllable margins. (The idea of "better" and "worse" is expressed in terms of ranking: Since the constraint *M/a—"*[a] should not be a margin*"—is the highest-ranked constraint, it is also the constraint that is most important to avoid violating.)

*M/a » *M/e,o » *M/i,u » *M/l,r » *M/n,m ...etc.

These sorts of constraints can be thought of enhancement constraints in that all the types of "prominence" referred to in these analyses have the same phonetic cues: increased duration and increased amplitude. That is, stressed vowels are usually longer and louder than non-stressed vowels. Syllabic segments are usually longer and louder than the same segment found in a non-syllabic role. Sonorous vowels are longer and louder than a similar less-sonorous vowel (Lehiste 1970). In other words, the combination of different prominence categories (stress, syllabicity, sonority) produces a combined effect that is extremely long and loud, thus mutually enhancing the percept of duration and amplitude of each component element. It should be noted here that the idea of "sonority" is not well-defined. Some (cf. Hankamer and Aissen 1974) have suggested that the sonority scale is open to language-specific modifications, since sonority sequencing effects in syllabification can vary from language to language. Rather than addressing this problem here, I will simply point out, as mentioned above in section 1.2.1.0, that at least for vowels, sonority relations seem fairly universal cross-linguistically. (That is, disagreements about the organization of the sonority hierarchy really only pertain to the relative sonority of consonants.)

1.3.2 Vowel Features

Optimality Theory can be used with any set of phonological features. For example, McCarthy and Prince (1993) and Prince and Smolensky (1993) use a fairly traditional articulatory feature set similar to that used in Chomsky and Halle (1963). Flemming (1997) uses OT with both articulatory and acoustic feature sets. Many authors have recently begun using articulator-based feature systems such as that of Clements (1989) or Clements and Hume (1995). The analysis of vowel reduction in OT is not a very probative case for deciding between different phonological feature sets. Almost any feature set that allows reference to the usual natural vowel classes seems to be adequate for purposes of vowel reduction. For easy interpretation of my constraints and other theoretical discussion, I have chosen to use the familiar articulatory vowel features [front, high, low, round, ATR]. However, it should be noted that the same theoretical results discussed in this study could equally well be derived using other feature sets. The feature specifications that I am assuming in this study are given below for those vowels that are most commonly referred to in the following chapters:

(13) Assumed Feature Specifications

	i	e	a	o	u
high	+	-	-	-	+
front	+	+	Ø	-	-
low	-	-	+	-	-
round	-	-	Ø	+	+

In addition, I assume that the vowels [ɛ,ɔ] are specified [-ATR], while their tense counterparts [e,o] are specified [+ATR].

1.3.3 Moraic Theory

The moraic theory that I adopt here is basically that of Hayes (1989, 1994), McCarthy and Prince (1986), Hyman (1985) and other authors working within a similar framework. This type of moraic theory differs from the classical Trubetskojan view in several ways—indeed, this may be the reason why Hyman (1985) refers to his prosodic units not as "moras" but as "Weight Units" (WU's), or simply "timing units" or "beats", although he notes in the introduction that these units "to some extent, correspond to the traditional notion of the 'mora'". For example, in Trubetskoj (1939/1969), the mora occurs only in "moraic languages", while "syllabic languages" employ the syllable nucleus (rather than the mora) as the smallest unit of prosody. In the moraic theory of Hayes, Hyman, etc., the mora is employed in a manner similar to the C/V timing slots of McCarthy (1981) or the X timing slots of Levin (1985): It is a universal prosodic unit that occurs in all languages between the levels of syllable and segment. Languages may vary with respect to the number of tautosyllabic moras they tolerate: Syllables are uniformly monomoraic in quantity-insensitive languages, whereas quantity-sensitive languages tolerate syllables with two (or more) moras. In addition, this type of moraic theory allows phonological phenomena to introduce *surface* variations in mora count—for example, the phenomenon of weight-by-position in Hayes (1989) can create heavy (bimoraic) syllables in a language where they would not otherwise exist, and the phenomena of iambic lengthening and open-syllable lengthening can create surface long (bimoraic) vowels in languages that do not contrast long and short vowels phonemically (see, for example, the analyses of Hixkaryana and similar languages in Hayes 1994 or the analysis of Italian in Repetti 1989). This treatment of quantity-sensitivity contrasts with previous analyses. For example, de Chene and Anderson (1979) hypothesize that lengthening-via-mora-addition can occur only in languages which already possess a phonemic contrast between monomoraic short vowels and bimoraic long vowels, thus explaining why languages with compensatory lengthening phenomena are generally languages that also contrast V and V: underlying. However, Hayes (1989) points out that compensatory lengthening also exists in languages that do not possess phonemic vowel length. Based on Hayes' argumentation, the correct generalization is this: Surface long vowels can be created through mora addition only in languages that tolerate more than one tautosyllabic mora—regardless of the underlying moraic distribution of the language. In summary, then, moras as they are used here are not primarily contrastive units—they are timing units (or "timing slots") that are often (though not necessarily) used in determining phonemic length distinctions and in calculations of prosodic weight. Recent experimental phonetic work also suggests that phonological moras of the type adopted here may be referred to directly in the calculation of phonetic duration, although this calculation may be complex and language-specific (Port *et al.* 1987, Nagano-Madsen 1992, Hubbard 1995, Broselow *et al.* 1997)

1.4 Organization of this Study

Now that I have laid out the appropriate background materials concerning the definition of vowel reduction, the phonetic principles that will be called on in subsequent chapters, and the basics of Optimality Theory as my theoretical framework, I will proceed in the chapters that follow to present an analysis for phonological vowel reduction. As alluded to in this chapter, I will analyze only phonological forms of vowel reduction as defined in section 1.0.0, but my approach will be motivated by phonetic considerations of the type laid out in section 1.2. This motivation will take the form of phonetically-motivated constraints on vowel reduction—the precise complement of such constraints is elucidated in Chapter 2. In Chapter 4, I will discuss how the different patterns of vowel neutralization observed in the world's languages can be derived using this approach and these constraints. An in-depth case study concerning vowel reduction in Russian dialects is provided in Chapter 3 to show how the analysis works in a concrete case. Chapter 5 cleans up a few odds and ends concerning some common types of exceptions to vowel reduction (i.e., places where vowel reduction is blocked). Importantly, these seemingly problematic details offer strong support for the general approach to vowel reduction taken in the study. In Chapter 6 I consider some wider-ranging ramifications of my approach to vowel reduction—in particular, I investigate a possible link between certain types of vowel reduction and rhythm-type (i.e., syllable-timing, stress-timing, etc.). Chapter 7 presents an overview of previous theoretical approaches to vowel reduction, and compares them with the approach advanced here

Chapter 2 Motivating Reduction: The Constraint Set

"Under any conditions, anywhere, whatever you are doing, there is some ordinance under which you can be booked."
-ROBERT D. SPRECHT

2.0 Introduction

In this chapter, I will present a theoretical account of how vowel reduction works. My main claim is that vowel reduction has a bipartite motivation, reflected in the existence of two different constraint families to be used in the analysis of vowel reduction. One is perceptual, based on the idea of eliminating challenging perceptual categories from unstressed positions. The other is articulatory, based on the idea of eliminating vowels that prefer longer articulation times from positions that prefer shorter durations. Acknowledging the bipartite nature of vowel reduction is key to explaining the empirical facts, resolving reduction paradoxes, and fitting the typology to the data. In what follows, I will lay out the two constraint families, their phonetic motivations, and examples of how they work.

An additional point to be made is that the two constraint families alluded to above only identify the vowels to be eliminated by vowel reduction and the contexts in which they are to be eliminated. They do not, however, identify the method for eliminating them. My hypothesis, based on comparison of several vowel-reduction languages, is that patterns of neutralization are determined by the relative ranking of vowel-reduction constraints (of whatever ilk) with respect to faithfulness constraints. This idea is further explored in Chapter 4, where a factorial typology for vowel reduction is considered.

2.1 Contrast Enhancing Reduction

In contrast-enhancing reduction, difficult perceptual contrasts are avoided in all but the most favorable contexts, leaving a smaller number of grosser vowel contrasts in the remaining positions. Typically, this eliminates "bad" contrasts, and strengthens "good" contrasts, whence the description of this type of phenomenon as contrast-enhancing reduction.

2.1.0 Introduction to Contrast Enhancement

As discussed in section 1.2.0.1, not all vowel qualities are perceived equally well. Non-peripheral vowel qualities, vowels with counter-enhancing acoustic cues, and vowels that are of short phonetic duration are all cases where a listener may misperceive the intended vowel quality. From the speaker's point of view, it is undesirable for a vowel's quality to be misperceived—not merely out of charitable concern for the listener, but also out of selfish reasons: If you produce a vowel that is misperceived, you have expended articulatory effort in an ineffective manner. This approach is the basis for Steriade's (1994a,b) licensing-by-cue approach to phonological neutralizations: If a given contrast is in danger of being missed by the listener, why should the speaker go to the trouble of *producing* it? In other words, positional neutralizations based on the desire to avoid ineffectual expenditure of articulatory effort can be thought of as the grammaticalization of the speaker's preference to "not deploy a feature in positions where its defining [acoustic] cues are necessarily absent or diminished" (Steriade 1994a). There are two logical courses of action for a speaker who wants to avoid ineffectual articulation: (1) Don't say the vowel at all, or (2) Say a different vowel. In this study, I do not consider strategy 1 (vowel deletion), instead focussing on strategy 2 (vowel reduction). In the following sections, I will investigate several subcases of vowel reduction that result from this strategy.

2.1.1 The Use of LICENSING Constraints:

Before moving on to discuss cases of contrast-enhancing vowel reduction, let's take a moment to examine the type of constraints that will be used to formalize contrast-enhancing reduction. To account for contrast-enhancing vowel reduction, I will use LICENSING constraints—a non-faithfulness-based version of Steriade's (1994a) IMPLEMENT constraint family. (See also Steriade's (1994b) Positional Neutralization constraints, as well as the Stress-Prominence constraints used by Majors (1998) in the analysis of stress-dependent vowel harmony.) The form of a LICENSING constraint is as follows:

LIC-Q (β): The vowel quality Q is only licensed in context β.

Where F = any vowel quality or a natural vowel class
β = any context that enhances the accurate perception of Q

It should be underscored at this time that Licensing constraints are not members of the faithfulness constraint family. A constraint such as LIC-Q(β) will assign a violation mark for every instance of [Q] that occurs without β, irrespective of whether [Q] is underlying or inserted.

In this respect, Licensing constraints are similar to the grounding conditions discussed by Archangeli and Pulleyblank (1993). For example, drawing on the fact that [-ATR] and [+low] are enhancing features, they posit constraints of the type **ATR/Low**, which prohibits the [-ATR] feature specification to co-occur with a [-low] specification (i.e., [-ATR] vowels must be low). The Licensing constraints used here will use a similar approach, applying to both combinations of features (as in ATR/Low) as well as combinations of features with positions (such as stressed position). It should also be pointed out that Archangeli and Pulleyblank's motivation for the ATR/Low constraint (and, indeed, for most of their grounding conditions) is based on articulatory considerations: it is difficult to both lower the tongue and advance the tongue root. Put another way, retraction of the tongue root allows easier depression of the tongue body—thus [-ATR] and [+low] are *articulatorily* compatible. Archangeli and Pulleyblank also allow grounding conditions to refer to acoustic compatibility of the type discussed with respect to Licensing above, but their emphasis is usually on articulatory compatibility.[7] In the enhancement-based Licensing constraints used here, articulatory considerations do not play a role.

2.1.2 Predicting Patterns of Neutralization:

Finally, it should be noted that Licensing constraints only *motivate* vowel reduction: they do not specify the specific pattern of neutralization that will be implemented in order to avoid the dispreferred vowels. For example, a constraint such as LIC-mid(stress) simply tells us that mid vowels cannot be implemented in unstressed positions. It does not tell us whether unstressed mid vowels will be raised to the corresponding high vowel (e,o > i,u), or lowered (e,o > a). In fact, both patterns are attested cross-linguistically, as are asymmetric patterns where one mid vowel raises while the other lowers (e > i, o>a and e > a, o > u). The Lic-mid(stress) constraint could also motivate *deletion* of unstressed mid vowels. Based on a comparison of vowel reduction systems, I believe that the pattern of neutralization found in any given language is determined by the relative ranking of the LIC constraint with respect to various faithfulness constraints. For example, the ranking IDENT(hi), LIC-mid(stress) » IDENT(low) will generate a pattern of neutralization where unstressed mid vowels undergo lowering, since the change of /e,o/ to [a] maintains the underlying [-high] specification. Similarly, IDENT(low), LIC-mid(stress) » IDENT(hi) generates the opposite pattern—reduction via raising, since the change of /e,o/ to [i,u] maintains the underlying [-low] specification. In other words, we can think of contrast-enhancing reduction as motivating the adandoment of certain underlying qualities of an unstressed vowel in order

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[7] But see Casali (1998) for an argument that the acoustically-grounded approach to the relationship between [ATR] and [low] offers a superior account of certain vowel harmony facts.

to allow emphasis of certain others. For example, reducing unstressed /e/ to [i] abandons its underlying [-high] quality, but its underlying [-low] quality is emphasized. In a case such as this, the choice of [-low] as the feature to be emphasized and [-high] as the feature to be abandoned results from a high ranking of Ident(low) and a low ranking of Ident(high). This is demonstrated below for hypothetical input forms.

reduction via lowering

/totá/	LIC-MID	IDENT(hi)	IDENT(low)
☞tatá			* (o>a)
tutá		*! (o>u)	
totá	*!		

reduction via raising

/totá/	LIC-MID	IDENT(low)	IDENT(hi)
☞tutá			*(o>u)
tatá		*! (o>a)	
totá	*!		

In both of the patterns illustrated above, the motivation is the same—to get rid of mid vowels in unstressed positions. However, the method for achieving this goal is different. Additionally, by adding IDENT constraints for other vowel features, attested patterns of asymmetric vowel reduction can also be accounted for. These and other types of ranking arguments will be discussed in Chapter 4, where the matter or determining neutralization patterns will be discussed in more depth.

2.1.3 Types of Contrast-Enhancement

As noted in section 1.2.0.1, increased exposure to a vowel quality (in the form of increased duration of the vowel) increases the likelihood for correctly identifying *any* vowel feature. However, the features or feature combinations that are targeted in the contrast-enhancing reductions that I have identified are specifically those which present a listener with a perceptual challenge, especially in contexts of short duration. Due to this fact, many types of contrast-enhancing vowel reduction have non-phonological counterparts—i.e., various phonetic phenomena have the same (or similar) underlying motivations. These attested Licensing constraints are discussed below.

2.1.3.0 Enhancing Dispersion

Vowel reduction based on the elimination of nonperipheral vowels is attested in a number of languages. This type of reduction will be treated here as the result of a Licensing constraint focussed on nonperipheral vowel qualities: **Lic-Nonperiph.** Typically, in a five- or seven-vowel system, the elimination of unstressed nonperipheral vowels equates to elimination of unstressed mid vowels. Examples include: some Southern dialects of Russian (Avanesov & Orlova 1965, Stroganova 1965, Meshcherskii 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989), the Algueres dialect of Catalan (Recasens 1991), Bortzetierra Basque (Hualde 1991), and Bergün Romansh (Lutta 1923, Kamprath 1991), to name a few. Examples of this type of reduction are given below from the Native American language Luiseño (Munro and Benson 1973):

	Vowels Under Stress		Same Vowels Unstressed	
unstressed	tʃóka	‘to limp’	tʃukátʃkaʃ	‘limping’
/e,o/ raise	hédin	‘will open’	hidíki-	‘to uncover’
	tʃapómkat	‘liar’	tʃáʃpumkatum	‘liars’
unstressed	máha	‘to stop’	mahámhaʃ	‘slow’
/i,u,a/ do	kú·mit	‘smoke’	kumíkmiʃ	‘smoky colored’
not reduce	ʂú·kat	‘deer’	pá·ʂukat	‘elk’
	takítkiʃ	‘straight’	tá·kiʃ	‘stone for smoothing pottery’

As noted above, the method for neutralizing the unstressed mid vowels can vary from language to language—either lowering or raising can be used. Typically, this type of vowel reduction occurs in languages with 5-7 underlying vowel qualities ([i,u,e,o,a] or [i,u,e,o,ɛ,ɔ,a]), and produces a maximally dispersed 3-vowel inventory in unstressed positions: [i,u,a]. This draws a parallel between the vowel sub-inventory produced by Lic-Nonperiph and the full vowel inventories of some existing languages—as described by Lindblom (1986), this type of vowel inventory shows maximal dispersion.

It should be noted that contrast-enhancing vowel reduction based on the constraint LIC-Nonperiph is treated here as formally distinct from cases where the similar but less-dispersed inventory [i,u,ə] is produced via prominence reduction—this type of vowel reduction will be discussed in section 2.2.1.

It should be pointed out that Lic-Nonperiph only points out which vowels are to be avoided, and the contexts where they should be avoided. It does not, however, point out the method for avoiding them—a characteristic shared by all Licensing constraints. For example, Luiseño (illustrated above) avoids unstressed mid vowels by raising them to

/i,u/. In southern Russian dialects, unstressed mid vowels are avoided by lowering them to /a/. In the Bergün dialect of Romansch, mid vowels are avoided by raising the tense ones (/o,e/ > /u,i/) and lowering the lax ones (/ɔ,ɛ/ > /a/). As mentioned above in section 2.1.2, the method used to generate these and other patterns of reduction is the relative ranking of reduction constraints with faithfulness constraints—an approach discussed in more detail in chapter 4.

2.1.3.1 Eliminating Counter-Enhancement

As discussed in section 1.2.0.1, some combinations of vowel features are counter-enhancing, in that they require opposing acoustic correlates. One type of vowel reduction seeks to eliminate this sort of counter-enhanced vowel in unstressed positions. Two examples are discussed:

Lic[-low, -ATR]: In this type of vowel reduction, the lax mid vowels /ɛ,ɔ/ are eliminated in all but stressed position. This type of reduction is found in a number of languages, including standard Italian, the Valencia and North-Western dialects of Catalan (Recasens 1991), and in standard Brazilian Portuguese (pretonic syllables) (Dukes 1993, Redenbarger 1981). Examples of this type of reduction are given below from standard Italian:

	Vowels Under Stress		Same Vowels Unstressed	
unstressed ɔ > o	akkɔ́ʎʎere fɔ́ʎʎo	'to receive' 'page'	akkoʎʎɛ́nte foʎʎétto	'welcoming' 'slip of paper'
unstressed ɛ > e	bɛ́lla pɛ́ddʒo	'beautiful' 'worse'	belléttsa peddʒóre	'beauty' 'to worsen'
unstressed o *(no change)*	sóle bókka	'sunlight' 'mouth'	soleddʒáto bokkáʎʎo	'sunny' 'mouthpiece'
unstressed e *(no change)*	pélo réte	'hairy' 'net'	pelóso retícolo	'hairy' 'network'

All known examples of this type of vowel reduction involve neutralization of /ɛ,ɔ/ via raising to [e,o]. However, the opposite pattern is also theoretically possible. In fact, the lowering of unstressed /ɛ,ɔ/ to [a] occurs in the Bergün dialect of Romansh—however, since the tense mid vowels /e,o/ also undergo reduction in this language (to [i,u]), this seems to be a case involving LIC-Nonperiph (see above).

As pointed out by Archangeli and Pulleyblank (1993), [+low] and [-ATR] are mutually enhancing features in that they both produce similar acoustic correlates—both are associated with an increase in the frequency value for F1—in the case of [+low], this is caused by increased jaw opening (lowering the tongue), while in the case of [-ATR] it is caused by decreased tongue advancement. By the same token, [-low] and [-ATR] have opposing acoustic correlates—[-low] is associated with a decrease in the formant frequency value for F1, while [-ATR] is associated with an increase in this value—which makes [-low, -ATR] a counter-enhancing combination. In the cases mentioned above (Italian, Catalan, Brazilian Portuguese), the underlying vowels that possess this counter-enhancing feature combination are neutralized via loss of the [-ATR] specification, producing [-low, +ATR] vowels—which do not violate the constraint under consideration: LIC[-low, -ATR]. However, the contrapositive of this constraint should also be possible. This alternative is discussed in the following paragraphs:

Lic[-high, +ATR]: This type of reduction is based on the fact that [+ATR] and [-high] are counter-enhancing. That is, both raising the tongue and advancing the tongue root cause a decrease in the formant frequency value for F1—which means that [+high] and [+ATR] are enhancing features. Since [-high] involves an increase in the formant frequency value for F1, but [+ATR] involves a decrease, the combination [-high, +ATR] is dispreferred. Therefore, the constraint Lic[-high, +ATR] causes the elimination of the tense mid vowels /e,o/ in unstressed positions, while the lax mid vowels /ɛ,ɔ/ are not affected. This type of vowel reduction is numerically less frequent than elimination of unstressed /ɛ,ɔ/ (see above), but has nonetheless been reported in more than one instance. For example, unstressed /e,o/ reduce to [ɛ,ɔ] in the North-Eastern dialects of Brazilian Portuguese (Brakel 1985, Perrone and Ledford-Miller 1985); in various northern dialects of Russian unstressed /e,o/ reduce to either [i,ɔ] or [ɛ,ɔ]; and in Slovene unstressed /e,o/ reduce to [ɛ,ɔ] (Bezlaj 1939, Toporishich 1976, Lencek 1982). The Slovene pattern is illustrated below (data from Bidwell 1969):

	Vowels Under Stress		Same Vowels Unstressed	
unstressed ɔ (*no change*)	gɔ́:ra pɔ́:tɔk	'mountain' nom. sg. 'stream' nom. sg.	gɔré: pɔtó:ka	'mountain' gen. sg. 'stream' gen. sg.
unstressed ɛ (*no change*)	plɛ́:ma sɛ́:stra	'tribe' nom. sg. 'sister' nom. sg.	plɛmé:na sɛstré:	'tribes' nom. pl. 'sister' gen. sg.
unstressed o > ɔ	móʒ kó:st	'man' nom. sg. 'bone' nom. sg.	mɔʒjé: kɔstí:	'men' nom. pl. 'bone' gen. sg.
unstressed e > ɛ	ré:tʃ tsé:sta	'word' nom. sg. 'road' nom. sg.	rɛtʃí: tsɛsté:	'word' gen. sg. 'road' gen. sg.

(Note: the same neutralizations also occur in Slovene *monomoraic* stressed syllables, about which see section 2.1.4.0.).

As noted above, this type of vowel reduction is numerically less common than reduction based on Lic[-low, -ATR]. In fact, it may be the case that this type of vowel reduction is non-existent. For example, in an instrumental description of Slovene vowels, Lehiste (1961) finds that the neutralized vowels transcribed above as [ɛ] and [ɔ] are actually intermediate between non-neutralized /e/ and /ɛ/ or /o/ and /ɔ/. Further analysis of this type of vowel reduction must wait until more data can be uncovered on the precise nature of the neutralizations that exist in these languages.

2.1.3.2 Color Enhancement

Another rather uncommon type of vowel reduction is based on enhancing color distinctions (palatality and rounding). As noted, for example, by Donegan (1978), vowel color seems to be opposed to vowel sonority: the combination of extreme color and extreme sonority is vanishingly rare. This fact seems to be based on the fact that color requires a close jaw position, in order to achieve either narrowing of the front of the oral cavity (palatality) or extension of the lips (rounding)—either gesture is more difficult with a low jaw position. However, the fact that extreme color requires a close jaw position also means that extremely colored vowels will be phonetically quite short—close jaw position corresponds to low inherent duration. As pointed out by Steriade (1994), short duration inhibits correct perception of *any* vowel quality. This relationship between color, height, and duration seems to lie at the basis for several types of vowel reduction, and will be formalized using a licensing constraint that refers to the combination of color features (either [+round] or [+front]) and [+high]: **Lic[color, +high]/(stress).**

For example, in the now-extinct Native American language Gabrielino (Munro *in progress*) and Slovene (Lencek 1982), color features have a restricted distribution. In Gabrielino, high vowels and mid vowels are contrastive under stress, but in unstressed position the high vowels lower to the corresponding mid vowel (i.e., unstressed /i/ > [e], unstressed /u/ > [o]). In the Upper and Lower Carniolan dialects of Slovene (including colloquial standard Slovene), the high vowels /i,u/ neutralize to [ə].

This type of reduction might also occur in certain dialects of Italian, in which color distinctions are eliminated from all non-high vowels that occur in an unstressed syllable in the pretonic portion of the word (high and mid vowels > [ə], underling /a/ remains unreduced).

2.1.3.3 Reduction to Schwa

Finally, the last sort of contrast-enhancing vowel reduction to be discussed is based on the elimination of *all* vowel contrasts—reduction of the entire vowel inventory to [ə]. I will use the constraint Lic[*any F*] to derive this type of vowel reduction. Typically, this type of vowel reduction produces massive neutralization, with the indistinct vowel quality [ə] predominating in stressless positions.

If the vowel quality [ə] is represented phonologically as a vowel that lacks an articulatory target (i.e., a featureless vowel), aggressive neutralization of all vowels to [ə] can be interpreted as the elimination of all feature specifications in unstressed positions. This representation of [ə] has been adopted by several previous researchers, both for phonological reasons (cf., for example, Anderson 1982 on French schwa, or van Oostendorp 1998 on schwa in general) as well as phonetic reasons (cf. for example, van Bergem 1994 on Dutch schwa)[8]. For this reason, the vowel notated with the symbol [ə] will be given a different theoretical representation from that given the vowel notated with the symbol [ʌ]. The symbol [ʌ] will be used to represent a phonemic vowel of normal duration that can potentially bear stress (as is found, for example, in English or Bulgarian), and which is phonologically specified as mid central. The symbol [ə] will be used to represent an non-phonemic vowel that is typically very short and of indistinct quality, and which is *not* phonologically specified mid central (but which may be specified for a certain degree of jaw opening, as per Browman and Goldstein's (1992) suggestions).

This type of vowel reduction can be described as maintenance of only the contrast *presence of vowel* vs. *absence of vowel*—the underlying distinctions between different vowel qualities are forsaken. In other words, in this type of language listeners do not use the quality of unstressed vowels to aid in identifying a spoken word, and instead pay attention only to the fact that a vowel of some underlying quality appears in that position in the word.

2.1.4 What Contexts Can Act as Licensers?

Another question concerning Licensing constraints is this: What positions can be mentioned in these constraints as licensing contexts? As mentioned above, the environment used in a Licensing constraint must be one which somehow improves the likelihood for correct perception of the feature or feature combination in question. Up to this point, I have presented examples of vowel reduction under the simplifying assumption that all of them are based on the opposition stressed vs. stressless—i.e., that certain features are OK in stressed positions, but undergo neutralization in stressless positions. Now, I will demonstrate that this is only one of the available options.

The assumption made here is that stressed syllables can be used in Licensing constraints due to the extra (non-phonemic) length that is observed in stressed syllables—

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[8] See, however, Browman and Goldstein (1992) for a critique of this approach.

a phonetic fact which increases the duration of the vowel, and therefore gives a listener more acoustic information to use in identifying the vowel's quality. Indeed, it is interesting to note that those languages that have vowel reduction phenomena all seem to have duration as one of the primary acoustic correlates of stress—I have not found any examples of vowel reduction occurring in pitch-accent languages or in languages where accent is mainly amplitude-based. As it turns out, other contexts marked by increased duration can also be specified in Licensing constraints.

2.0.0.1. Primary Stress:

In some languages, Licensing constraints are sensitive to varying *levels* of stress. For example, in standard Italian, the distinction between /e,ɛ/ and /o,ɔ/ is maintained only under primary stress (Flemming 1995). Under both secondary stress and stresslessness, this distinction is neutralized. It has also been reported that in some dialects of Chamorro (Topping 1969, Topping Ogo and Dungca 1975), the distinction between /æ/ and /ɑ/ is maintained only under primary stress: under secondary stress they neutralize to a low central vowel [a], and under stresslessness they neutralize to [ə][9]. Such languages would use a constraint like LIC(-low, -ATR)/primary stress.

[9] This alternation is reported, for example, by Witucki (1973). She reports, however, that /æ/ and /ɑ/ neutralize to [æ] under 2ry stress rather than to [a]. Instrumental measurements from Saipanese Chamorro, however, indicate a vowel quality approximately midway between the two stressed vowel qualities—approximately [a] (which native speakers may find more similar to [æ].) Furthermore, these measurements also suggest that this alternation may be only partial. It is possible, however, that other speakers or other dialects show a complete merger.

2.1.4.0 Bimoraicity:

Of course, the ultimate in terms of increased duration is bimoraicity—phonemically long vowels offer an exceptionally long stretch of vowel that should provide more than ample amount of stimulus for quality identification. Indeed, there is evidence that suggests that unstressed bimoraic vowels in some language are immune to vowel reduction, while unstressed monomoraic vowels are not. This is the case, for example, in Eastern Ojibwa. In Eastern Ojibwa, unstressed monomoraic vowels reduce via centralization: unstressed /i/ and /a/ reduce to [ə], while unstressed /o/ reduces to a slightly rounded variant of [ə]. (Eastern Ojibwa only has three monomoraic vowel qualities: /i,o,a/). However, unstressed bimoraic vowels do not reduce. This suggests a constraint such as LIC(any F)/μμ, indicating that bimoraicity should be included in the inventory of possible licensing contexts available for LIC constraints.

However, this example of bimoraicity as used in a Licensing constraint is open to alternative analysis. For example, Miller (1972) suggests the possibility that all long vowels in Eastern Ojibwa bear some degree of stress. An example that is not open to such reinterpretation comes from Slovene. In this language, the mid vowels /e,ɛ/ and /o,ɔ/ are distinctive only for stressed, **bimoraic** vowels. For both stressed and unstressed **monomoraic** vowels, the opposition between mid tense and mid lax is neutralized; compare, for example, the words kmé:ta 'peasant' gen. sg., which has an underlying tense vowel, and nɔ́:ʒa 'knife' gen. sg,, which has an underlying lax vowel. When these vowels are shortened, both surface lax: kmét 'peasant' nom. sg. and nɔ́ʒ 'knife' nom. sg. The neutralization of /i,u/ > [ə] in various dialects of Slovene is also conditioned by monomoraicity, not stresslessness. In these two cases from Slovene, it is clear that the correct distinction for the alternations is not *stressed* vs. *unstressed*, but *long* vs. *short*.

It is also interesting to note that in some languages, vowel reduction is said to be blocked not only under stress, but also in absolute word-final position. This has been claimed, for example, for some speakers of Contemporary Standard Russian, as well as for the Trigrad dialect of Bulgarian. However, in both of these cases, observers have noted that this effect only occurs when the word-final vowel is subject to phrase-final lengthening (Stoikov 1963, Zubkova et al. 1985). A similar pattern is seen in most dialects of Bulgarian, including the standard dialect, where the vocative endings *–e* and *–o* are immune to vowel reduction due to the additional length with which they are pronounced (the vocative almost always being placed phrase-finally within an utterance). In these cases, it is possible to claim that the additional length found under phrase-final lengthening results from the addition of an extra mora—making these patterns open to analysis using LIC/μμ constraints. Although I will adopt this approach here, it should be emphasized that it is not a forgone conclusion that this structural analysis of phrase-final lengthening is correct. It could be the case, for example, that phrase-final position simply needs to be added to the list of potential licensing environments.

Finally, two other positions are sometimes described as blocking vowel reduction: hiatus positions (Russian, Catalan), and absolute word-initial position (Russian, Dutch).

However, I have only found these blocking positions to be active with respect to prominence-reduction, and they will be discussed in Chapter 5.

2.2 Prominence Reduction

The second major type of vowel reduction is prominence-reduction. In this type of vowel reduction, the segmental prominence (sonority) of unstressed vowels is reduced. This type of vowel reduction will be modeled using Prominence Alignment constraints, as discussed by Prince and Smolensky (1993).

2.2.0 Introduction to Prominence Reduction:

The main idea of Prominence Alignment is that different levels of prominence (sonority, syllabicity, stress) should line up, occurring on a single segmental locus. Similarly, non-prominent elements (non-sonorous segments, non-syllabics, non-stressed elements) should also accumulate into highly localized areas of non-prominence which will contrast well with the prominent areas of an utterance. Prominence reduction is a term initially used by Jiang-King (1996) to refer to the latter half of this phenomenon—the alignment of non-prominent elements. As described by Prince and Smolensky, Prominence Alignment/Reduction can basically be understood as an acoustic-enhancement type of phenomenon: elements with the same or similar acoustic cues are made to co-occur, mutually strengthening one another's phonetic realization. Thus, an utterance will consist of easily-recognizable areas of high prominence contrasting markedly with easily-recognizable areas of low prominence. Steriade (1994b) uses this idea with respect to vowel reduction processes, hypothesizing that diminishing an unstressed vowel's sonority makes it easier to correctly identify where the stress is located. In languages where stress placement is phonemic, this is a useful trait. However, Prominence Reduction also serves an additional purpose: the sonority of unstressed vowels is reduced simply to produce vowels that are more time-efficient, and which are therefore easier to produce in environments where time is limited. Therefore, reducing the sonority of unstressed vowels not only helps delineate the contrast stressed vs. stressless, but it aids in increasing articulatory ease. That is, as discussed in chapter 1, the articulation of the more sonorous vowels requires a greater degree of jaw opening. Assuming that speakers do not use quicker jaw depression gestures for more sonorous vowels, this means that lower vowels will require longer articulation times—indeed, highly sonorous vowels like [a] are consistently the vowels with the longest inherent duration. In unstressed syllables where duration is short, there may not be enough time for (unhurried) jaw opening.

2.2.1 Prominence Reduction in Bulgarian:

The jaw-opening interpretation of prominence reduction is well-suited, for example, to the analysis of Bulgarian vowel reduction. In most dialects of Bulgarian, step-wise raising of unstressed non-high vowels occurs: unstressed /a/ raises to [ʌ], while unstressed /e/ and /o/ raise to [i] and [u], respectively. (Note: in the pronunciation norm of Sofia and other western areas of Bulgaria, vowel reduction is weaker than in the eastern areas. In particular, unstressed /e/ is oftentimes immune to reduction, although unstressed /o/ and /a/ usually reduce—cf. Scatton 1984.) This has sometimes been a troublesome alternation from the point of view of generative phonology, since it cannot be analyzed as the elimination of any natural class of vowels. That is, this reduction process cannot be analyzed as the elimination of mid vowels or elimination of non-high vowels, since the reduction of unstressed /a/ produces the mid vowel [ʌ]—recall that in Bulgarian, /ʌ/ is a phonemic mid central vowel which is capable of occurring both stressed and unstressed.

The importance of jaw-opening for Bulgarian vowel reduction has been investigated by Pettersson and Wood (1987a, 1987b). They first verified the existence of neutralizing vowel reduction using spectrographic evidence—the formant frequencies measured for unstressed /e,o,a/ were found to coincide with those measured for the vowels /i,u,ʌ/, respectively. (It should also be recalled that the vowel neutralizations seen in Bulgarian are complete enough to be used in forming poetic rhymes—see chapter 1.) Using X-ray evidence (previously published in Tilkov 1970), they conclude that the vowel reduction changes seen in Bulgarian are not due to re-organizations of tongue posture, but to the elimination of jaw opening. That is, they claim based on the X-ray evidence that unstressed /e/, /o/ and /a/ in Bulgarian maintain the same (non-contrastive) tongue postures that are characteristic of their (respective) pronunciation when stressed, but take on a high jaw position when unstressed—i.e., a height similar to that seen for the vowels /i/, /u/, and /ʌ/. For example, they describe the tongue postures used for Bulgarian stressed /i/ as being more bunched and tense, while the tongue postures used for Bulgarian stressed /e/ are more flat and lax—a distinction that was preserved in unstressed syllables, despite the fact that they all had the same acoustic quality ([i])[10]. On the other hand, they describe the vowels /e,o,a/ as having on average 4 mm more mandible depression when stressed than did the stressed vowels /i,u,ʌ/. In other words, the change from an underlying *e*-quality to a surface *i*-quality was not brought about by actively raising the tongue, but by passively raising it by decreasing the amount of jaw opening, thus creating a high front vowel—with similar changes in jaw position accounting for the changes /o/ > [u] and /a/ > [ʌ].

Since opening the jaw is a somewhat slow procedure (in comparison with tongue gestures), these changes have the effect of replacing the time-greedy vowel qualities /e,o,a/ with more time-efficient qualities [i,u,ʌ], while still being faithful to the tongue postures used for the underlying vowel qualities. Bulgarian vowel reduction can therefore be analyzed using the following Prominence Reduction constraint:

> *UNSTRESSED/NON-HIGH: An unstressed syllable may not contain any vowel with sonority greater than that of [i] or [u].

If sonority is equated for purposes of vowel reduction with jaw opening, then the Bulgarian vowel [ʌ] should be considered to be of a sonority equal to that of [i,u]: the X-ray evidence examined by Pettersson and Wood indicate that the vowels [i,u,ʌ] in Bulgarian all have the same degree of jaw opening. (However, see Keating (1983),

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[10] It is interesting to note that the reduced /e,o/ differ articulatorily from unstressed /i,u/ in the manner described. This observation might be accounted for by the observations by Perkell & Cohen (1989) that the vowel qualities /i,u,a/ show quantal effects: i.e., these qualities can be produced by a range of slightly-differing articulatory configurations.

Nathan (1989), and Malsch & Fulcher (1989) for some arguments on why sonority in general cannot be equated simply with jaw opening.)

2.2.2 Prominence Reduction in Sri Lankan Portuguese:

Another interesting case of vowel reduction via prominence-reduction comes from Sri Lankan Portuguese Creole (Smith, 1978). In this language, all vowels under stress are long. When stress shifts to a different syllable, the vowel shortens. For example, the long stressed mid vowels in *ó:j* 'eye' and *tʃé:ru* 'fragrance' correspond to short mid vowels in *ojá:* 'to see' and *tʃerá:* 'to smell pleasant'. However, if the stressed vowel is low, it not only shortens, but also raises to the corresponding mid vowel, as shown in the data below. This presents a case where low and mid vowels are contrastive under stress, but are neutralized (in favor of the mid vowels) when not under stress.

	Low Vowels Under Stress		**Same Vowels Not Under Stress**	
unstressed ɒ > o	ɒ́:brə	'profession'	obré:ru	'manual worker'
	nɒ́:mi	'name'	nominá:	'nominate'
unstressed æ > e	pǽ:dərə	'stone'	pedriyá:du	'ornamented with stones'
	fǽ:ru	'iron'	feréru	'blacksmith'
unstressed a > ə	bá:jlu	'dance'	bəjldó:r	'dancer'
	bá:rvə	'beard'	bərvé:ru	'barber'

To account for this type of vowel reduction, the following Prominence-Reduction constraint must be used:

> *UNSTRESSED/low: An unstressed syllable may not contain any vowel with sonority equal to that of a low vowel.

In this language, the only low vowels are vowels /a,ɒ,æ/. When not under stress, the sonority of the three low vowels is reduced by replacing them with a mid vowel of the same palatality and rounding, which has the result of neutralizing /ɒ/ and /o/ on the one hand, and /æ/ and /e/ on the other. (The vowel [ə] is not phonemic in this language, so the change of /a/ to [ə] is not neutralizing, although this change also occurs.) Like the Bulgarian prominence reduction phenomenon, the Sri Lankan Portuguese process reduces a vowel's sonority while remaining faithful to other underlying features.

There are a number of other languages which also utilize prominence reduction in unstressed syllables. However, most of them combine prominence reduction with contrast-enhancing vowel reduction—producing a vowel reduction pattern with two separate sets of neutralizations that occur in unstressed positions. This type of vowel reduction language is discussed in the next section.

2.3 Summary of Vowel Reduction Types

In the preceding two sections on contrast-enhancement and prominence-reduction, several different types of vowel reduction were discussed. I present here a summary of these types of vowel reduction:

Types of Contrast-Enhancement	
color-bearing high vowels (low inherent duration) mid lax vowels (counter-enhancing features) mid tense vowels (counter-enhancing features) nonperipheral vowels (not maximally distinctive) all vowels	Any stressed syllable A syllable with *primary* stress Bimoraicity (and possibly word-final position)

Theoretically, a Licensing constraint could involve any combination of one item from the left column, and one from the right. The commonalities expressed in this table are: things that might need licensing are those things which might be misperceived; those things which can do licensing are those which provide greater-than-average duration.

Types of Prominence Reduction	
long vowels (V:)	Syllables without stress
low vowels (a,æ)	Syllables without primary stress
non-high non-tense vowels (a, æ, ɛ, ɔ)	Vowels without moras
non-high vowels (a, æ, ɛ, ɔ, e, o)	Vowels with only one mora
	Non-syllabic segments

As discussed above, a prominence-reduction constraint militates against combining segmentally prominent (i.e., sonorous) vowel qualities with prosodically non-prominent positions. Theoretically, a prominence-reduction constraint could involve a combination of any group of sonorous vowels from the left-hand column, and any non-prominent prosodic position from the right-hand column.

In comparing the two tables provided above for contrast-enhancement and prominence-reduction, it is clear that they can target some of the same prosodic positions, although there are some differences as well. Since both types of constraint have several options open to them for their "conditioning environments" (the right-hand columns), it is possible for the two types of vowel reduction to co-occur. This is discussed in the next section.

2.3.0 Two Pattern Vowel Reduction Systems:

In some vowel-reduction languages, there are two sets of neutralizations that occur in unstressed syllables. One, typically a "moderate" form of reduction, takes place in certain unstressed syllables, while a more "extreme" form of reduction takes place in the remaining syllables. This is the case, for example, in most dialects of Russian. In this language, unstressed /o/ and /a/ neutralize—in the syllable immediately preceding the stress, this generates the surface vowel quality [a], while in other unstressed syllables it generates the surface quality [ə]. This is demonstrated below with data from standard Russian (the relevant vowels are underlined):

in stressed σ		in immediately pre-stress σ		in other unstressed σ		gloss
dóm	nom. sg.	damá	nom. pl.	dəmavój	adj.	'house'
góləvu	acc.	galófka	diminutive	gəlavá	nom. sg.	'head'
kámʲinʲ	nom. sg.	kamʲnʲéj	gen. pl.	kəmʲinʲístəj	adj.	'stone'
dálʲiji	comp.	dalʲókʲij	adj.	dəlʲikó	adverb	'far'

A similar pattern is seen in some southern Russian dialects, where unstressed /e/ and /o/ both neutralize to [a] in the syllable immediately preceding the stress, but reduce either to [i] (for underlying /e/ and for underlying /o,a/ preceded by a palatalized consonant) or to [ə] (underlying /o,a/ elsewhere). Other such patterns are found in Rhodope Bulgarian dialects (Miletich 1936), southern Italian dialects (Maiden 1995), and standard Brazilian Portuguese (Dukes 1993, Redenbarger 1981), to name a few. These patterns are described in the table below:

Language	**"Moderate" Reduction**	**"Extreme" Reduction**
southern Russian	Unstressed /e,o/ both neutralize to [a] in the syllable immediately preceding the stress.	In all remaining unstressed syllables, /o,a/ reduce to [ə] (or [i] following a palatalized consonant) and unstressed /e/ reduces to [i].
Contemporary Standard Russian	Unstressed /o/ neutralizes to [a] in the syllable immediately preceding the stress	Unstressed /o/ and /a/ neutralize to [ə] in the remaining unstressed syllables.
Rhodope Bulgarian	Unstressed /e/ and /o/ both neutralize to [a] in any syllable preceding the stress	Unstressed /e/ and /o/ neutralize to [i] and [u], respectively in post-tonic positions. In the same contexts, unstressed /a/ neutralizes to [ʌ].
Southern Italian	All unstressed vowels *except /a/* neutralize to [ə] in any syllable preceding the stress.	*All* unstressed vowels neutralize to [ə] post-tonically.
Standard Brazilian Portuguese	Unstressed /ɛ,ɔ/ neutralize to [e,o], respectively, in unstressed non-word-final and non-word-initial syllables.	Unstressed /ɛ,e/ and /ɔ,o/ neutralize to [i] and [u], respectively word-final and word-initial unstressed syllables. Also, unstressed /a/ becomes [ə].

The "extreme" vowel reduction processes share some common features. First, the type of neutralization seen in "extreme" reduction is always sonority-decreasing—in contrast with the "moderate" reductions, which can be sonority-increasing (cf. the Russian and Bulgarian change of unstressed /o/ to [a]). Second, they occur in those syllables that happen to be the most durationally-impoverished syllables in a particular language. This fact makes it possible to identify "extreme" vowel reduction as a case of neutralization caused by prominence-reduction, while the changes seen in "moderate" reduction can be ascribed to contrast-enhancing reduction. An interesting parallel that can be drawn at this point is that contrast-enhancing reduction can occur in either stress-timed (English) or syllable-timed languages (Italian), but prominence-reduction appears to occur only in stress-timed languages. Based on evidence from various languages with vocalic prominence-reduction phenomena, I conclude that "extreme" reduction (a form of prominence reduction found in two-pattern systems) occurs in syllables that are identified moraically—i.e., in those syllables that are *nonmoraic*. This opens up the possibility of defining stress-timing and syllable-timing moraically—an approach that will be explored in more detail in chapter 7.

2.3.1 The Contexts for Extreme Vowel Reduction:

As noted above, the contexts for "extreme" vowel reduction comprise the most durationally-impoverished syllables found in a given language. Put another way, the "moderate" vowel reductions are only found in those unstressed syllables which have slightly greater duration than the others. Two examples—standard Russian and Brazilian Portuguese—are discussed in the paragraphs below.

The immediately pretonic syllable in Russian has long been recognized as having a special durational status—it is much longer than other unstressed syllables, and can sometimes even be longer than the stressed syllable (this is often the case, for example, with words where the stressed vowel has a low inherent duration ([i,u]), and the immediately-pretonic vowel has a high inherent duration ([a]).) This difference in the duration of Russian unstressed syllables is significant enough to have been accurately noted by ear and described by 19th-century Russian grammarians such as Potebnja (1865). This phenomenon is also easily observed indirectly when listening to Russian speech: at conversational speech tempos, non-immediately pretonic unstressed vowels are often completely or near-completely elided, but immediately pretonic ones are immune to this process. For example, the word /xoroʃó/ '*good*' is often pronounced [xraʃó], but not *[xərʃó] or *[xrʃó].

The special durational status of Russian immediately pretonic syllables has also been confirmed experimentally a number of times (see, for example, Zlatoustova 1981). Investigators have also noted a link between this type of durational effect and the presence vs. absence of varying degrees of vowel reduction in Russian dialects (Vysotskii 1973, Al'mukhamedova & Kul'sharipova 1980, Kasatkina et al. 1996, etc.). For example, in a certain group of north-central Russian dialects (the Vladimir-Volga Basin group), the immediately pretonic syllable has the same special durational status that is seen in Contemporary Standard Russian—similarly, in those dialects the immediately pretonic syllable also has a special status with respect to vowel reduction, in that all other unstressed syllables are subject to vowel reduction, but the immediately pretonic one is immune (i.e., unstressed /o/ remains [o]). In another case, the immediately pretonic syllable in certain southern Russian dialects predictably displays either "moderate" reduction or "extreme" reduction. As shown by Kasatkina et al. (1996), this predictable variation in vowel reduction pattern is accompanied by changes in prosody—when the immediately pretonic syllable displays "moderate" reduction, this syllable has relatively longer duration; when it displays "extreme" reduction, it has a duration about equivalent to that of the other unstressed syllables.

A similar situation is seen in standard Brazilian Portuguese. For example, in instrumental work by Major (1980), it was found that post-tonic syllables in Brazilian Portuguese undergo greater shortening than do pretonic syllables. Based on this and other evidence, Major hypothesizes that the post-tonic syllables in Brazilian Portuguese are stress-timed, while the pretonic syllables are syllable-timed. I will assume here that this is equivalent to saying that post-tonic syllables in Brazilian Portuguese can be nonmoraic, while pre-tonic ones cannot. (This will be expanded on in Chapter 6.) Major also suggests that this dichotomy in the durational properties of pre- and post-tonic unstressed syllables is related to the two different vowel reduction patterns seen in this language, although in a way that is slightly different from the relationship hypothesized here—Major hypothesizes that the sonority-decreasing vowel neutralizations seen post-tonically (ɛ,e>i; ɔ,o>u; a>ə) exist in order to heighten the effect of the post-tonic shortening. Since Major also observed some shortening pretonically (i.e., in faster speech tempos), he suggests that Brazilian Portuguese is in the process of converting from syllable-timing (which is typical of several Romance languages, including Spanish and Italian) to stress-timing. Judging from the comments made by Brakel (1985) and de Carvalho (1988-92), this process is already at a more advanced stage in the European (Iberian) variant of Portuguese. Both researchers notes that one of the differences between Brazilian and European Portuguese is the absence in the European variant of the "moderate" vowel reductions seen in the Brazilian variant. That is, in European Portuguese, all unstressed syllables are subject to "extreme" reduction.[11] They further note that European Portuguese differs from Brazilian Portuguese in the type of manipulation that an unstressed vowel endures—in the European variant, unstressed vowels (including pretonic vowels) are subject to extreme shortening, which often results in the devoicing and/or complete deletion of the vowel—a type of pronunciation that is less typical for Brazilian Portuguese.

My general approach to accounting for these observations is that stress-timed languages—with their ultra-short vowels that are prone to devoicing or deletion—are languages which allow some subset of their vowels to surface without associated moras. The exact distribution of these nonmoraic vowels varies from language to language—in

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[11] Other differences between Brazilian and European Portuguese vowel reduction include: (1) in European Portuguese, vowel reduction is obligatory even in slow speech; in Brazilian Portuguese the pretonic

Brazilian Portuguese, they are post-tonic, in Russian they cannot occur immediately before the stressed syllable, and in Iberian Portuguese they seem to occur in most unstressed syllables. An analysis based on this approach will be laid out for Russian dialects in Chapter 3. In Chapter 6, the general relationship of moraicity to vowel reduction and stress timing will be discussed in more detailed.

"moderate" reduction is optional in careful (citation) speech; (2) in European Portuguese, unstressed /e/ reduces to [ə], whereas in Brazilian Portuguese it reduces to [i] (post-tonically).

Chapter 3
Case Study: Russian Vowel Reduction

3.0 Vowel Reduction in Russian

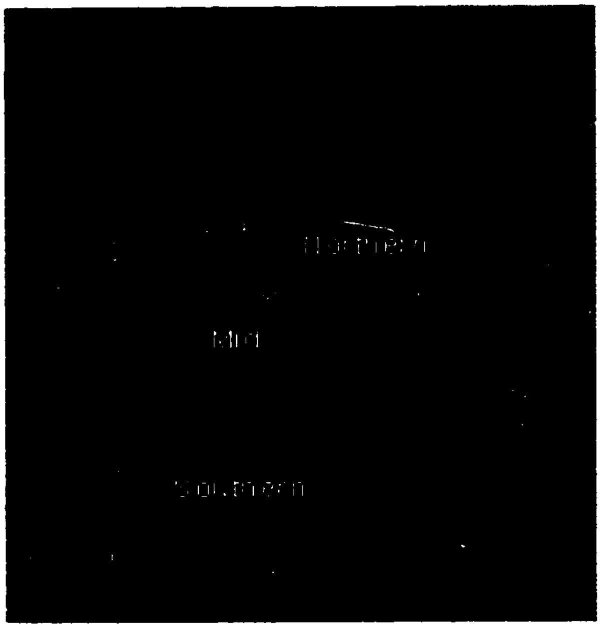
Vowel reduction is a prominent characteristic of the phonology of both Contemporary Standard Russian (CSR) and many Russian dialects. In this chapter, I will discuss the different types of vowel reduction found in the Russian language, and provide a formal analysis for several of these patterns according to the general approach to vowel reduction laid out in Chapter 2. The vowel reduction patterns that will be discussed are quite diverse, and will help to illustrate the wide range of vowel reduction phenomena that are possible in the world's languages.

3.1 Data

Before discussing the formal analysis of the Russian vowel reduction patterns, I will lay out the data to be accounted for. Since the data is rather complex, and since it may be unfamiliar to most readers, I will provide some background information that may be helpful in understanding the nature of the data to be analyzed later in section 3.2.

3.1.0 Russian Dialects and Dialectology: Background

The dialects of Russian discussed here are all considered "folk dialects"—a term used in Russian dialectology to refer to dialects of Russian spoken in those areas traditionally inhabited by a Russian-speaking population, excluding major metropolitan areas. The patterns described here are based on the descriptions provided in Avanesov and Orlova (1964), Kuznetsov (1973) and Kasatkin (1989). The general area of the Russian folk dialects is shown in (14) below. As shown in the map, these dialects are usually grouped into three large groups: the Northern, Central (or Mid), and Southern dialect groups:



(14) Northern, Central (Mid) and Southern Russian dialect groups

Each of these three dialect groups is associated with particular phonological characteristics. For example, the dialects in the Northern group tend to either lack vowel reduction, or have only limited vowel reduction. Strong reduction patterns are characteristic for the Central and Southern dialect groups. However, it should be noted that there is no such thing as "the" Northern dialect of Russian—each of these three dialect groups comprise a multitude of individual dialects, often showing significant variation from village to village. In addition, dialects vary not only with respect to vowel reduction, but also with respect to other phonological parameters (vowel inventory, consonant inventory, patterning of consonant clusters, accentual patterns, etc.) as well as a number of other linguistic parameters, including lexical, syntactic, and morphological characteristics. It is not the case, for example, that a specific vowel reduction pattern is associated with a single unique dialect. Instead, a given vowel reduction pattern might be attested in several individual dialects that differ significantly with respect to other parameters. Therefore, Russian dialectologists do not refer, to e.g. "*the* [e]-reduction dialect of Russian", but rather to "those dialects showing [e]-reduction". Similarly, although the dialects that show a specific vowel reduction pattern tend to group geographically, these geographical groupings may be cross-cut by groupings based on other parameters—therefore, although there are some groups of dialects that are both linguistically similar and geographically compact (i.e., "Vladimir-Volga Basin dialects"), geographically-based dialect names are usually linguistically uninformative. For example, the Obojan "dissimilative" vowel reduction pattern was first noted outside the south Russian city of Obojan—however, other vowel reduction patterns are also noted in and around Obojan, and the Obojan pattern is noted in numerous other southerly regions of Russia. Therefore, we can speak of the Obojan *pattern* of vowel reduction, or dialects displaying the "Obojan pattern"—realizing that the collection of all dialects displaying this pattern might differ in their syntax, morphology, lexicon, etc. We can also speak of the "Obojan dialects", which would refer to those dialects found in the geographical area of Obojan, regardless of whether or not they are linguistically similar. However, we cannot really speak of "*the* Obojan dialect".

3.1.1 Similarities in Reduction Patterns: Surface Sub-Inventory

As mentioned above, not all dialects of Russian have vowel reduction. The dialects belonging to the Northern dialect group usually either lack reduction, or have only a weak form of reduction. Dialects in the Central and Southern dialects groups (including Contemporary Standard Russian (CSR), which is technically a member of the Central dialect area) are characterized by vowel reduction. Of those dialects that show vowel reduction processes, the majority show a "two-pattern" reduction process, with a moderate reduction pattern operating in the syllable that immediately precedes the stress, and an extreme reduction pattern operating in (most of the) the remaining unstressed syllables.

Before investigating the many and varied patterns of reduction, let us take a moment to look at the ways in which these patterns are similar. Specifically, most of these reduction patterns generate similar surface sub-inventories of vowels. In other words, many of these different dialects achieve the same ends by different means. Before discussing the ways in which the dialects differ, I will first discuss the ways in which they are similar—the vowel sub-inventories they use.

As just mentioned, the majority of Russian dialects that have vowel reduction display two degrees of reduction. These two different degrees of reduction produce different vowel sub-inventories. Specifically, the first and more moderate degree of reduction usually occurs in the syllable that immediately precedes the stress, and usually produces the vowel sub-inventory [i,u,a]. The second and more extreme degree of reduction occurs in the remaining unstressed syllables, and usually produces the vowel sub-inventory [i,u,ə]. These vowel sub-inventories are illustrated in the following diagram. (Note: Here and throughout this chapter, I will not be dealing with the more subtle changes in vowel quality seen, for example, when comparing stressed and unstressed tokens of /i/ or /u/. Therefore, in comparison with the phonetic transcriptions provided by, e.g., Avanesov (1989), the surface forms provided here would be considered somewhat broad. See section 1.0.0 for discussion of this point in general.)

(15) Vowel Subinventories in Russian Dialects

Other Pretonic Syllables	Immediately Pretonic Syllable	Stressed Syllable	Post-tonic Syllables
i u ə *low-sonority V's only*	i u a *peripheral V's only*	i u e o a *all underlying V qualities*	i u ə *low-sonority V's only*

As noted above, the patterns of neutralization that generate these sub-inventories differ from dialect to dialect. For example, in CSR, unstressed /e/ reduces to [i] in the immediately pretonic syllable (as well as in the other unstressed syllables). In other dialects, unstressed /e/ reduces to [a] in the immediately pretonic syllable but reduces to [i] in other unstressed syllables. It is fairly constant cross-dialectally, however, that unstressed /o,a/ neutralize to [a] in the immediately pretonic syllable, but reduce to [ə] in other unstressed syllables.

In the so-called "dissimilative" vowel reduction pattern, which is found predominantly in dialects of the south and south-western regions of the Russian folk-dialect area, the surface sub-inventories differ from the pattern already described. In these dialects, the immediately pretonic syllable has a special status for reduction only in those forms with a stressed high vowel—in forms with stressed non-high vowels, the range of surface vowel qualities observed in the immediately pretonic syllable is the same as for the other unstressed syllables. There are several variations on this pattern—one of them is illustrated below. (As illustrated, many of these dialects have 6- or 7-vowel systems under stress.)

(16) Vowel Sub-Inventories: "Dissimilative" Russian Dialects

	Other Pretonic Syllables	Immediately Pretonic σ	Stressed Syllable	Post-tonic Syllables
words with a stressed high vowel	i u ə *low-sonority V's only*	i u a *peripheral V's only*	i u *high V's only (by definition)*	i u ə *low-sonority V's only*
words with a stressed non-high vowel	i u ə *low-sonority V's only*	i u ə *low-sonority V's only*	e,ɛ o,ɔ a *non-high V's only (by def.)*	i u ə *low-sonority V's only*

This type of vowel reduction pattern is traditionally referred to as "dissimilative" vowel reduction—this name derives from the observation that the reduction vowel [a] cannot be used in the immediately pretonic syllable if the vowel under stress is also [a].

In the following sections, I will discuss the patterns of neutralization that actually generate the sub-inventories presented above.

3.1.2 Vowel Neutralization in Non-Immediately-Pretonic Unstressed Syllables

The neutralization processes found in the non-immediately-pretonic syllable (i.e., extreme or 2^{nd}-degree reduction) show little variation, compared to the neutralizations that are seen in the immediately-pretonic syllable. One question surrounding the neutralization processes seen in Russian extreme reduction, however, surrounds the status of unstressed /e/. This is discussed below.

3.1.2.0 Reduction of Unstressed /e/

In the non-immediately-pretonic syllables of Russian dialects, vowel reduction is often profoundly affected by the palatality of the preceding consonant. In most dialects, /o,a/ reduce to [i] in non-immediately-pretonic syllables if the preceding consonant is palatalized, and reduce to [ə] in other non-immediately-pretonic syllables. This pattern presents something of a riddle for the analyst of Russian vowel reduction patterns because unstressed /e/ also reduces to [i] after palatalized consonants. Is this because Russian reduces /e/ to [i] directly (similar to vowel reduction in Bulgarian, for example), or because of the influence of the preceding palatalized consonant? In order to test this hypothesis, it is necessary to see how unstressed /e/ reduces when *not* preceded by a palatalized consonant. Unfortunately, due to the historical development of the Russian vowel system, /e/ does not occur in such positions, or does so only marginally—making this a largely academic question.

Evidence from CSR indicates that /e/ > [i] is not due to the presence of a preceding palatalized consonant. In this dialect, /e/ can occur after some non-palatalized consonants—namely /t͡s, ʃ, ʒ/. These consonants were originally palatalized, but subsequently lost palatalization. In most dialects, the non-palatalized consonants /t͡s, ʃ, ʒ/ still produce the vowel reduction patterns seen after palatalized consonants—unstressed

/e,a,o/ reduce to [i][12]. However, in some dialects, including CSR, /t͡s, ʃ, ʒ/ do not have this behavior. In these dialects, /a,o/ reduce to [ə] after /t͡s, ʃ, ʒ/, but /e/ reduces to [i]. Some examples of this pattern are given below using the consonant /t͡s/, where this behavior is most consistent:

(17) Reduction of /e/ > [i] and /o,a/ > [ə] After Nonpalatalized Consonant

	Vowels Under Stress	**Same Vowels Unstressed**	*gloss*
unstressed e > i	t͡sérkəf^{j}	t͡sirkóvnij	'church' noun/adj.
	t͡sélij	t͡sil^{j}ikóm	'whole'/'in whole'
unstressed o,a > ə	t͡sár^{j}	t͡səradvór^{j}its	'czar'/'czar's palace'
	t͡sókət	t͡səkatát^{j}	'chirp' noun/verb

We can also see the direct reduction of /e/ to [i] in the nativized pronunciations of certain foreign words that contain /e/ at the absolute beginning of the word. For example, forms like [ékspərt] 'export (noun)' versus [ikspart^{j}írəvət^{j}] 'to export' show that the *e>i* alternation is not a consonant~vowel assimilation process. The suffixed form /eksport^{j}írovat^{j}/ also has a more conservative pronunciation without vowel reduction on the initial vowel—this type of pronunciation sometimes gives the impression that the unreduced vowel was pronounced with a secondary stress. However, there is no variant

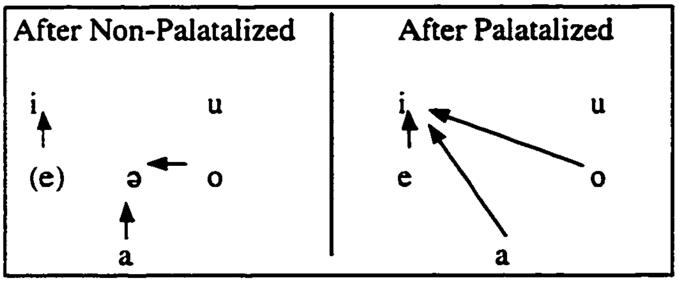
[12] It is possible that this anomalous behavior is caused by the high tongue position characteristic of the /ʃ,ʒ/ phonemes, which are strongly velarized in many dialects. For example, in the Old Muscovite pronunciation norm (which was prevalent earlier this century), /ʒ,ʃ/ caused /o,a/ to reduce to [i]. These consonants were also produced with such noticeable velarization that some Russian phoneticians considered them to be doubly-articulated consonants (Akishina & Baranovskja 1980). Currently, /ʃ,ʒ/ do not cause reduction of /o,a/ to [i], and are no longer obligatorily velarized.

pronunciation with reduction of /e/ to [ə] or [a], and native speakers find such a pronunciation unacceptable: *[akspartʲírəvətʲ]. Therefore, it can be assumed that in at least some dialects of Russian, e>i is a straightforward case of vowel neutralization under reduction, and not a consonant-vowel assimilation effect.

<u>3.1.2.1 Neutralization Pattern Summary</u>

With this in mind, we can summarize vowel neutralization patterns in the non-immediately-pretonic syllables as illustrated below. Example forms from CSR are provided.

(18) Extreme Neutralizations, common to most dialects with reduction



After Non-Palatalized		**After Palatalized**	
/tsexovój/	[t͡si̱xavój] 'shop' (adj.) cf. [t͡séx] 'shop'	/rʲet͡ʃʲovój/	[rʲi̱t͡ʃʲivój] 'speech' (adj.) cf. [rʲé t͡ʃʲ] 'speech' (n.)
/sadovód/	[sə̱davót] 'gardener' cf. [sát] 'garden'	/pʲatot͡ʃʲók/	[pʲi̱tat͡ʃʲók] 'five kopeck coin' cf. [pʲátʲ] 'five'
/gorodók/	[gə̱radok] 'little city' cf. [górət] 'city'	/tʲoplotá/	[tʲi̱platá] 'warmth' cf. [tʲóplij] 'warm'

The vowel /e/ is shown in parentheses in the illustration above (in the context representing reduction after a non-palatalized consonant) since it is not clear if this portion of the process can be generalized to all dialects.

In summary, the vowel neutralization patterns seen in the non-immediately-pretonic unstressed syllables in Russian dialects characteristically avoid the occurrence of high-sonority mid and low vowels, which typically surface as low-sonority [ə] (after non-palatalized consonants) or [i] (after palatalized consonants or for underlying /e/).

3.1.3 Vowel Neutralization Patterns in Immediately-Pretonic Syllables—Nondissimilative Patterns

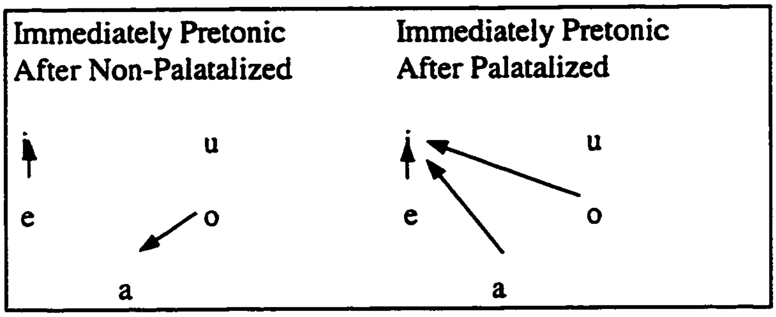
The vowel neutralization patterns found in the immediately pretonic syllables in Russian dialects show more variety than the pattern discussed above. Generally, the vowel reduction patterns found in immediately pretonic syllables can use more sonorous reduction vowels than those found in other unstressed syllables.

3.1.3.0 Dialects with *[i]-reduction*

In many dialects, including CSR, the immediately pretonic syllable differs from other unstressed syllables in that /a,o/ neutralize to highly sonorous [a] in this context, except when this tendency is attenuated by the existence of a preceding palatalized consonant. In that case, /o,a/ reduce to [i] in the immediately pretonic, just as in the non-immediately-pretonic syllables. Similar to the pattern discussed above for other unstressed syllables, underlying /e/ reduces to [i] regardless of the preceding consonant.

This pattern can be referred to as "[i]-reduction". This pattern is seen in many central Russian dialects, including CSR, from which the example forms listed below are taken.

(19) Moderate neutralization via [i]-reduction

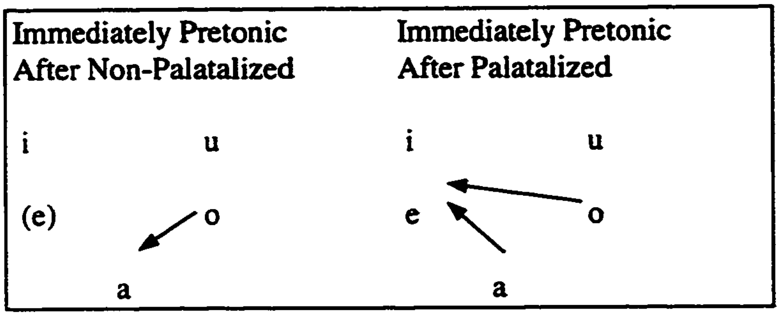


After Non-Palatalized		After Palatalized	
/etáʒ/	[itáʃ] 'floor, story' cf. variant [etáʃ]	/rʲeká/	[rʲiká] 'river' cf. [rʲé t͡ʃʲka] 'little river'
/davátʲ/	[davátʲ] 'to give' (iter.) cf. [dátʲ] 'to give'	/pʲatʲí/	[pʲití] 'five' (gen. sg.) cf. [pʲátʲ] 'five' (nom. sg.)
/kotá/	[katá] 'cat' (gen. sg.) cf. [kót] 'cat' (nom. sg.)	/tʲopló/	[tʲipló] 'warmly' cf. [tʲóplij] 'warm'

3.1.3.1 Dialects with *[e]-reduction*

The diachronic predecessor of *[i]-reduction* is a type of reduction pattern where /e/ does not undergo reduction, and where unstressed /o,a/ after palatalized consonants also surface as [e]. This pattern, "[e]-reduction", still exists in many dialects in the Moscow region, and was characteristic of Moscow pronunciation at one time.

(20) Moderate Neutralization via [e]-reduction

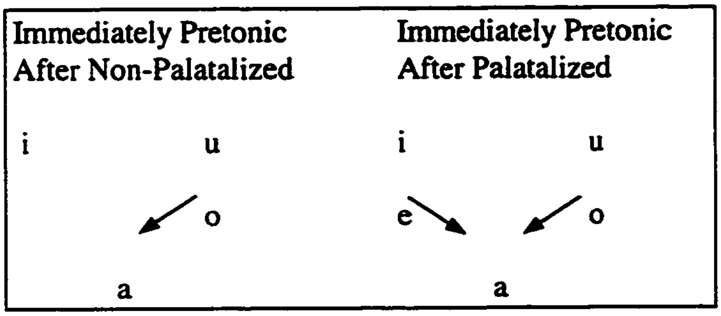


/rʲeká/	[rʲeká] 'river'	cf. [rʲétʃkə] 'little river'
/pʲatí/	[pʲetí] 'five' (gen. sg.)	cf. [pʲátʲ] 'five' (nom. sg.)
/nʲosú/	[nʲesú] 'I carry'	cf. [nʲós] 'he carried'

3.1.3.2 Dialects with *[a]-reduction*

In a number of other dialects, the immediately pretonic syllable is characterized by always using [a] as the reduction vowel for unstressed non-high vowels, even in contexts after a palatalized consonant. (This pattern does not extend to the contexts of extreme reduction, which retain the neutralizations already discussed in section 3.1.2.1.) This pattern can be referred to as "[a]-reduction", and is illustrated below. (In this diagram, /e/ is not listed in the environment after a non-palatalized consonant since data establishing the occurrence of /e/ in that context is not available for these dialects.)

(21) Moderate Neutralization via [a]-reduction

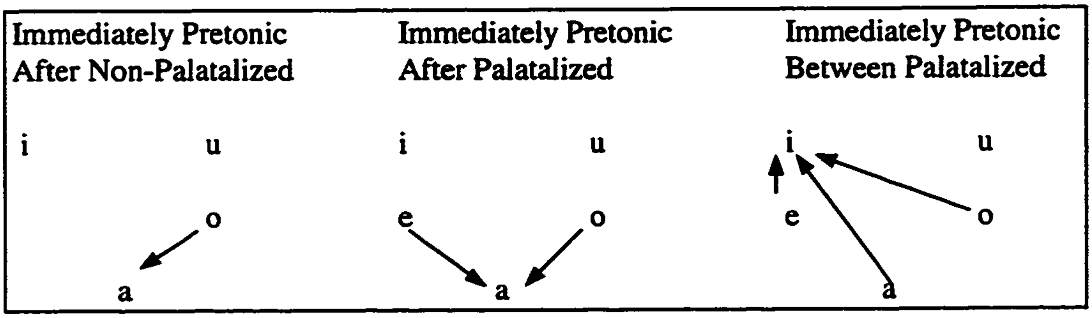


/rʲeká/	[rʲaká] 'river'	cf. [rʲétʃkə] 'little river'
/pʲatí/	[pʲatí] 'five' (gen. sg.)	cf. [pʲátʲ] 'five' (nom. sg.)
/nʲosú/	[nʲasú] 'I carry'	cf. [nʲós] 'he carried'

3.1.3.3 Dialects with *Attenuated [a]-reduction*

And finally, in some dialects, the immediately pretonic syllable uses the sonorous vowel [a] as a reduction vowel except in contexts where the unstressed vowel is *flanked* by palatalized consonants on both sides, as illustrated below. This pattern can be referred to as "attenuated [a]-reduction", since the [a]-reduction pattern is attenuated (or interrupted) in the presence of a double-sided palatalization environment. This pattern occurs in a number of central and southern dialects in the regions of Moscow, Kalinin, and Tula.

(22) Moderate Neutralization via attenuated [a]-reduction



After Palatalized		Between Palatalized	
/rʲeká/	[rʲaká] 'river' cf. [rʲé t͡ʃʲka] 'little river'	/rʲét͡ʃʲnój/	[rʲit͡ʃʲnój] 'river' (adj.) cf. [rʲé t͡ʃʲka] 'little river'
/pʲata/	[pʲatá] 'heel' (sg.) cf. [pʲáti] 'heels'	/pʲatʲí/	[pʲití] 'five' (gen. sg.) cf. [pʲátʲ] 'five' (nom. sg.)
/tʲopló/	[tʲapló] 'warmly' cf. [tʲóplij] 'warm'	/tʲolét͡s/	[tʲilét͡s] 'calf' cf. [tʲólkə] 'heifer'

In summary, the patterns seen in the immediately pretonic syllables in Russian dialects are characterized by increased usage of the more sonorous vowels (such as *e* and *a*) as reduction vowels, while the less sonorous reduction vowels *ə* and *i* continue to be used as reduction vowels in other unstressed syllables. As detailed above, the tendency to use more sonorous reduction vowels in immediately pretonic syllables can be attenuated by the interference of other factors, such as the palatality of the surrounding consonants.

3.1.4 The "Dissimilative" Vowel Reduction Patterns

As noted above, in some dialects, the appearance of moderate vowel reduction in the syllable immediately preceding the stress is dependent on the quality of the stressed vowel. In the default case the pattern is: if the stressed vowel is high, the immediately pretonic syllable shows moderate reduction; if the stressed vowel is non-high, the immediately pretonic syllable shows extreme reduction. This pattern is traditionally referred to as "dissimilative" vowel reduction due to the observation that the vowel [a] cannot occur in both the immediately pretonic and tonic syllables. However, as is frequently noted by Russian dialectologists, use of the term "dissimilative" is not meant to imply an actual dissimilative process at work in these dialects. As Kuznetsov states with respect to the names for different types of Russian vowel reduction:

> The terms "assimilation" and "dissimilation" are used according to tradition, in order to explain the essence of the structures of the contemporary vocalism, and do not suggest the presence in the dialects in question of corresponding processes of accommodation (and anti-accommodation) of sounds one to another at the present time. (Kuznetsov 1973)

Avanesov and Bromlei (1986) echo this sentiment in their commentary to the Russian dialect atlas (DARJa) issued by the Institute for the Russian Language, stating:

> The names "dissimilative", "assimilative-dissimilative", "moderate-dissimilative", etc. are used on the maps only as traditional terms for representing the given systems of jakan'e [*i.e., system of reduction –KC*]. One should look upon them neither as an indication of phonetic processes nor as an indication of the history of the development of the corresponding vocalism.

There are several variations on the "dissimilative" pattern for vowel reduction. The data below provide an illustrative example ("Don" subtype).

(23) Vowel Reduction in the dialects with the Don dissimilative pattern

	After Nonpalatalized Consonant			**After Palatalized Consonant**		
	Surface	*Input*	*Gloss*	*Surface*	*Input*	*Gloss*
reduce to [a]	[damú]	/domú/	*'home', loc.*	[n^jasú]	/n^josú/	*'carry' 1st sg.*
reduce to [ə,i]	[dəmá]	/domá/	*'homes'*	[$n^j$is^{j}óm]	/n^jos^{j}óm/	*'carry' 1st pl.*
	[dəməvój]	/domovój/	*'home', adj.*	[n^jislá]	/n^joslá/	*'carried', fem.*

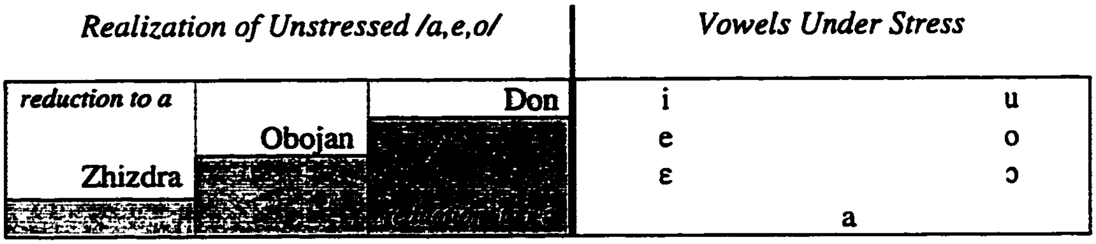
The three main subtypes of this pattern differ based on the behavior of the mid vowels when under stress. In many of these dialects, there is a seven-vowel system under stress (although in many cases this system is currently being lost). In different dialects, the class of vowels that condition the appearance of the more sonorous reduction vowel [a] varies. As shown in the following diagram, the Don pattern uses [a] only in syllables that precede stressed /i,u/ (this is the pattern illustrated above); the Obojan pattern uses [a] only before stressed /i,u,e,o/; the Zhizdra pattern uses [a] before any stressed non-low vowel /i,u,e,o,ɛ,ɔ/. These three patterns are summarized below:

(24) Types of Dissimilative Vowel Reduction Patterns (formulaic format)

Don pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú
→ [ə,i] / ___ é,ó,ɛ́,ɔ́,á
Obojan pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú, é,ó
→ [ə,i] / ___ ɛ́,ɔ́,á
Zhizdra pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú,é,ó,ɛ́,ɔ́
→ [ə,i] / ___ á

Alternatively, the differences between these three patterns can be summarized in the following way:

(25) Types of Dissimilative Vowel Reduction Patterns (schematic format)



The Zhizdra pattern is the most common, seen in many dialects in the western region of the Southern dialect area, as well as in many adjacent dialects of Belarusian (whence the alternate name "Belarusian" for this pattern). The Obojan pattern is also fairly common, occurring mainly in the south-central region of the Southern dialect area, although investigations by Kasatkina *et al.* (1996) claim that it is more widespread than previously reported. The Don pattern is relatively rare at the current time, and occurs in dialects found along the Don river. In addition to these three patterns, there are a number of other, more complex patterns that only occur in limited environments (such as after or between palatalized consonants).

3.2 Analysis

As discussed in Chapter 2, the vowel reduction phenomena discussed in the current work fall into two main classes: contrast-enhancement and prominence reduction The general approach I will take towards two-pattern vowel reduction phenomena such as those observed in Russian dialects is as follows: Moderate reduction occurs in all unstressed syllables, and can be equated with contrast-enhancement. Extreme reduction occurs in a subset of unstressed syllables, and can be equated with prominence-reduction. The context in which extreme reduction pertains is represented moraically—extreme reduction affects those unstressed syllables which are *nonmoraic*. Since these environments constitute a set~subset relation, a two-pattern reduction system will only occur if the subset constraint (prominence reduction, causing the "extreme" neutralizations) outranks the more general constraint (contrast enhancement, causing the "moderate" neutralizations). This also predicts, correctly, that extreme reduction will occur in the intersection of these two sets (the subset), while only moderate reduction will occur in the complement.

This approach to the Russian dialectal vowel reduction data discussed above shows that this two-constraint approach to two-pattern vowel reduction can provide a unified formal treatment for the attested patterns. In addition, some of the dialectal variants are generated by grammars where some constraint(s) must intervene between the two vowel reduction constraints or where one of them is absent—a result that is only possible if there are two constraints causing vowel reduction in the language to begin with. At certain points, parallels will be drawn between Russian and other two-pattern vowel reduction languages.

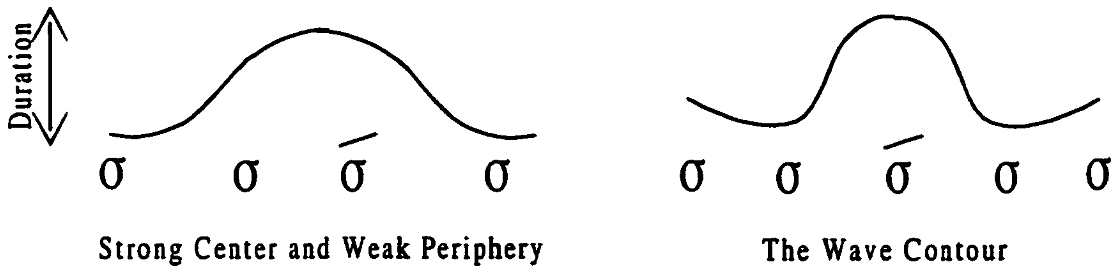
I will start by discussing extreme reduction, which is caused in this analysis by a prominence reduction constraint. The first step in analyzing this pattern is to isolate the environment in which extreme reduction occurs. I will argue that in Russian, extreme reduction strikes unfooted, nonmoraic unstressed syllables.

3.2.0 Extreme Reduction and Russian Foot Form

As laid out above, Russian vowel reduction shows a moderate neutralization pattern in the immediately pretonic syllable, and an extreme neutralization pattern in other unstressed syllables. In the analysis provided here, I will account for this fact by analyzing these two syllables as constituting a prosodic domain—a foot. This foot structure has previously been proposed for Russian by Halle and Vergnaud (1987) and Alderete (1995). The proposed foot structure is right-prominent: ($\sigma\acute{\sigma}$), suggesting that Russian is an iambic language. In accordance with Prince and Smolensky (1993, chapter 4), I will conclude that Russian uses the constraint RhType=Iamb.

Phonetically, the vowels within the foot are durationally different from vowels outside of the foot: the unfooted vowels are shorter than footed vowels. In addition, the unfooted vowels are more liable to be devoiced or deleted in faster or more colloquial speech—according to Zemskaja (1987, p. 201), vowel deletion is most common for the unstressed vowel immediately following the proposed foot, and next most common for the vowel immediately preceding it. It should be noted, however, that this foot form is not common to all the Russian dialects. Research by Vysotskii (1973) and Almukhamedova and Kul'sharipova (1980) reveal the existence of various dialectal rhythmical variants. However, as pointed out by Kasatkina (1996), all of these variants can be grouped into two large categories: the "strong center and weak periphery" group and the "wave contour" group. Graphical representations based on Kasatkina's (1996) description are provided below.

(26) Rhythmic Patterns in Russian



As suggested by the names, the "strong center and weak periphery" rhythmic pattern is characterized by increased duration of the tonic and immediately pretonic syllables (which constitute the "strong center") and decreased duration for all remaining syllables (the "weak periphery"). Kasatkina (1996) suggests that this prosodic pattern is a defining characteristic of the central Russian dialect area, to which Contemporary Standard Russian (CSR) belongs. The "wave" rhythmical pattern is characterized by increased duration for the stressed vowel, with lengthening also occurring for syllables removed by one syllable from the stress; the syllables immediately adjacent to the stress are short. Almukhamedova and Kul'sharipova (1980, p. 47) observe this pattern in north Russian dialects without vowel reduction, and note that this sort of rhythmic organization is similar to that of Ukrainian and may be a remnant of a previous prosodic system. Importantly, these different rhythmical patterns are found in areas with different vowel reduction behaviors: the strong center and weak periphery pattern predominates in the central Russian dialect area, whose members usually show moderate or no reduction in the immediately pretonic syllable, but extreme reduction in the remaining unstressed syllables; the wave pattern is found in the north Russian dialect area, whose members typically lack significant vowel reduction. It seems reasonable to suppose, therefore, that the conditioning environment for moderate vowel reduction is tied to foot form: dialects with moderate reduction in the immediately pretonic syllable use the foot form (σσ́).

To account for the fact that the foot form of the central Russian dialects has such a profound effect of the duration of unfooted vowels, I will make the following claim: the footed syllables of Russian are *moraic*, while the unfooted syllables are *nonmoraic*, using "mora" in the sense delineated in section 1.3.3. We can say, for example, that the moraic (footed) vowels of Russian are guaranteed to attain a certain minimum duration, since they possess timing units (moras). The nonmoraic (unfooted) syllables, however, are not guaranteed any minimum duration since they lack timing units—this might mean realization of a nonmoraic vowel as very short, deleted, devoiced, or (as described for extremely reduced Russian vowels in Bondarko *et al.* 1966, p. 63) as a vowel that is highly overlapped with the preceding consonant. Formally, the moraic distribution described above for Russian can be derived using the following constraints:

*STRUC-μ: Moras do not occur in output forms.

CULMINATIVITY: A prosodic word has exactly one stress.

FTBINμ: Feet have at least two moras.

The constraint *Struc-μ is a structure avoidance constraint. It assigns one violation mark for every mora that occurs in an output candidate. Culminativity assigns one violation mark to any output candidate that does not have exactly one stress. The FtBinμ constraint is a familiar binarity constraint that demands all feet have two moras: It assigns one violation mark to any foot in an output form that does not have at least two moras. The appropriate moraic distribution is achieved in Russian by ranking Culminativity and FtBinμ above *Struc-μ, as shown in the following tableau:

(27) Deriving Foot Structure: Culminativity, FtBinμ » *Struc-μ

/σσσσ́σσ/	Culminativity	FtBinμ	*Struc-μ	*comments:*
☞ $\sigma\sigma(\sigma_\mu\acute{\sigma}_\mu)\sigma\sigma$				winner
$\sigma_\mu\sigma_\mu(\sigma_\mu\acute{\sigma}_\mu)\sigma_\mu\sigma_\mu$				too many moras
$\sigma\sigma\ (\sigma\acute{\sigma}_\mu)\sigma\sigma$		*!		foot isn't binary
$\sigma\sigma\sigma(\acute{\sigma}_\mu)\sigma\sigma$		*!		foot isn't binary
σσσσσσ	*!			no stress
$(\sigma_\mu\grave{\sigma}_\mu)(\sigma_\mu\acute{\sigma}_\mu)(\sigma_\mu\grave{\sigma}_\mu)$	*!			too many stresses

As shown in this tableau, the combination of FtBinμ and *Struc-μ conspires to exclude all but two moras from the winning output form: In other words, the winning candidate is the one that has as few unstressed moras as possible without violating the two higher-ranking constraints.

Before moving on, it should be noted that at this point it is difficult or impossible to determine that moraicity is the critical factor in deciding where extreme reduction and moderate reduction apply. Based on the vowel reduction facts discussed so far, the different distribution of extreme vs. moderate vowel reduction in Russian could be described in terms of footedness vs. nonfootedness. There are, however, certain exceptions to the pattern already described—these exceptions can be described in terms of moraicity, but not footedness. For example, unstressed /a,o/ undergo moderate reduction when they occur in unstressed position at the extreme left edge of the prosodic word—regardless of the distance between that syllable and the stressed syllable. For example, forms like /ogoród/ 'vegetable garden' and /antropológija/ 'anthropology' are pronounced [agarót] and [antrəpalóg^{j}ijə], respectively. Note that the initial vowels reduce to [a] and not [ə], even though they are *not* immediately pretonic: Extreme reduction has been blocked. This blockage cannot be the result of a foot, since there is no secondary stress on these vowels. Furthermore, mere extension of the main stress foot to include the word-initial vowels cannot be a possibility, since such a structure would predict that all vowels intervening between the first vowel and the stressed vowel would also be subject to moderate reduction. The form [antrəpalóg^{j}ijə] shows that this is not the case. There is nothing, however, that would prevent these vowels from being moraic. In fact, the duration of word-initial unstressed vowels is increased (Zlatoustova 1981), and such vowels are not subject to the deletion and devoicing phenomena observed with nonmoraic unstressed vowels in Russian. An alignment constraint can derive this effect:

Align-μ: The left edge of every word must align with some mora.

Assuming that onset consonants are barred from being moraic, this constraint will enforce the presence of a word-initial mora only in those cases when the first segment of a word is a vowel. (This form of partial reduction blocking is discussed in more detail in section 5.1.1.)

The moraic basis for the distribution of extreme vs. moderate vowel reduction is also supported by evidence from European and Brazilian Portuguese (Brakel 1985, Carvalho 1988-92). This evidence is discussed in more detail in section 3.4.0

3.2.1 Extreme Reduction as Prominence Reduction

Given the moraic distribution discussed for Russian in the preceding section, the constraint that motivates extreme vowel reduction can now be introduced:

> ***Nonmoraic/-high**: Nonmoraic vowels may not have a sonority greater than that of i,u.

Recall from chapter 1 that vowel sonority is defined here based on inherent duration, according to which [ə] is the least sonorous vowel, and [i,u] are the next most sonorous. This means that the *Nonmoraic/-high constraint will assign one violation mark to any surface nonmoraic vowel that is not [i], [u], or [ə]. As discussed in section 3.1.2, the neutralizations that are used to avoid violation of *Nonmoraic/-high are different for underlying /o,a/ on the one hand and underlying /e/ on the other. First let us look at a case of nonmoraic /o,a/ (after a non-palatalized consonant). Note: only violations for the *un*footed unstressed vowel are considered in this tableau.

(28) **Extreme Reduction for /o,a/: *Nonmoraic/-high » Dep[+high]**

	/domovój/ *'house spirit'*	*NONMORAIC/ -high	DEP +HI
a.	☞ də(mavój)		
b.	du(mavój)		*!
c.	di(mavój)		*!
d.	da(mavój)	*!	
e.	do(mavój)	*!	
f.	de(mavój)	*!	

	/sadovód/ *'gardener'*	*NONMORAIC/ -high	DEP +HI
g.	☞ sə(davót)		
h.	su(davót)		*!
i.	si(davót)		*!
j.	sa(davót)	*!	
k.	so(davót)	*!	
l.	se(davót)	*!	

As shown in the preceding tableau, the ranking of *Nonmoraic/-high above Dep[+Hi] produces the correct neutralization pattern for both nonmoraic /o/ and /a/. The *Nonmoraic/-high constraint rules out all candidates with sonorous vowels in nonmoraic position (candidates d-f and j-l). Of the remaining candidates, the [ə]-reduced forms (candidates a and g) are the winners because they do not involve insertion of a [+hi] feature specification. The candidates with high vowels (candidates c,d, h,i) do involve insertion of [+hi], and are therefore ruled out by Dep[+hi].

Now let's consider the reduction of nonmoraic /e/ in Russian. Recall that nonmoraic /e/ does not follow a centralizing reduction pattern: instead of reducing to [ə], nonmoraic /e/ reduces to [i]:

(29) **Extreme Reduction for /e/: *Nonmoraic/-high and Max[+front] » Dep[+high]**

/t͡sexovój/ *'(factory) shop' (adj.)*	*NONMORAIC/ -high	MAX[+FT]	DEP +HI
☞ t͡si(xavój)			
t͡sə(xavój)		*!	
t͡su(xavój)		*!	
t͡se(xavój)	*!		
t͡so(xavój)	*!		
t͡sa(xavój)	*!		

As demonstrated here, reduction via raising is derived for underlying /e/ due to the constraint Max[+front], which dominates Dep[+hi]. In other words, the [ə]-reduced form is unacceptable here since it involves sacrifice of the underlying frontness of the unstressed /e/. Reduction via raising is therefore the best option. Since /o,a/ are not underlyingly front, the constraint Max[+front] has no effect on the reduction of those vowels.

Finally, extreme reduction of /o,a/ after a palatalized consonant produces [i] instead of [ə]. I will account for this effect using the following constraint:

C^j/[+front]: A palatalized consonant must be followed by a [+front] vowel.

(30) **Extreme Reduction after a Palatalized Consonant: C^j[+ft] » Dep[+high]**

/tʲoploxod/ *'motorized ship'*	*NON-MORAIC/ -high	MAX[+FT]	MAX-HI	C^j/[+FT]	DEP +HI
☞ tʲi(plaxót)			*		
tʲə(plaxót)			*	*!	
tʲu(plaxót)			*	*!	
tʲe(plaxót)	*!				
tʲo(plaxót)	*!				
tʲa(plaxót)	*!				

/t͡ʃʲastotá/ *'frequency'*	*NON-MORAIC/ -high	MAX[+FT]	MAX-HI	C^j/[+FT]	DEP +HI
☞ t͡ʃʲi(statá)			*		
t͡ʃʲə(statá)			*	*!	
t͡ʃʲu(statá)			*	*!	
t͡ʃʲo(statá)	*!				
t͡ʃʲe(statá)	*!				
t͡ʃʲa(statá)	*!				

Assuming that underlyingly palatalized consonants are specified [+front], the ranking Max[+Front] » C^j/[+front] will prevent de-palatalization of the consonant when followed by a non-front vowel underlyingly. Also note that in these tableaux the constraint Max[-high] has been added, although it does not affect the choice of the winning candidate. Furthermore, the evidence provided in these tableaux does not give us enough information to determine its ranking with respect to the C^j/[+front] constraint, although we do know that it must be dominated by the vowel reduction constraint *Nonmoraic/-high (otherwise it would block reduction). The ranking of Max[-high] with respect to C^j/[+front] will be discussed as it pertains to moderate reduction in subsequent sections, where it will be shown that the ranking of these two constraints varies dialectally and causes variation in moderate neutralization patterns.

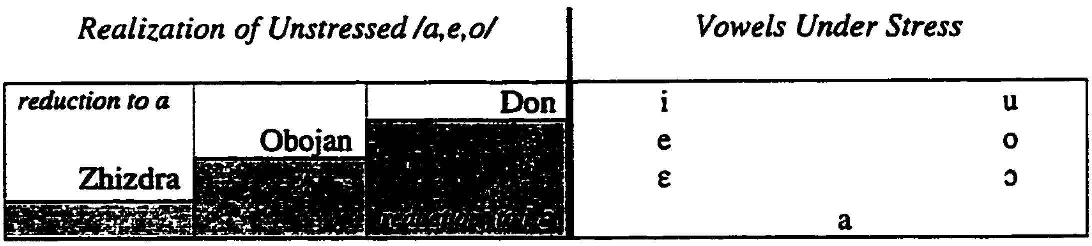
3.2.2 Extreme Reduction in Dissimilative Dialects

The analysis of extreme reduction in "dissimilative" dialects is similar to the situation laid out in the preceding section. The operative difference is that extreme reduction has a wider sphere of application in the dissimilative dialects: the immediately pretonic syllable sometimes undergoes extreme vowel reduction instead of moderate vowel reduction.

In addition to the different distribution of extreme vs. moderate reduction, the dissimilative dialects are also set apart by their rhythmic pattern. Recall that the occurrence of moderate reduction in the immediately pretonic syllable is associated with the "strong center and weak periphery" rhythmic pattern described in section 3.2.0 above. In the dissimilative dialects, the "strong center and weak periphery" pattern is only found in that subset of words where the immediately pretonic syllable undergoes moderate reduction (Kasatkina 1996, Kasatkin *et al.* 1989). In these words, the immediately pretonic syllable is parsed as part of the foot. In words where the immediately pretonic syllable undergoes extreme reduction, this syllable is not durationally longer than other unstressed syllables and is not, therefore, included as part of the foot. In other words, the different distribution of extreme and moderate reduction in the dissimilative dialects is caused by the fact that different words (predictably) place foot boundaries in different locations. Let's look again at the three basic types of dissimilative dialect:

(31) Types of Dissimilative Reduction (repeated here from (24))

Don pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú
→ [ə,i] / ___ é,ó,έ,ɔ́,á
Obojan pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú, é,ó
→ [ə,i] / ___ έ,ɔ́,á
Zhizdra pattern: immediately pretonic /a,e,o/ → [a] / ___ í,ú,é,ó,έ,ɔ́
→ [ə,i] / ___ á



In these dialects, certain stressed vowels condition the appearance of extreme reduction in the immediately pretonic syllable, or in other words, certain stressed vowels condition the appearance of a monosyllabic foot (i.e., a foot that does not include the immediately pretonic syllable). Broadly speaking, the vowels that condition this occurrence can be described as the sonorous vowels of that dialect. The three different sub-types illustrated above vary with respect to which vowels are considered sonorous enough to have this effect: in the Zhizdra pattern, only the highest sonority vowel [á] conditions extreme reduction in the preceding syllable; in the Obojan pattern low vowels and lax mid vowels pattern together in this behavior [á,έ,ɔ́]; and in the Don pattern all the non-low vowels do [á,έ,ɔ́,é,ó]. Put another way, in the Zhizdra pattern (for example), a syllable with stressed [á] is capable of being footed alone, while a syllable with some other stressed vowel must be footed in conjunction with the preceding syllable: for purposes of building feet, a stressed [á] is equivalent to [é] plus another vowel, [í] plus another vowel, or any other non-low stressed vowel plus another vowel. This is shown schematically below. A period stands for a syllable boundary, and square brackets indicate foot boundaries:

(32) Foot Equivalences in Dissimilative Dialects

Zhizdra	[Cá]	=	[CV.Cɛ́] [CV.Cɔ́] [CV.Cé] [CV.Có] [CV.Cí] [CV.Cú]
Obojan	[Cá] [Cɛ́] [Cɔ́]	=	[CV.Cé] [CV.Có] [CV.Cí] [CV.Cú]
Don	[Cá] [Cɛ́] [Cɔ́] [Cé] [Có]	=	[CV.Cí] [CV.Cú]

This brings to mind classical weight equivalence phenomena, such as that in Latin where a single long vowel (V:) is equivalent in weight to two short vowels (VV) or a short vowel plus a coda consonant (VC). In Russian dialects there are no phonemic length contrasts, but assuming (following works such as Repetti 1989) that phonological phenomena can introduce vowels with varying mora counts at the surface level even in languages that do not underlying contrast long and short vowels, the dissimilative patterns described above can be accounted for moraically. That is, I analyze the monosyllabic feet displayed in (32) as containing a single bimoraic vowel, and the disyllabic feet as containing two monomoraic vowels. For example, in dialects displaying the Zhizdra pattern, a stressed [á] is bimoraic while stressed [ɛ́, ɔ́, é,ó,í,ú] are monomoraic: [C$\acute{a}_{\mu\mu}$] vs.

$[CV_\mu C\acute{e}_\mu]$.[13] The different dissimilative patterns can be derived by placing limitations on which vowels can lengthen under stress. As predicted by Prince and Smolensky's (1993) prominence alignment mechanism, the vowels that are most likely to lengthen are those that are segmentally prominent (sonorous). The appropriate constraints for generating this pattern are shown below:

Prominence Alignment Constraints: *μμ/i,u » *μμ/e,o » *μμ/ɛ,ɔ » *μμ/a,æ

As described by Prince and Smolensky, prominence alignment constraint families like the one shown above are produced by "crossing" two phonetic scales. The constraint family shown above was produced by crossing a moraic prominence scale with segmental prominence. Note that the symbol "»" means "dominates" and is used with constraints, while the symbol "➤" means "is less prominent than", and is not used with constraints.

Moraic Prominence:	μ ➤ μμ	"1 mora is less prominent than 2."
Segmental Prominence:	i,u ➤ e,o ➤ ɛ,ɔ ➤ a,æ	"Low sonority vowels are less prominent than higher sonority ones."

Since these scales are arranged from low sonority to high, the constraint family that results from crossing them is a "prominence reduction" constraint hierarchy, and defines the type of vowels that are not sonorous enough to co-occur with a bimoraic level of

---

[13] It should be noted that stressed [á] is quite longer in these dialects than unstressed (i.e., moderately reduced) [a]. However, it should also be noted that this is the case in most dialects, since Russian stress is duration-based (Zlatoustova 1981). Since inherent vowel duration differences are quite striking in Russian, it is not suprising that stressed vs. unstressed duration differences are most pronounced with high-sonority stressed vowels and their unstressed counterparts.

prominence. That is, a constraint like *μμ/i,u expresses the notion that high vowels are not sonorous enough to be bimoraic.

By interleaving the members of the *μμ/X constraint family with an additional constraint, it is possible to derive the differences in foot structure observed in the dissimilative dialects. The constraint that must be used is the Weight-to-Stress Principle (WSP) (Smolensky, 1993). The version of WSP used here is formulated as:

WSP: Stressed vowels should be bimoraic.

This constraint, if given full rein, would cause lengthening of all stressed vowels. However, its sphere of influence will be limited by the *μμ/X constraint family discussed above. Specifically, any *μμ/X constraint that dominates WSP will block vowel lengthening for its specific vowel quality. For example, if *μμ/i,u outranks WSP, then stressed high vowels will not be able to lengthen under stress. Similarly, if all the *μμ/X constraints except *μμ/a outrank WSP (as shown below), then only low vowels will lengthen under stress:

*μμ/i » **WSP** » *μμ/e » *μμ/ɛ » *μμ/a

The following tableau illustrates how the ranking shown above derives the correct foot boundary placement in the Zhizdra pattern. Note: in these and subsequent tableaux, only the relevant portion of the *μμ/X constraint family will be shown, due to space considerations.

Tableau (33): Lengthening of Stressed [á] Due to WSP and *μμ/a (Zhizdra)

Words with Stressed Low Vowel				
/luná/ *'moon'*	***Struc-μ**	***μμ/ε**	**WSP**	***μμ/a**
☞ lu($ná_{\mu\mu}$)	**			
4($lu_{\mu}ná_{\mu}$)	**		*!	
($lu_{\mu}ná_{\mu\mu}$)	***!			

Words with Stressed Non-Low Vowels				
/lut͡ʃʲɔ́k/ *'ray'*	***Struc-μ**	***μμ/ε**	**WSP**	***μμ/a**
☞ (lu_{μ}t͡ʃʲ$ɔ́_{\mu}$k)	**		*	
lu(t͡ʃʲ$ɔ́_{\mu\mu}$k)	**	*!		
(lu_{μ}t͡ʃʲ$ɔ́_{\mu\mu}$k)	***!			

In the first tableau, the optimal output lu[$ná_{\mu\mu}$] shows lengthening of the tonic vowel [a]. The second candidate, *[$lu_{\mu}ná_{\mu}$], without lengthening of the tonic vowel, is ruled out because it violates WSP. In addition, the final candidate, *[$lu_{\mu}ná_{\mu\mu}$] shows that the immediately pretonic syllable must be left unfooted when the tonic vowel undergoes lengthening, in order to avoid excessive violation of *Struc-μ In the second tableau, the optimal output [lu_{μ}tʃʲ$ɔ́_{\mu}$k] does not have lengthening of the tonic vowel. Lengthening of the tonic vowel would cause a fatal violation—either a fatal violation of *μμ/ε (as shown in the second row), or a fatal violation of *Struc-μ (as shown in the third row).

By changing the ranking of WSP with respect to the *μμ/X constraint family, the Obojan and Don patterns can also be derived. Additionally, by ranking WSP below the entire *μμ/X family, a di-syllabic foot shape will always result, since no vowel qualities will be able to lengthen—this is the type of pattern that is seen in the non-dissimilative dialects (including CSR).

(34) Possible Rankings for WSP, and Resulting Reduction Patterns

Pattern	Ranking
Non-Dissimilative	*μμ/i,u » *μμ/e,o » *μμ/ɛ,ɔ » *μμ/a » **WSP**
Zhizdra	*μμ/i,u » *μμ/e,o » *μμ/ɛ » **WSP** » *μμ/a
Obojan	*μμ/i,u » *μμ/e,o » **WSP** » *μμ/ɛ,ɔ » *μμ/a
Don	*μμ/i,u » **WSP** »*μμ/e,o » *μμ/ɛ,ɔ » *μμ/a

At this point, it should be noted that the *μμ/X and WSP constraints need to be dominated by faithfulness constraints for vowel height—otherwise, changes in vowel quality might be expected in order to satisfy the higher-ranking *μμ/X constraints while still satisfying WSP. This can be avoided by ranking the faithfulness constraint Max [+Hi] and Dep [+Low] above the *μμ/X constraints, as shown in the following tableaux:

Tableau (35): Avoidance of Quality Changes to Satisfy *μμ/X and WSP Constraints

/nʲɔ́s/ *'he carried'*	**Dep +Lo**	**Max +Hi**	***μμ/i**	***μμ/e**	***μμ/ɛ**	***μμ/a**
☞ nʲɔ́:s						
nʲá:s	*!					

/ʒíznʲ/ *'life'*	**Dep +Lo**	**Max +Hi**	***μμ/i**	***μμ/e**	***μμ/ɛ**	***μμ/a**
☞ ʒí:znʲ						
ʒé:znʲ		*!				
ʒɛ́:znʲ		*!				
ʒá:znʲ	*!					

In the first tableau, lowering of underlying /ɔ/ to [a] is blocked by Dep[+low]—without this ranking, we would expect the incorrect output candidate *[nʲaːs] to emerge as the winner, since it violates a less-highly ranked *μμ/X constraint. Similarly, in the second tableau, lowering of input /i/ is also blocked by the faithfulness constraints. Here, a number of lowering possibilities are considered—each is ruled out by either Dep[+low] or Max[+high].

3.3 Analyzing Moderate Reduction

Now that extreme vowel reduction is accounted for, I will turn towards the analysis of moderate reduction. Recall that in the current approach, moderate vowel reduction will occur in moraic syllables, where it generates a vowel sub-inventory containing only the peripheral vowels [i,u,a] in the output. To account for this fact, I will propose the following licensing constraint:

> LIC NONPERIPH/STRESS: A nonperipheral vowel may not occur in the output unless under stress.

To avoid violation of this constraint, unstressed mid vowels will have to either raise to the high peripheral vowels [i,u] or lower to the peripheral vowel [a]. As explained in the preceding chapter, different dialects choose differently in this respect. I will begin with an analysis of [a]-reduction below, along with a discussion concerning the combination the analyses for moderate and extreme reduction. Afterwards, I will work through the other types of moderate reduction described in section 3.1.3.

3.3.0 Moderate Neutralizations in *[a]-reduction*

In [a]-reduction, unstressed /e,o/ both reduce to [a] in the immediately-pretonic syllable, regardless of the palatality of the preceding consonant. This neutralization pattern is observed in many south Russian dialects, including those displaying the dissimilative patterns discussed above. (For this reason, they are traditionally referred to as *dissimilative [a]-reduction* dialects). In order to derive reduction via lowering, the faithfulness constraint Dep[+low] must be dominated both by Lic-Nonperiph/Stress and Max[-high]. This is demonstrated in the following tableau for reduction after a non-palatalized consonant. In this and subsequent tableaux, I will present di-syllabic foot forms with monomoraic stressed vowels, unless otherwise noted.

Tableau (36): Moderate Neutralization Via *[a]-reduction*—Max[-high] » Dep[+low]

/domú/ *'home' (loc.)*	LIC NONPERIPH/ STRESS	MAX[-HI]	DEP +LO
☞ (damú)			
(dumú)		*!	
(dimú)		*!	
(domú)	*!		
(demú)	*!		
(dəmú)	*!		

/sadú/ 'garden' (loc.)	LIC NONPERIPH/ STRESS	MAX[-HI]	DEP +LO
☞ (sadú)			
(sudú)		*!	
(sidú)		*!	
(sodú)	*!		
(sedú)	*!		
(sədú)	*!		

Here, the last three candidate forms in each tableau are ruled out by Lic-Nonperiph: they all contain a nonperipheral vowel that is not stressed. The second two candidates are both ruled out for deleting an underlying [-high] specification, in violation of Max[-high]. The winner violates only the low-ranked constraint Dep[+low] (and only in the first tableau), since a [+low] specification has been inserted which was not present underlyingly. It should also be pointed out at this time that Max[-high] must also dominate faithfulness constraints for [front] and [round]—if Max[+front] or Max[round] were ranked above Max[-high], they could force reduction via raising in order to preserve the palatality or rounding of the underlying vowel. Since this is not the case in the pattern under consideration, it must be the case that Max[-high] » Max[+front], Max[round].

Now let's look at [a]-reduction after a palatalized consonant. Recall that [a]-reduction is not affected by this environment—unstressed nonperipheral vowels in the immediately-pretonic syllable reduce via lowering to [a] regardless of the quality of the preceding consonant. This results from the ranking Max[-high] » C^j/[+front], as shown in the following tableau for unstressed /o/ preceded by a palatalized consonant:

(37) Moderate Neutralization of /o/ via *a-reduction*: After a Palatalized Consonant

/p^j^okú/ '*I bake*'	LIC NONPERIPH/ STRESS	MAX[-HI]	C^j/[+FT]	DEP +LO
☞ (p^jakú)				
(p^jukú)		*!		
(p^jikú)		*!		
(p^jokú)	*!			
(p^jekú)	*!			
(p^jəkú)	*!			

The same result is also generated for unstressed /e/ and /a/ preceded by a palatalized consonant:

(38) Moderate Neutralization of /a/ or /e/ via *[a]-reduction*: After Palatalized

/r^jeká/ '*river*'	LIC NONPERIPH/ STRESS	MAX[-HI]	C^j/[+FT]	DEP +LO
☞ (r^jaká)				
(r^juká)		*!		
(r^jiká)		*!		
(r^joká)	*!			
(r^jeká)	*!			
(r^jəká)	*!			

/pʲatʲi/ *'five' (gen.)*	LIC NONPERIPH/ STRESS	MAX[-HI]	Cʲ/[+FT]	DEP +LO
☞ (pʲatʲɪ)				
(pʲutʲɪ)		*!		
(pʲitʲɪ́)		*!		
(pʲotʲɪ)	*!			
(pʲetʲɪ́)	*!			
(pʲətʲɪ)	*!			

3.3.1 Combining Moderate and Extreme Reductions

Now that we have examined both the moderate and extreme vowel neutralizations in isolation, let's take a look at them in combination to ensure that the constraints and rankings discussed separately do not produce the incorrect results when combined. In particular, the Cʲ/[+front] constraint must be ranked in a manner such that it will motivate reduction to [i] in cases of extreme reduction, but not in cases of moderate reduction. The ranking Max[-high] » Cʲ/[+front] suggested above has the appropriate effect. Recall from tableau (30) that the ranking of Cʲ/[+front] and Max[-high] cannot be determined based only on the evidence provided from extreme reduction. In other words, the correct extreme reduction patterns result from either ranking. In the [a]-reduction dialects, the ranking must be Max[-high] » Cʲ/[+front], since this ranking avoids reduction to [i] in contexts of moderate reduction. To see how this works, compare the following two tableaux illustrating reduction of unstressed /o/ in both extreme and moderate reduction cases:

(39) **Moderate Reduction of /o/ After Palatalized: Full Constraint Set**

/tʲopló/ *'warmly'*	*NONMORAIC/ -high	LIC-NONPERIPH/ STRESS	MAX [+FT]	MAX [-HI]	Cʲ/ [+FT]	DEP [+HI]
☞ (tʲapló)						
(tʲipló)				*!		
(tʲupló)				*!		
(tʲepló)		*!				
(tʲopló)		*!				
(tʲəpló)		*!				

(40) **Extreme Reduction of /o/ after Palatalized: Full Constraint Set**
Note: Only violations for the first unstressed vowel are shown

/tʲoploxód/ *'motorized ship'*	*NON-MORAIC/ -high	LIC-NONPERIPH/ STRESS	MAX +FT	MAX [-HI]	Cʲ/ [+FT]	DEP [+HI]
☞ tʲi(plaxót)				*		
tʲu(plaxót)				*	*!	
tʲə(plaxót)		*!				
tʲa(plaxót)	*!					
tʲe(plaxót)	*!					
tʲo(plaxót)	*!					

Note that in the first tableau, an [a]-reduced form is the optimal candidate, due in part to the fact that it satisfies the Max[-high] constraint. This ranking allows the [a]-reduced form to win despite the fact that it violates the Cʲ/[+front] constraint. However, in the second tableau the [a]-reduced form is cast out of the running at an early stage by the *Nonmoraic/-high constraint. In other words, although [a]-reduction is optimal in this dialect with respect to the ranking Max[-high] » Cʲ/[+front], it produces a vowel that is too sonorous to be used under extreme reduction due to the higher-ranking constraint *Nonmoraic/-high. Therefore, in [a]-reduction dialects the Cʲ/[+front] constraint is able to play a decisive role under extreme reduction, but not under moderate reduction.

The remainder of this sections will demonstrate how additional moderate neutralization patterns can be derived.

3.3.2 Dialects with *[i]-reduction*

A number of Central Russian dialects, including CSR, show a pattern referred to as *[i]-reduction*, exemplified in section 3.1.3.0. In this type pattern, reduction to [i] after a palatalized consonant occurs in under moderate reduction as well as under extreme reduction. This pattern can be accounted for by ranking Max[-high] *below* Cʲ/[+front]. (This is the opposite of the [a]-reduction pattern described above.) This ranking will allow Cʲ/[+front] to motivate reduction to [i] in all unstressed syllables:

(41) Moderate Neutralization via *[i]-reduction*: Cʲ/[+front] » Max[-high]

/nʲoslí/ '*they carried*'	NON-MORAIC-i	LIC NONPERIPH/ STRESS	MAX +FT	Cʲ/ [+FT]	MAX –HIGH	DEP +LOW
☞ (nʲislí)						
(nʲaslí)				*!		
(nʲuslí)				*!		
(nʲəslí)		*!				
(nʲeslí)		*!				
(nʲoslí)		*!				

Since Max[-high] still dominates Dep[+low], reduction via lowering is still produced when not preceded by a palatalized consonant, as shown below:

(42) Moderate Reduction in [i]-reduction dialect after Nonpalatalized

/domá/ *'homes'*	*NON-MORAIC/ -high	LIC NONPERIPH/ STRESS	MAX +FT	C^j/ [+FT]	MAX -HIGH	DEP +LOW
☞ (damá)						
(dimá)					*!	
(dumá)					*!	
(dəmá)						
(demá)						
(domá)						

3.3.3 Dialects with *[e]-reduction*

Many of the dialects in the Moscow area are characterized by *[e]-reduction*—a neutralization pattern from which [i]-reduction derives historically. In this type of dialect, immediately pretonic unstressed /e/ does not reduce—it remains [e]. In addition, the other non-high vowels /o,a/ will surface as [e] in the immediately pretonic position when preceded by a palatalized consonant. This pattern differs from the [i]-reduction analysis given above in that the Lic-Nonperiph/Stress constraint is more lowly ranked. As shown below, this blocks raising:

(43) Moderate Reduction of /e/ via [e]-reduction

/r^jeká/ 'river'	NON-MORAIC/i	MAX +FRONT	C^j/ +FT	MAX −HIGH	LIC NONPERIPH/ STRESS	DEP +LOW
☞ (r^jeká)					*	
(r^jiká)				*!		
(r^joká)		*!				
(r^jaká)		*!				
(r^jəká)		*!				
(r^juká)		*!				

Here, the optimal candidate retains the underlying mid vowel in an unstressed syllable, despite the fact that this violates Lic-Nonperiph/Stress. To do otherwise would mean either raising to [i], which violates the more highly-ranked constraint Max[-high]; lowering to [a] or centralizing to [ə], both of which violate Max[+front]. The same constraints and rankings also correctly predict that unstressed /o,a/ will reduce to [e] when preceded by a palatalized consonant. This is illustrated below for underlying /o/:

(44) Moderate Reduction of /o/ via [e]-reduction (after palatalized)

/t^jopló/ 'warmly'	NON-MORAIC/i	MAX +FT	C^j/ +FT	MAX −HIGH	LIC NONPERIPH/ STRESS	DEP +LOW
☞ (t^jepló)						
(t^jipló)				*!		
(t^jopló)			*!			
(t^japló)			*!			
(t^jəpló)			*!			
(t^jupló)			*!			

Note that this re-ranking does not mean that unstressed /o/ can remain unreduced: presence of Lic-Nonperiph/Stress, even in a lowly-ranked position, will still motivate reduction, as shown below:

(45) Moderate Reduction of /o/ in [e]-reduction dialect (after nonpalatalized)

/domá/ *'homes'*	NON-MORAIC/i	MAX +FT	C^j/ +FT	MAX −HIGH	LIC NONPERIPH/ STRESS	DEP +LOW
☞ (damá)						
(demá)					*!	
(domá)					*!	
(dəmá)				*!		
(dimá)				*!		
(dumá)				*!		

Here, the constraints Max[+front] and C^j/[+front] have no effect—in the analysis of [i]-reduction, they helped to motivate raising. In the case of underlying /o,a/ *not* preceded by a palatalized consonant, there is nothing that would motivate reduction via raising—instead, the default pattern of reduction via lowering is maintained.

Finally, it should be emphasized that the [e]-reduction pattern does not allow unreduced [e] in *all* unstressed positions—only moraic unstressed syllables can use [e] as a reduction vowel. In nonmoraic unstressed syllables, unstressed /o,a/ preceded by a palatalized consonant and unstressed /e/ reduce to [i]. This fact is nicely derived by the fact that *Nonmoraic/-high retains its high-ranked position, thus ruling out reduction to highly-sonorous [e] in nonmoraic syllables. This is demonstrated in the following tableaux for underlying /e/ and /o/, respectively:

(46) **Extreme Reduction of /e/ in an [e]-reduction dialect**

/rʲet͡ʃʲovój/ *'vocal'*	NON-MORAIC/i	MAX +FRONT	Cʲ/ +FT	MAX −HIGH	LIC NONPERIPH/ STRESS	DEP +LOW
☞ rʲi(t͡ʃʲevój)						
rʲə(t͡ʃʲevój)		*!				
rʲu(t͡ʃʲevój)		*!				
rʲe(t͡ʃʲevój)	*!					
rʲa(t͡ʃʲevój)	*!					
rʲo(t͡ʃʲevój)	*!					

(47) **Extreme Reduction of /o/ in an [e]-reduction dialect**

/tʲoplovátoj/ *'warmish'*	NON-MORAIC/i	MAX +FRONT	Cʲ/ +FT	MAX −HIGH	LIC NONPERIPH/ STRESS	DEP +LOW
☞ tʲi(plavá)tij						
tʲu(plavá)tij			*!			
tʲə(plavá)tij			*!			
tʲe(plavá)tij	*!					
tʲo(plavá)tij	*!					
tʲa(plavá)tij	*!					

3.3.4 Attenuated *[a]-reduction*

In a number of dialects in the South Russian dialect area, reduction to [i] also occurs in the immediately pretonic syllable, similar to the [i]-reduction pattern described immediately above, but only when the unstressed vowel in question is *flanked* by palatalized consonants on both sides. In unfooted unstressed positions, reduction to [i] occurs after palatalized consonants, as normal (no double-sided environment is necessary). This pattern is traditionally referred to as "attenuated [a]-reduction", since the tendency to reduce to [a] is attenuated, not occurring in the double-sided palatalization environment. This pattern can be derived by adding a double-sided phonotactic constraint such as the following:

> **$C^j\_C^j$:** A vowel may not occur between two palatalized consonants unless it is [+front].

By sandwiching the Max[-high] constraint between the double-sided palatalization constraint and the single-sided palatalization constraint, the correct results will be produced: the high-ranking $C^j\_C^j$ constraint will force reduction to [i] in all appropriate contexts, including footed positions, due to the ranking $C^j\_C^j$ » Max[-high]. The low-ranking constraint C^j/[+front] will also motivate reduction to [i], but will be blocked in nonmoraic unstressed syllables by the ranking Max[-high] » C^j/[+front].

3.3.5 Incomplete *okan'e*

The last dialect type to be considered in this chapter is traditionally referred to as "incomplete okan'e". In this type of dialect, the mid vowels do not reduce at all in the immediately pretonic syllable—unstressed /o/ remains [o], and unstressed /e/ remains [e]. However, in other unstressed syllables, there is the same sort of "extreme" reduction as there is in the dialects already discussed. This type of pattern is characteristic of the Vladimir-Volga Basin dialect group, which is found in an area that is transitional between the vowel-reducing Central dialects and the non-reducing Northern dialects. According to Vysotskii's (1973) phonetic survey of dialect vowel duration, the Vladimir-Volga Basin group is similar to the central Russian dialects in terms of the duration of the immediately-pretonic vowel, and is usually considered a member of the Central dialect group. In Kasatkina's (1996) terminology, the Vladimir-Volga Basin group displays the "strong nucleus and weak periphery" pattern. This contrasts with the vowel duration results that Vysotskii (1973) reports for the northern neighbors of the Vladimir-Volga Basin group, which would be more similar to the "wave" rhythmic pattern.

The Vladimir-Volga Basin "incomplete okan'e" pattern is easily assimilated into the analysis already provided by demoting the Lic-Nonperiph/Stress constraint below Max[-low], thus making it preferable to deploy mid vowels in unstressed syllables rather than incur a faithfulness violation. However, this does not prevent *Nonmoraic/-high from producing vowel reduction in the remaining unstressed, nonmoraic syllables. In the nonmoraic syllables, unstressed /o/ and /e/ are not allowed to surface—but this is due to their relatively sonorous status, not to their nonperipheral nature. Of course, if the remaining unstressed vowels were to regain their moraic status, there would be no chance for vowel reduction at all under this grammar. This is a desirable effect in that it allows us to account for those Northern dialects that lack vowel reduction entirely. As described by Vysotskii (1973), the non-reducing dialects do not make sharp durational distinctions among different types of unstressed syllable—it would therefore be reasonable to assume that the Northern dialects lacking reduction altogether have a much lower ranking for the constraint *Struc-μ, which prevents the occurrence of both nonmoraic vowels and (resultantly) extreme reduction in these dialects.

3.3.6 Morphologized Dissimilative Reduction Patterns

Before concluding this chapter, it should be noted that there are several complex sorts of dissimilative vowel reduction that have not been accounted for in the preceding sections. According to both Avanesov & Bromlei (1986) and Flier (1978) many of the non-basic dissimilative vowel reduction patterns are best analyzed as morphological or lexical alternations. This is particularly the case for dissimilative vowel reduction after palatalized consonants. In this position, the two reduction vowels [i] and [a] are both phonemic vowels in Russian—it is therefore possible to re-lexicalize individual forms as containing underlying /i/ or /a/, or to analyze cases of [i]-reduction as a morphological process such as umlaut (note: many of the alternations observed in these patterns are caused by stress shifts associated with inflectional and derivations processes). It has been suggested that these factors are responsible for the fact that dissimilative vowel reduction is much more widespread cross-dialectally after palatalized consonants than after non-palatalized. That is, there are a number of dialects where dissimilative vowel reduction is found only after palatalized consonants, and where some other reduction pattern occurs after non-palatalized consonants. Such dialects are found over a wide area of South and Central Russia. It is theorized that these dialects once had a fully dissimilative vowel reduction system, which was completely lost after non-palatalized consonants and re-analyzed in some manner after palatalized consonants. Finally, there are also a number of dissimilative patterns that are only attested after palatalized consonants—such as the Sudzha and Mosal'sk patterns. However, according to Avanesov & Bromlei (1986), the

Mosal'sk pattern is very limited, and is always found alongside a more standard type of vowel reduction pattern. Furthermore, as noted by Jakobson (1929), Stroganova (1965), and Platt (1974), the Sudzha pattern and others like it can be explained by introducing consonant-vowel assimilation effects for some immediately-pretonic vowels that are flanked by palatalized consonants.[14] A full treatment of the Sudzha, Mosal'sk and other similar non-basic dissimilative patterns is beyond the scope of the present survey.

3.4 Conclusion

In this chapter, I have presented an analysis of the various two-pattern vowel reduction systems that are attested in the southern and central dialects of Russian. This analysis is presents a non-dissimilatory explanation for the Don, Zhizdra, and Obojan reduction patterns that can be easily converted to account for a range of other attested Russian vowel reduction patterns.

This analysis also demonstrates that the two different vowel reduction patterns found in these dialects ("extreme" and "moderate") are in fact caused by two different types of phonetic motivation: the desire to avoid certain perceptually-challenging vowel qualities (in this case, mid vowels), and the desire to avoid sonorous vowels in non-prominent positions (in this case, nonmoraic positions). This is especially clear from the

[14] This is possible since the front mid vowels /e,ɛ/ only occur after soft consonants, while /o/ only occurs after non-palatalized. The lower-mid back vowel /ɔ/ is the only one that can occur in either context. In patterns such the Sudzha pattern, stressed /ɔ/ behaves differently w.r.t. vowel reduction based on the palatality of the consonant that precedes it (i.e., the consonant that follows the immediately pretonic vowel.)

analysis of [e]-reduction (section 3.3.3), where the two vowel reduction constraints—Lic-Nonperiph/Stress and *Nonmoraic/-high—must have distinct rankings; and from the analysis of incomplete okan'e (section 3.3.5), where one of these vowel reduction processes is absent. Furthermore, it should also be pointed out that the rich variety of two-pattern vowel reduction systems attested in Russian dialects all follow a single generalization: the extreme vowel reduction patterns differ from the moderate vowel reduction patterns in disallowing certain sonorous reduction vowels, such as [a] or [e]. This observation meshes well with the proposed analysis for these dialects. The analysis of extreme vowel neutralization as prominence reduction predicts that it will never be the case that extreme vowel neutralization will differ from moderate reduction in disallowing certain non-sonorous reduction vowels. This is especially clear when one compares the vowel sub-inventories that are most commonly observed in stressless position in Southern and Central Russian dialects: [i,u,a] in moraic unstressed syllables and [i,u,ə] in nonmoraic unstressed syllables. This is a telling fact since it is *not* the case that extreme reduction results in the preservation of fewer contrasts or the usage of a smaller sub-inventory. Instead, it seems to be the case that extreme reduction is a completely independent type of vowel reduction process.

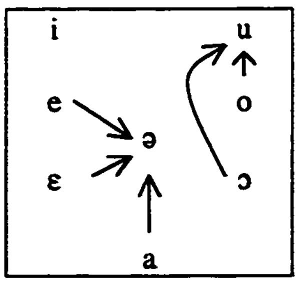
3.4.0 Beyond Russian: Evidence from Other Languages

Now that we have a clear picture of how vowel reduction works in Russian, we can investigate some linkages between vowel reduction in other languages and vowel reduction in Russian. In particular, many of the formal mechanisms investigated above are also useful in accounting for reduction in other languages, such as Catalan. Similarly, evidence from other languages—such as European Portuguese—helps to provide additional support for some of the formal mechanisms used in the analysis for Russian, such as the use of the moraic vs. nonmoraic distinction for extreme reduction rather than the footed vs. unfooted distinction.

3.4.0.0 Catalan

In standard Catalan (Mascaró 1978, Recasens 1991), unstressed syllables may not contain vowels other than [i,u,ə]. This contrasts with the situation found in stressed syllables, where the phonemic vowel inventory includes /i,u,e,o,ɛ,ɔ,a/. The neutralizations used to reduce the phonemic 7-vowel inventory to the 3-vowel subinventory [i,u,ə] are depicted below, with examples from Mascaró (1978):

(48) Vowel Neutralization in Catalan (data from Mascaró 1978):



V under stress		Same V unstressed	
pɔ́rt	'harbor'	purtuári	'related to harbor'
gós	'dog'	gusás	'big dog'
ʎúm	'light'	ʎuminós	'light' (adj.)
sák	'sack'	səkɛ́t	'small sack'
pɛ́l	'hair'	pəlút	'hairy'
sérp	'snake'	sərpɔ́tə	'big snake'
prím	'thin'	əprimá	'to make thin'

This pattern of reduction is similar to that seen in Russian extreme (non-immediately-pretonic) reduction: a vowel sub-inventory of [i,u,ə] is produced, using a reduction strategy that involves both raising and centralization. However, the Catalan reduction pattern differs in two important respects. First, the neutralizations utilized are the reverse of those seen in Russian: in Russian, the front mid vowel raises and the back mid vowel centralizes with /a/ to [ə]; in Catalan, the front mid vowels centralize with /a/ to [ə], while the back mid vowels raise. Second, in Catalan, these neutralizations are not part of a two-pattern reduction system. That is, there is no "moderate" reduction in Catalan. Note, for example, that [ə] can occur in the syllable immediately preceding the stress (cf. [səkɛ́t], 'little sack').

To account for the Catalan neutralization pattern, we can use basically the same reduction constraint that was seen in the Russian case. The only modification necessary concerns the conditioning environment: whereas in Russian, we used *Nonmoraic/-high, in Catalan we must use *Unstressed/-high. It should be pointed out, however, that if we make the simplifying assumption that Catalan unstressed vowels are nonmoraic, we could use exactly the same reduction constraint for both languages. However, in the absence of any additional data supporting this claim for Catalan, I will make the less controversial assumption that all Catalan vowels are moraic, and simply modify the reduction constraint accordingly. (This is possible in Catalan, but not in Russian, since Catalan does not have a two-pattern reduction system.) The vowel reduction constraint used in Catalan will therefore be:

> ***Unstressed/-high:** Unstressed syllables may not contain a vowel with a sonority greater than that of [i,u].

As mentioned above for Russian, the vowel [ə] is not more sonorous than [i,u], so the constraint given above will not be violated if [ə] occurs in an unstressed syllable.

The other difference mentioned above—the different neutralization strategy seen in Catalan—is accomodated simply by changing the rankings of vocalic faithfulness constraints with respect to the reduction constraint. Recall that in the Russian case, Max[-high] was high-ranked, making lowering/centralization the preferred reduction strategy. This will remain the case in Catalan: if possible, vowels will reduce via centralization. In the Russian case, Max[+front] was also ranked high, causing the unstressed vowel /e/ to forego centralization in favor of raising, in order to preserve its underlying palatality. In Catalan, the situation is reversed: Max[+front] is ranked low, but Max[round] is ranked high. Thus, Catalan unstressed /o,ɔ/ will forego reduction-via-centralization for raising, in order to maintain their underlying rounding. Example tableaux are provided below to show how this ranking works (the first tableau demonstrates reduction of a front mid vowel; the second tableau demonstrates reduction of a back mid vowel):

	/pɛlút/	*UNSTRESSED/ -high	MAX[ROUND]	MAX[-HI]
a.	☞ pəlút			
d.	pilút			*!
e.	pulút			*!
b.	pɛlút	*!		
c.	pelút	*!		
f.	polút	*!		
g.	pɔlút	*!		
h.	palút	*!		

	/gosás/	*UNSTRESSED/ -high	MAX[ROUND]	MAX[-HI]
a.	☞ gusás			*
g.	gəsás		*!	
d.	gisás		*!	
e.	gosás	*!		
f.	gɔsás	*!		
b.	gesás	*!		
c.	gɛsás	*!		
h.	gasás	*!		

Vowel reduction is also blocked in a few contexts in Catalan. These are discussed in chapter 7.

3.4.0.1 European Portuguese

In European Portuguese (Brakel 1985, Carvalho 1988-92), stressed syllables can contain the vowels /i,u,e,o,ɛ,ɔ,a/ and, with a limited distribution, /ɐ/. In unstressed syllables, however, only [i,u,ə] and sometimes [ɐ] can occur—the neutralizations that produce this subinventory are similar to those seen in Catalan: /e,ɛ/ > [ə], /o,ɔ/ > [u], /a/ > [ə] (or [ɐ]).

(49) Iberian Portuguese Vowel Reduction (Brakel 1985)

	Vowels Under Stress		Same Vowels Unstressed	
i > i *(no change)*	píʃku	'I blink'	piʃkár	'to blink'
u > u *(no change)*	púlu	'I jump'	pulár	'to jump'
e > ə	méðu	'fear'	məðrózu	'fearful'
ɛ > ə	pɛ́kə	'sins'	pəkár	'to sin'
a > ə	kátə	'picks up'	kətár	'to pick up'
ɔ > u	tɔ́ku	'I play'	tukár	'to play'
o > u	bókə	'mouth'	bukərɐ̃w̃	'big mouth'

Furthermore, vowel reduction in European Portuguese is also similar to that found in Catalan in that it is not part of a two-pattern reduction system. This being the case, we might be tempted to simply apply the same analysis sketched above for Catalan to European Portuguese. However, there is one important difference between the European Portuguese and Catalan vowel reduction systems that needs to be addressed. Namely, vowel reduction in European Portuguese is blocked in unstressed syllables that end with a sonorant consonant. Examples of this sort of vowel-reduction blockage include the following forms (from de Carvalho 1992 and Brakel 1985).[15]

[15] The behavior of syllable-final [r] seems to be unstable—in Brakel (1985) it does not block reduction, but in de Carvalho (1992) it does. It is possible that syllable-final /r/ is sometimes pronounced as a non-sonorant, as in Brazilian Portuguese, where syllable-final /r/ is pronounced /x/.

(50) **Blockage of Vowel Reduction in European Portuguese**

syllable-final *j*	bajxár	tejmár
syllable-final *w*	kawzár	ewrópə
syllable-final *r*	əsúkar	cədáver
syllable-final *l*	faltár	voltár
syllable-final *n*	konsəsɐ̃w̃[16]	sentár

It would be tempting to assume that blockage of vowel-reduction in these syllables is simply due to the adjacency of a sonorant consonant—we might assume, for example, that V + sonorant is a combination that is particularly easy to articulate or that it has some special perceptual advantage. However, it seems as though the sonorant consonants can only block vowel reduction when they are syllable-final. That is, intervocalic sonorant consonants do not block reduction of a preceding unstressed vowel—consider [dəlatór][17] (*[delatór]), [kurɛtívu] (*[korɛtívu]), where the initial unstressed vowel undergoes reduction despite the following non-tautosyllabic sonorant (for blockage of reduction on the unstressed vowels [a] and [ɛ] see fn. 17). In fact, according to Brakel, a following non-tautosyllabic sonorant increases the likelihood that an unstressed vowel will be deleted—for example, deletion of the unstressed [u] in

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[16] The vowel /ɐ/ occurs in Iberian, but not Brazilian, Portuguese. It is minimally contrastive with [a]—this contrast is mainly limited to verbal desinences. The vowel /ɐ/ reduces in a manner identical to unstressed /a/.

[17] The blockage of vowel reduction seen with the unstressed [a] and [ɛ] in these forms effects a number of derived forms, and is not associated with the preceding sonorant—see Brakel (1985) for discussion of this effect in Iberian Portuguese.

[pulár] is more likely than deletion of the [u] in [tukár]. (He also states, however, that the unstressed [u] in [tukár] is more likely to be devoiced.)

Blockage of vowel reduction in European Portuguese before a sonorant coda is an important point, since it introduces a parallel between European Portuguese and the two-pattern reduction system seen in Russian: in both languages, completely unstressed syllables must be divided into two groups based on their behavior with respect to reduction. In the Russian case, these two groups are (1) moderately-reducing unstressed syllables (the immediately pretonic and word-initial onsetless syllables), and (2) extremely-reducing unstressed syllables. In European Portuguese, the two groups are (1) unstressed syllables that are immune to reduction and (2) unstressed syllables that are not immune to reduction. The same formal device used to account for these two groups in the Russian case can also be applied to the European Portuguese case: some of the unstressed syllables are nonmoraic, while others are not. Namely, I claim that unstressed syllables in European Portuguese are nonmoraic, unless they are closed by a sonorant consonant.

Before discussing this possibility, first let's look at an alternative that won't work: namely, that the syllables where reduction is blocked receive secondary stress. This alternative is similar to one proposed by Miller (1972)for Easter Ojibwa: she proposes that all long vowels in that language receive some degree of stress, explaining why they are resistant to vowel reduction. Following this example, it might be possible to hypothesize that in European Portuguese, all syllables closed by a sonorant consonant are heavy, similar to the case seen in Kwakw'ala (Boas 1947) and Inga Quechua (Levinsohn 1976). If this were the case, heavy syllables might attract secondary stress and therefore escape vowel reduction. However, although European Portuguese *does* possess secondary stress, its placement is not determined in the manner under consideration. In current pronunciations as described by Lüdtke (1953) and de Carvalho (1988-92), secondary stress falls on the initial syllable of any word where there would otherwise be more than two unstressed syllables preceding the main stress, as in *rèctangulár*. Both sources also mention other, less common, patterns for placing secondary stress in European Portuguese, but none seem to place secondary stress on syllables closed by a sonorant. Consider, for example, the form *vagàbundágem* cited by Carvalho. Clearly, these examples show that the immunity of sonorant-final syllables to vowel reduction cannot be explained in terms of stress placement.

It is, however, possible to explain the immunity of sonorant-final syllables to vowel reduction in terms of moraicity. For example, if the sonorant coda consonant is obligatorily moraic (as suggested above), the preceding vowel might share the consonantal mora, or may be prevented from undergoing demorification in order to avoid a situation in which a coda consonant is moraically more prominent than the nuclear vowel of that same syllable. With this being the case, it would be possible to apply the *Nonmoraic/-high constraint of Russian to European Portuguese and predict the correct results: only nonmoraic unstressed vowels—that is, unstressed vowels not followed by a sonorant coda—will undergo reduction.

It should be noted that it seems phonetically reasonable to posit nonmoraic vowels for European Portuguese. Unstressed vowels (other than those that are immune to reduction) are phonetically similar to the non-immediately-pretonic vowels of Russian, in that they are extremely short, and are commonly devoiced or deleted entirely (Brakel 1985, Carvalho 1988-92).

3.4.0.2 Additional Two-Pattern Systems

Finally, it should be noted that the approach taken to the two-pattern reduction system of Russian has repercussions for prosodic structures of other languages with a two-pattern reduction system. In some languages with two-pattern reduction systems, the conditioning environment for extreme vs. moderate corresponds to the difference between post-tonic and pre-tonic. For example, in both Rhodope Bulgarian (Miletich 1936) and northern Italian dialects (Maiden 1995), any unstressed syllable that precedes the stress will undergo moderate reduction, while any unstressed syllable that follows the stress will undergo extreme reduction. This suggests that these languages use foot structures such as those illustrated below:

(51) **Assumed Foot Structure for Rhodope Bulgarian and northern Italian**

$$(\sigma_\mu\ \sigma_\mu\ \sigma_\mu\ \sigma_\mu\ \sigma_\mu\ \sigma_\mu\ \sigma_\mu\ \acute{\sigma}_\mu)\ \sigma\ \sigma$$

Assuming that some high-ranking constraint in these languages requires footed syllables to be moraic, the pretonic unstressed syllables will be protected from demorification (*Struc-μ), while post-tonic unstressed syllables will not be. The proposed foot structure is also supported in the northern Italian case by data discussed by Maiden (1995). He points out that there are several processes in addition to vowel reduction that are sensitive to the post-tonic vs. pre-tonic difference (for example, certain types of vowel assimilations occur in pretonic, but not post-tonic, unstressed syllables in these dialects)[18].

Another example of a language that has a two-pattern reduction system is Brazilian Portuguese (Redenbarger 1981, Dukes 1993). As described by Dukes, all stressed syllables (including both primary and secondary stresses) in Brazilian Portuguese are immune to vowel reduction[19]. Secondary stresses are found on every other syllable to the left of the main stress: σσ̀σσ̀σσ́σ. Furthermore, those unstressed syllables that are found between stresses are subject to moderate vowel reduction (/ɛ/ > [e], /ɔ/ > [o]). That is, in the example given in the preceding paragraph, the 2nd and 4th syllables would be subject to moderate reduction, but not the 1st or 6th. Unstressed syllables that do not occur between stressed syllables are subject to extreme reduction (/ɛ,e/ > [i]; /o,ɔ/ > [u], /a/ > [ə]). Such syllables will occur in two places: word-final unstressed position and word-initial unstressed position. Given our assumption that extreme reduction in two-

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[18] It should be pointed out, however, that Maiden proposes a tripartite prosodic structure for these words, in which the pretonic unstressed syllables constitute a prosodic domain apart from the stressed syllable.

[19] The descriptions of moderate reduction and extreme reduction in Brazilian Portuguese provided, respectively, by Dukes (1993) and Redenbarger (1981) do not agree in all details. It seems as though dialectal variation regarding some aspects of this pattern.

pattern systems results from nonmoraicity, we must assume the following prosodic structure for Brazilian Portuguese:

(52) Brazilian Portuguese Prosodic Structure (proposed)

$$\sigma\ (\grave{\sigma}_{\mu}\ \sigma_{\mu})\ (\grave{\sigma}_{\mu}\ \sigma_{\mu})\ (\acute{\sigma}_{\mu})\ \sigma$$

Note that in any word with a penultimate main stress, the main stress foot will be monosyllabic under this analysis: the syllable immediately preceding the stress is the weak member of the preceding syllabic trochee, and the following syllable is left unfooted. The unfooted nature of the final syllable can easily be derived using Prince & Smolensky's (1993) **Nonfinality** constraint, which prohibits a foot to stand at the right edge of a word ("the right edge of a word may not align with the right edge of a foot"). This proposal is supported in Brazilian Portuguese by the fact that in words with an antepenultimate main stress, the penultimate syllable (unstressed) is subject to only moderate reduction, suggesting a foot form such as $(\grave{\sigma}_{\mu}\sigma_{\mu})(\acute{\sigma}_{\mu}\sigma_{\mu})\sigma$, for example.

Chapter 4
Predicting Neutralization: Factorial Typology

"If the human mind was simple enough to understand, we'd be too simple to understand it."

~Emerson Pugh

4.0 *Introduction*

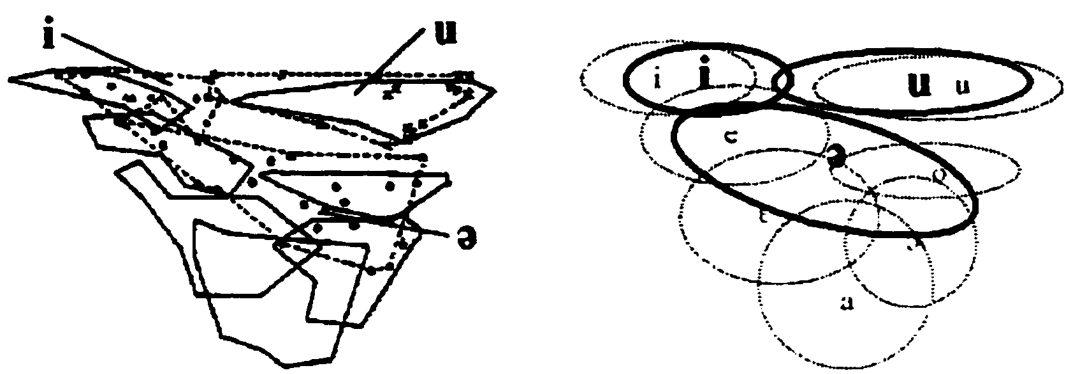
In the preceding chapters, I laid out two sets of constraints that can motivate vowel reduction. As described previously, these constraints only identify the vowel qualities to be avoided, and the contexts in which to avoid them. They do not, however, identify the method that should be used for avoidance. I claim, based on a survey of vowel reduction systems, that the method for avoiding a dispreferred vowel is determined by the relative ranking of the reduction constraint and featural faithfulness constraints. In this chapter, I investigate this claim more thoroughly by considering a factorial typology using the constraints I propose for vowel reduction.

4.1 An Alternative Analysis: Phonetic Determinism

Before investigating the factorial typology of vowel reduction, let's consider an alternative approach to predicting vowel neutralizations: The idea that neutralization patterns are derived from phonetic similarity between vowels. That is, it is possible to imagine that vowel reduction phenomena would be more likely to neutralize pairs of vowels that are already rather similar phonetically—i.e., that the vowels separated by comparatively little distance in the acoustic vowel space will be the vowels that neutralize. In other words, it is possible that vowel reduction is not only phonetically *motivated* by constraints sensitive to universal phonetic factors like enhancing contrast and increasing articulatory ease, but that vowel reduction is also phonetically *determined* by language-specific phonetic facts. In order to test this hypothesis, let's look at the vowel systems of some languages with vowel reduction.

First, let's look at standard Catalan (Recasens 1991, 1986). The vowel distribution of Catalan is shown in figure (53).

(53) Vowel Plots for Stressed and Unstressed Vowels of Catalan (standard): *Left: Illustration from Recasens (1986)—solid-line polygons indicate stressed vowels, and dashed-line polygons indicate unstressed vowels. Right: Schematized version based on figure to left. Dark ellipses represent unstressed vowels, and grey ellipses represent stressed vowels.*

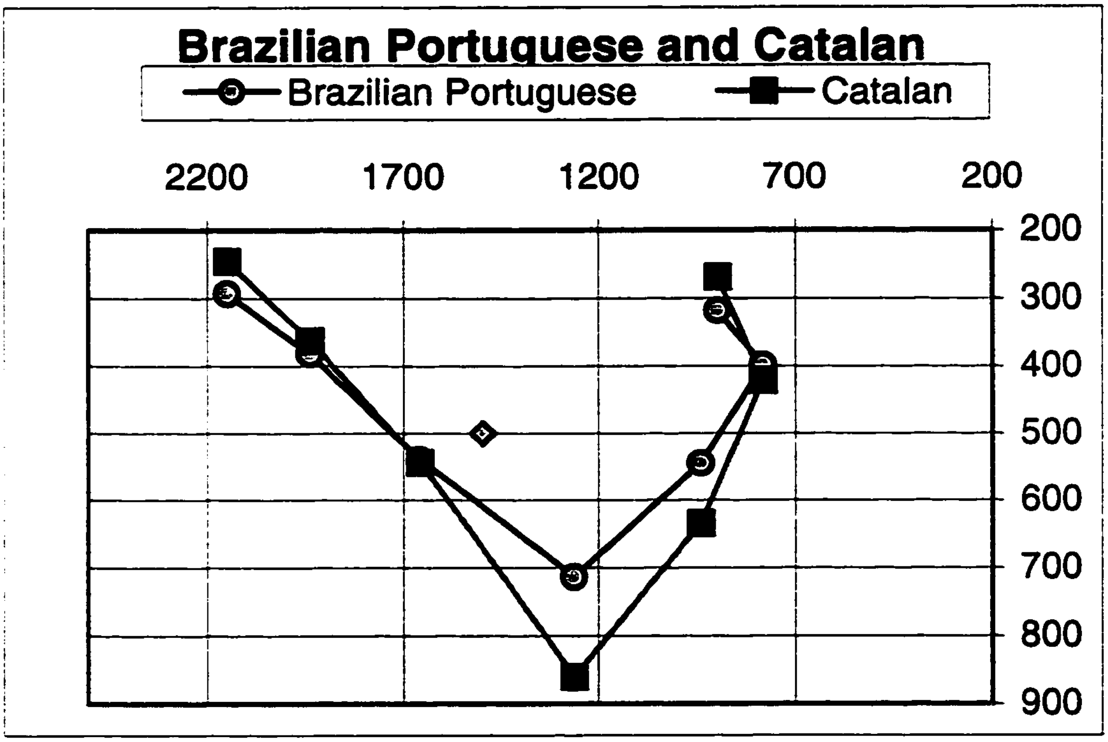


Recall that the Catalan reduction pattern neutralizes /o,ɔ/ to [u], and /e,ɛ,a/ to [ə]. If these neutralizations were phonetically determined, we might expect Catalan *é, ɛ́* to be more similar to *á* or *ə* than *ó, ɔ́* are or, alternatively, that *ó, ɔ́* would be phonetically more similar to *ú* than *é,ɛ́* are to *í*. However, based on the illustrations in figure (53) this does not seem to be the case. In fact, if anything, *é* is more similar to *í* than *ó* is to *ú* (the distributions of *e* and *i* overlap, but the distributions of *o* and *u* do not). Similarly, the distribution of stressed *á* seems to overlap that of *ɛ́* and *ɔ́* equally, and finally, the distribution of unstressed ə seems to include areas populated by all of the stressed mid vowels, although this distribution may be more heavily weighted towards the back of the vowel space (judging by the polygon-based illustration from Recasens).

Given these observations, the hypothesis that Catalan vowel neutralization patterns are phonetically determined by phonetic similarity seems exactly disconfirmed. However, based on examining this one language in isolation, the exact opposite theory of phonetic determinism might seem attractive—perhaps vowels neutralize towards qualities that are *less* phonetically similar to themselves. In order to test this hypothesis, let's compare Catalan with a language possessing a similar underlying vowel system but a different pattern of reduction: Brazilian Portuguese. Both languages have a prototypical 7-vowel system containing /i,e,ɛ,a,ɔ,o,u/. The standard dialects of these languages reduce this 7-vowel inventory to a 3-vowel sub-inventory [i,u,ə] (for Brazilian Portuguese, this occurs only in "extreme" reduction conditions), but they use different neutralizations to produce this sub-inventory. In Brazilian Portuguese, unstressed /e,ɛ/ under extreme reduction neutralize with [i], and unstressed /o,ɔ/ under extreme reduction neutralize with [u], and unstressed /a/ surfaces as [ə]. In Catalan, unstressed /e,ɛ/ reduce to [ə], as does unstressed /a/; on the other hand, Catalan unstressed /o,ɔ/ reduce to [u].

Let's look at the vowel inventories for these vowels under stress as shown in figure (54). The data presented here are average vowel formant frequency values as reported by Recasens (1986) for Catalan and Fails & Clegg (1992) for Brazilian Portuguese. (The point towards the middle of the graph is a prototypical schwa position, similar to the schwa observed in unstressed positions in both languages.)

(54) **Stressed vowels of Catalan and Brazilian Portuguese:** *Based on average formant frequency values from Recasens (1986) and Fails and Clegg (1992).*



From this graph, the Brazilian Portuguese and Catalan stressed vowels systems are quite similar acoustically, although the total acoustic space covered by the Catalan vowels is somewhat larger than the space covered by the Brazilian Portuguese vowels. (This is probably due to speaker variation—for example, the Catalan speakers may have been speaking more slowly.) However, the overall distribution of the vowel qualities is quite similar in the two languages. Note that the vowel *ɛ* in both languages is very similar to *ə*, and *e* in both languages is very similar to *i*. However, these vowels reduce differently in the two languages—in Brazilian Portuguese ("extreme" reduction), the vowels /e,ɛ/ reduce to [i], while in Catalan they reduce to [ə]. The back vowels /o,ɔ/ reduce similarly in both languages (they reduce to [u]).

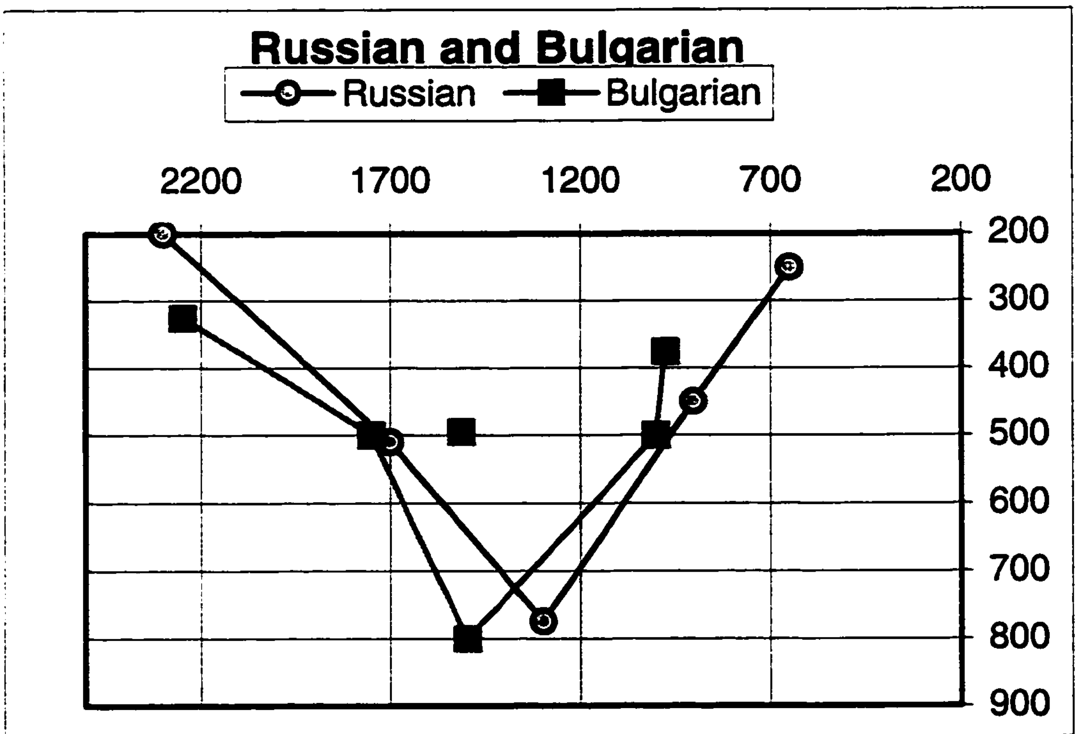
Since Catalan and Brazilian Portuguese have vowel distributions that are phonetically similar, but vowel neutralizations that are different, the hypothesis that vowel neutralizations are determined by language-specific phonetic facts does not appear supported.

A similar conclusion results from comparing vowel neutralizations in Russian and Bulgarian. Contemporary Standard Russian has a prototypical 5-vowel system /i,e,a,o,u/, while Bulgarian has a six vowel system that includes the same 5 vowels seen in Russian, plus a phonemic /ʌ/ (which can occur under stress or stressless). Both languages possess reduction to a low-sonority three-member sub-inventory [i,u,ə] (or [i,u,ʌ])[20]—however, the neutralizations that produce this sub-inventory are different in Bulgarian and Russian.

[20] Recall that [ə] and [ʌ] are represented using different symbols to indicate their different underlying featural content—[ə] is featureless, while [ʌ] is mid, central, unrounded. Acoustically, the Russian [ə] and Bulgarian unstressed [ʌ] are quite similar.

In Russian (extreme reduction), unstressed /e/ raises to [i], while unstressed /a,o/ reduce to [ə]. In Bulgarian, unstressed /e/ reduces to [i], unstressed /o/ reduces to [u], and unstressed /a/ reduces to [ʌ]. In order to test the question of phonetic determinism for these two languages, let's compare the average formant frequencies for the stressed vowels of these languages shown in figure (55). This graph uses the average F1 and F2 formant frequencies for standard Russian and Bulgarian vowels as reported in Lehiste and Popov (1970) for Bulgarian and in Jones (1959) for Russian. (The isolated ■ towards the middle of the chart is the Bulgarian stressed [ʌ].)

(55) **Stressed vowels of Russian and Bulgarian:** *Based on average formant frequency values from Jones (1959) and Lehiste and Popov (1970).*



As shown in this graph, the Bulgarian /o/ and /u/ under stress are quite close, so it might not be surprising that they neutralize under stresslessness. However, for the remaining vowels, this hypothesis does not seem to hold. Consider, for example, Bulgarian /e/, which is quite close to the Bulgarian /ʌ/--however, unstressed Bulgarian /e/ reduces to [i]. Furthermore, Russian /o/ seems to be about equidistant from Russian /u/ and the schwa position (which is roughly similar to the position shown here for Bulgarian /ʌ/), yet Russian /o/ reduces to [ə]. Finally, Russian /e/ seems to be much closer to the schwa position than Russian /o/ is, yet Russian /e/ reduces to [i] when unstressed. These observations suggest that the neutralization patterns for Bulgarian and Russian are not predictable phonetically.

So, it does not appear that the different neutralization patterns found in Bulgarian and Russian on the one hand, and in Brazilian Portuguese and Catalan on the other, are predictable from phonetic similarity. Furthermore, comparing across the languages presented in the two diagrams given above, there does not seem to be any consistent overall patterns predictable from the phonetic data. Finally, it should also be pointed out that the vowel reduction patterns seen in certain dialects of Russian and Bulgarian support the idea that neutralizations are not phonetically predictable. In these dialects, the neutralizations observed depend on the type of unstressed syllable undergoing reduction—i.e., they have two-pattern reduction systems. In certain southern Russian dialects, unstressed /e/ reduces to [a] in the syllable immediately preceding the stress, but reduce to [i] in other unstressed syllables. Similarly, in many of the Rhodope dialects of

Bulgarian, unstressed /e/ and /o/ reduce to [a] pre-tonically, but reduce to [i] and [u] (respectively) post-tonically (Miletich 1936).

4.2 Factorial Typology

Since patterns of neutralization do not seem to be predictable (at least based on phonetic data), let's proceed to investigate the claim that patterns of neutralization result from the relative ranking of vowel reduction constraints and featural faithfulness constraints. In order to test this claim, I have calculated a factorial typology for vowel reduction.

4.2.0 The Importance of Factorial Typologies

One of the cornerstones of Optimality Theory (McCarthy and Prince 1993, Prince and Smolensky 1993), is the tenet that all Optimality-Theoretic constraints are universal: All languages (purportedly) possess the same set of universal constraint, and differ only in the ranking of these constraints.[21] This hypothesis, if true, predicts that the acquisition of phonology is largely a matter of learning a language-specific ranking for universal constraints. Computational models of the learning of constraint rankings have been implemented (Tesar and Smolensky 1996, Tesar 1995), showing that constraint rankings are learnable through the application of simple algorithms. Therefore, the concept of universal constraints and language-specific rankings simplifies the language-acquisition

[21] Of course, some developments, such as the use of morpheme-specific constraints would introduce at least some language-specific constraints.

task by limiting the amount of language-specific information and computation necessary to learn a phonology.

Among other things, this means that any proposed analysis in Optimality Theory should account not only for the language under consideration, but should be capable of predicting what the legal variations on this pattern are. A child—armed with the suggested constraint set—should be able to acquire any possible variation of this language simply by installing the correct rankings between constraints. That is, if the constraints used in a novel analysis are truly universal, it should be possible for the *same constraints* to occur in a different language—but with a *different ranking*. In order to evaluate the predictive capability of suggested constraints, a factorial typology is generated and examined. A factorial typology is the predicted range of language variation that would result from all possible re-rankings of the suggested constraints—constraints are ranked in all logically possible manners, and the surface patterns they generate are identified as possible (or *predicted*) languages. Two questions should be asked when judging a factorial typology:

> **1. Adequacy:** Are there attested language patterns that are not predicted by the factorial typology?
>
> **2. Overgeneration:** Does the factorial typology predict the occurrence of impossible language patterns?

If the answers to both questions are "No", the likelihood increases that the suggested constraints truly are authentic members of the set of universal phonological constraints; if the answer to one or the other is "Yes", this likelihood decreases. It should be noted, however, that a "yes" answer to question #1 is a more serious flaw than a "yes" answer to question #2. That is, if an analysis predicts that a given language pattern is possible, but this language pattern is unattested, it is always possible that this is an *accidental gap*: i.e., that the appropriate language has simply not been identified yet, or is undocumented. It is more serious if an attested language pattern is ruled out as impossible by the proposed analysis. In fact, failure to achieve typological adequacy is often considered a fatal flaw for a proposed analysis, while overgeneration is often tolerable (i.e., if the gaps are plausibly accidental).

With this in mind, the analysis that I propose for phonological vowel reduction was subjected to the factorial typology test. Factorial typologies were generated for hypothetical 5-vowel and 7-vowel languages (with the canonical /i,u,e,o,a/ and /i,u,e,o,ɛ,ɔ,a/ inventories, respectively.) The typologies included the vowel reduction constraints Lic-Nonperiph, Lic[F], Lic[MidLax], and *Unstressed/-high discussed in chapter 2.[22] In the following sections, I will discuss how the factorial typology was produced, and how it stands with respect to the criteria of adequacy and overgeneration.

4.2.1 Producing the Factorial Typology

Factorial typologies were produced for two hypothetical languages: one hypothetical 5-vowel language with the vowel inventory /i,u,e,o,a/, and one hypothetical 7-vowel language with the vowel inventory /i,u,e,o,ɛ,ɔ,a/. The lexicons of these

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[22] The vowel reduction constraints Lic[MidTense] and Lic[Color] were not included since cross-linguistic evidence supporting these categories is not as robust as for the other constraints named above.

hypothetical languages consist of (respectively) five and seven words for the form /tVtá/, where V is an unstressed and/or nonmoraic vowel of a paticular quality. For clarity, the input forms used for each language are listed below.

(56) Hypothetical Input Forms Used in Factorial Typologies

Five-Vowel Language	Seven-Vowel Language
/titá/	/titá/
/tutá/	/tutá/
/tetá/	/tetá/
/totá/	/totá/
/tatá/	/tɛtá/
	/tɔtá/
	/tatá/

For each hypothetical input form, a series of possible candidate outputs was constructed. For thoroughness, I included candidate outputs where the unstressed/nonmoraic vowel either (1) remained faithful (no reduction), (2) was replaced with a different phonemic vowel quality of the language (all replacements were considered), and (3) was replaced by [ə]. Each input~output pair was then assessed for violations of the vowel reduction constraints as well as a full slate of featural faithfulness constraints. For clarity, all the input~output pairs for the hypothetical input /titá/ in a 5-vowel language are shown below, along with their constraint violations.[23] Note that violations are represented numerically, thus "1" indicates a single violation of the given constraint, while "0" indicates the given constraint is unviolated. As mentioned in previous sections, I am

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[23] The constraints Dep +ATR, Dep –ATR, Max +ATR, Max –ATR were added for the hypothetical 7-vowel language, but were not used in the hypothetical 5-vowel language to reduce processing time.

assuming that [ə] is featurally unspecified. Therefore, the only faithfulness violations involved in reduction to [ə] are Max[F] violations as underlying feature specifications are deleted and not replaced with anything. Also, as mentioned in chapter 1, I am assuming that /a/ is not specified for the feature [front]. This is because an early factorial typology with /a/ specified as [-front] produced erroneous results with /a/ reducing to [u] to maintain the underlying [-front] specification.

(57) Output Candidates for Unstressed /i/:

Input: /titá/	[titá]	[tutá]	[tetá]	[totá]	[tatá]	[tətá]
Lic-Nonperiph	0	0	1	1	0	1
Lic-LaxMid	0	0	0	0	0	0
Lic-[F]	1	1	1	1	1	0
*Unstressed –high	0	0	1	1	1	1
Dep +hi	0	0	0	0	0	0
Dep –hi	0	0	1	1	1	0
Dep +lo	0	0	0	0	1	0
Dep –lo	0	0	0	0	0	0
Dep +front	0	0	0	0	0	0
Dep – front	0	1	0	1	0	0
Dep round	0	1	0	1	0	0
Max +hi	0	0	1	1	1	1
Max –hi	0	0	0	0	0	0
Max +lo	0	0	0	0	0	0
Max –lo	0	0	0	0	1	0
Max +front	0	1	0	1	1	1
Max –front	0	0	0	0	0	0
Max round	0	0	0	0	0	0

Similar sets were generated for the remaining underlying vowel qualities. The input~output pairs resulting from this process were then subjected to a computerized factorial typology algorithm. All logically possible rankings of these constraints are compiled, and each ranking is applied to the input~output pairs provided. This was performed via computer, using Hayes' (1996) Ranker software. The set of winning output candidates generated by each distinct ranking of constraints can be thought of as a logically possible language pattern. Therefore, each distinct set of winning output candidates should either correspond to an actually-attested language, or the absence of such a language should be a reasonable accidental gap.

It should be pointed that the number of possible rankings for *n* constraints is *n*! (*n factorial*). So, for a set of 3 constraints, there are 6 possible constraint rankings (3!= 3x2x1=6), and therefore six possible grammars containing those three constraints. However, this does not mean that there are three distinct language patterns generated by these grammars. Often, the same language pattern is generated by more than one of the possible grammars. To illustrate this, consider the situation shown in (58).

(58) A Hypothetical Factorial Typology:

Purportedly Universal Constraints:	CAT = "Don't let the cat out." WINDOW = "Open the window." DOOR = "Open the door."
Possible rankings:	*Result of each ranking*[24]*:*
1. CAT » WINDOW » DOOR	The cat stays in; neither the door nor window is opened.
2. CAT » DOOR » WINDOW	The cat stays in; neither the door nor window is opened.
3. WINDOW » CAT » DOOR	The cat gets out; the window is opened but not the door.
4. WINDOW » DOOR » CAT	The cat gets out; both the window and door are opened.
5. DOOR » CAT » WINDOW	The cat gets out; the door is opened but not the window.
6. DOOR » WINDOW » CAT	The cat gets out; both the door and window are opened.

Grammars 1 and 2 generate the same result; so do grammars 4 and 6.

As shown in (58), there are six logically possible grammars containing the three constraints provided. However, these six grammars only generate four distinct output patterns. This is due to the fact that some of the grammars are *homophonous*: They generate the same output pattern. In this case, grammars 1 and 2 both result in the cat staying in and neither the window nor the door being opened, and both grammars 4 and 6 result in the cat getting out and both the window and the door being opened (see fn. 24). This homophony is caused by the fact that the constraints DOOR and WINDOW are not in conflict: Changing the ranking of these two constraints does not affect the output pattern. Therefore, it is possible to abbreviate homophonous grammars by eliminating rankings that do not affect the output pattern. For example, both grammars 1 and 2 can be reduced to the partial grammar CAT » WINDOW, DOOR. This notation indicates that CAT outranks both WINDOW and DOOR, but that no ranking exists between WINDOW and DOOR. Similarly, the grammars 4 and 6 can be reduced to the partial grammar WINDOW, DOOR » CAT. It should be emphasized that a *partial* grammar like WINDOW, DOOR » CAT is shorthand for two homophonous *total* grammars. In other words, certain output patterns are consistent with more than one total grammar. This is an important point, since it is conceivable that the frequency of a given output pattern could be affected by the number of total grammars that generate it: An output pattern that

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[24] Assuming, of course, that the cat *will* always get out if there is a possible escape route left open.

is generated by several different grammars might be more frequently encountered in the world's languages than an output pattern that is generated by only one grammar.[25]

With this in mind, the results of the factorial typology I present do *not* show illustrations of "all possible rankings", but all rankings that produce distinct output patterns. In other words, I will be discussing possible surface patterns of reduction, not possible rankings. All predicted output patterns plus the grammars that generate them are listed in appendices B and C.

Now that is clear how the factorial typologies were produced, I will proceed to consider the questions of adequacy and overgeneration.

4.2.2 The Question of Adequacy

In order to evaluate the question of adequacy, I compiled a database of as many vowel-reduction languages as I could find. The resulting database includes over 40 vowel reduction patterns. A complete listing of these attested patterns can be found in Appendix A. Some of the languages included in the survey are not 5- or 7-vowel languages, but many of them are. The only two languages included in the database that are not also included in the typology represent vowel patterns that were purposefully excluded from the factorial typology experiment—Standard Slovene and Luiseno. As discussed in chapter 2, the vowel reduction constraints proposed for these two languages do not have the same robust cross-linguistic evidence seen for the remaining vowel

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[25] With the caveat that other factors could also conceivably affect frequency. For example, some constraints might have universal rankings imposed on them. This would affect frequency.

reduction constraints. Additionally, as discussed in chapter 2, the exact nature of the neutralized vowels in Standard Slovene vowel reduction is not completely understood (Lehiste 1961). All other 5- and 7-vowel languages included in the database are predicted as possible language patterns by the factorial typology. Therefore, based on the available evidence, the proposed factorial typology seems to be empirically adequate.

4.2.3 The Question of Overgeneration

The factorial typology produced a total of 235 possible 5- and 7-vowel reduction patterns (43 for 5-vowel systems and 192 for 7-vowel systems). Since the empirical database contains fewer than 235 attested reduction patterns, it is not surprising that the factorial typology contains a number of gaps, as summarized in (59) below. The category referred to as "Indirectly Attested" refers to predicted reduction patterns that are not perfect matches for any attested pattern, but which are highly similar to attested patterns. For example, predicted reduction pattern #3 (/u/ > [ə]) is unattested, but is highly similar to predicted reduction pattern #4 (/i/ > [ə]), which is attested in Pavlikianski Bulgarian.

(59) Attestation Rates for Factorial Typology of Vowel Reduction

Total # of Predicted Patterns	# Attested	# Indirectly Attested	# Unattested
235	27 (11.5%)	49 (21%)	159 (67.5%)

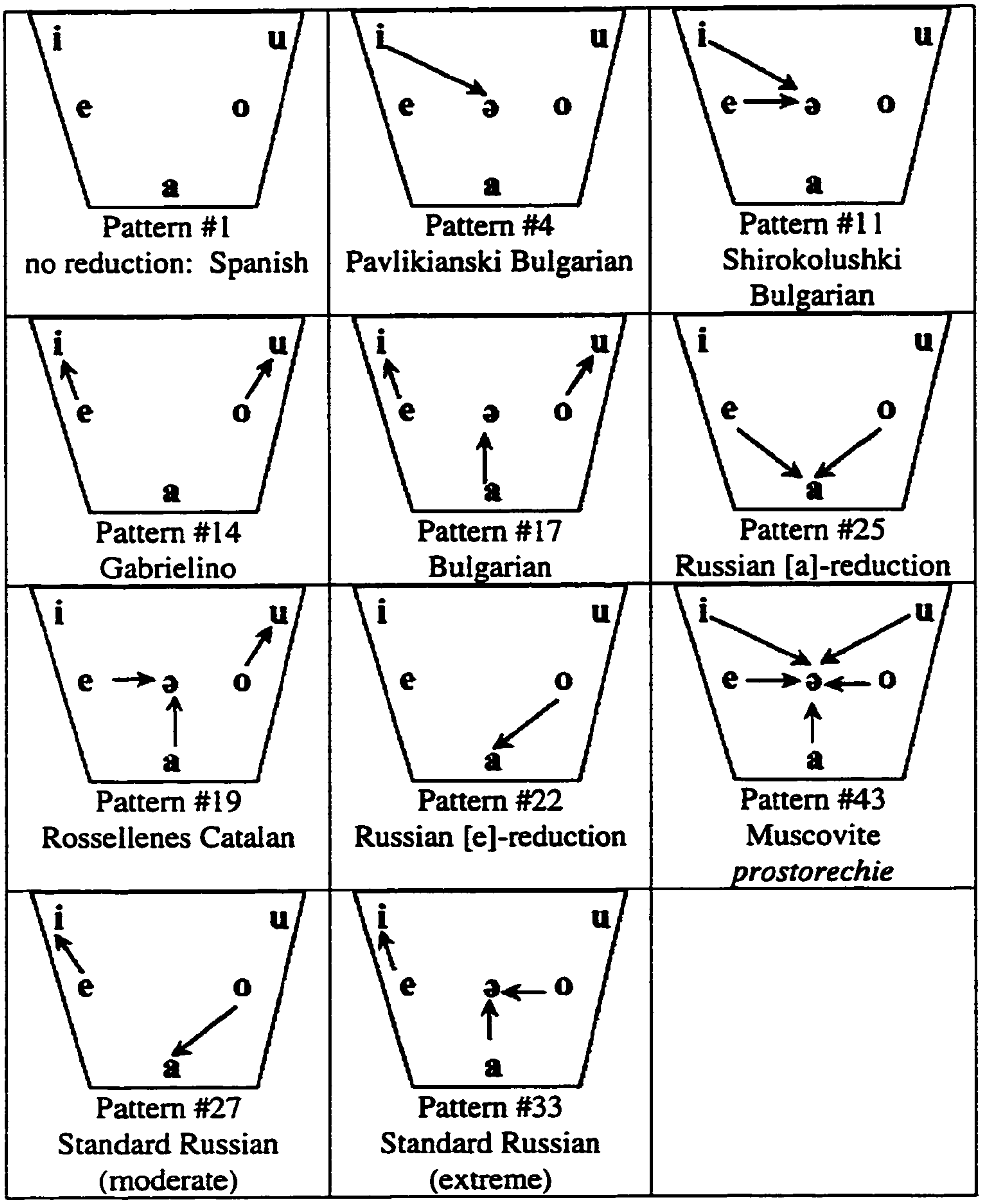
As inidicated by this table, a whopping 67.5% of the predicted patterns are unattested. However, based on an examination of the predicted patterns, none of these gaps in the predicted typology seem to be principled—they are all plausible accidental gaps in the typology. Furthermore, examination of the pattern of attestation rates as a function of number of crucial rankings needed to produce a given predicted output pattern reveals an interesting pattern: attestation rates are higher for output patterns with fewer crucial rankings; outupt patterns that require several crucial rankings are uniformly unattested. This pattern will be elaborated on in section 4.2.3.3. In addition, many of the unattested patterns bear striking resemblances to attested patterns. For example, some logically possible but unattested patterns for reducing 5-vowel systems bear striking resemblances to attested patterns for reducing 7-vowel systems. Importantly, it does not seem to be possible to predict *a priori* which will be the attested patterns and which will be the unattested patterns. In other words, it does not seem possible to eliminate the unattested patterns from the typology in any principled way—they are all plausible accidental gaps. In fact, any attempt to rule out some subset of the unattested patterns in a principled way seems to simultaneously rule out other, attested, patterns.

Since discussion of all 235 predicted pattens would be unwieldy and possibly umbersome for the reader, I will instead focus here only on the 43 patterns predicted by the smaller typology (5-vowel patterns). The larger typology (192 seven-vowel patterns) is similar in its attestation pattern. The larger typology will be considered in summary in section 4.2.3.3. Both typologies are presented in full in appendices B and C, including a helpful overview of the predicted patterns and their attestation status at the beginning of each of the typologies. Of the 43 patterns predicted for 5-vowel languages, 20 are not attested at all, 11 are unattested but highly similar to attested patterns, and 11 are attested.

For ease of comparison, these patterns are discussed in the following section by their attestation status.

4.2.3.0 Attested Patterns

(60) Attested Patterns for 5-Vowel Inventories (n=11)



Pattern #1 no reduction: Spanish

Pattern #4 Pavlikianski Bulgarian

Pattern #11 Shirokolushki Bulgarian

Pattern #14 Gabrielino

Pattern #17 Bulgarian

Pattern #25 Russian [a]-reduction

Pattern #19 Rossellenes Catalan

Pattern #22 Russian [e]-reduction

Pattern #43 Muscovite *prostorechie*

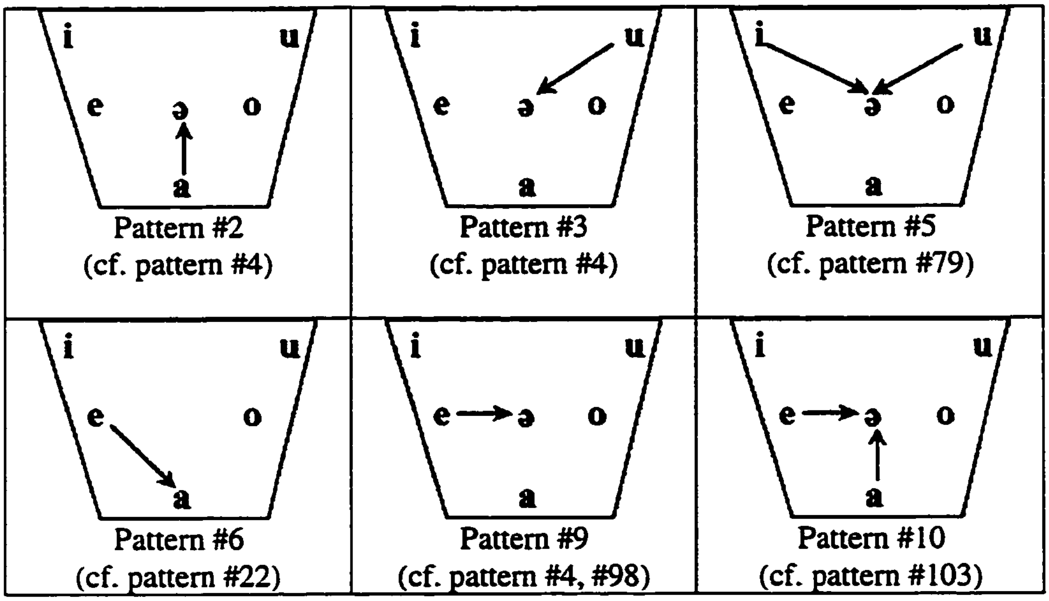
Pattern #27 Standard Russian (moderate)

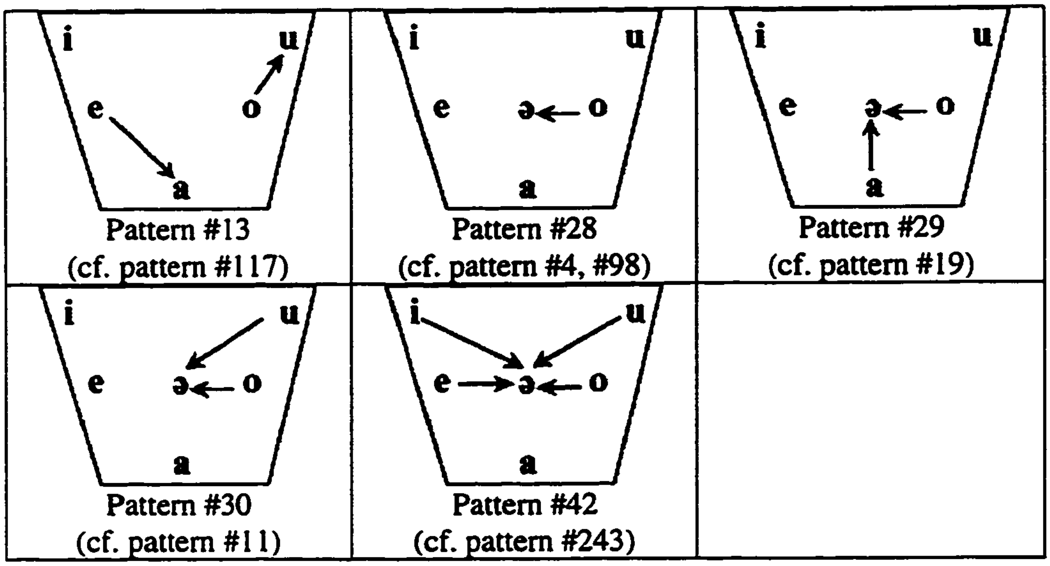
Pattern #33 Standard Russian (extreme)

For each of the attested patterns shown above, a single language is provided as an example of a language which attests for that particular reduction pattern. It should be noted, however, that this does not mean that the language named is the only language in which that pattern is attested. For example, lack of reduction (pattern #1) is found quite commonly in 5-vowel languages. Similarly, pattern #25 is attested not only in Russian dialects with [a]-reduction, but also in Rhodope Bulgarian. (For bibliographical information on the languages listed here and throughout the discussion on factorial typology, please refer to Appendix A.)

4.2.3.1 Indirectly Attested Patterns

(61) 'Indirectly Attested' Patterns for 5-Vowel Inventories (n=11)





Pattern #13 (cf. pattern #117)

Pattern #28 (cf. pattern #4, #98)

Pattern #29 (cf. pattern #19)

Pattern #30 (cf. pattern #11)

Pattern #42 (cf. pattern #243)

The 11 patterns listed above are predicted by the typology, but are not directly attested. However, each of these patterns is highly similar to either one of the 11 attested 5-vowel patterns, or an attested 7-vowel patterns. For example, patterns #2,3,9,28 all involve reduction of a single vowel to [ə]. In this respect, they are all similar to the attested pattern #4 (Pavlikianski Bulgarian, /i/ > [ə]). For ease of comparison, the following chart summarizes the resemblances. Since these unattested patterns are so similar to attested patterns, we can think of them as "indirectly attested" since it is highly likely that the absence of these patterns is accidental, and any attempt to rule out these unattested patterns would likely incorrectly rule out the corresponding attested pattern(s).

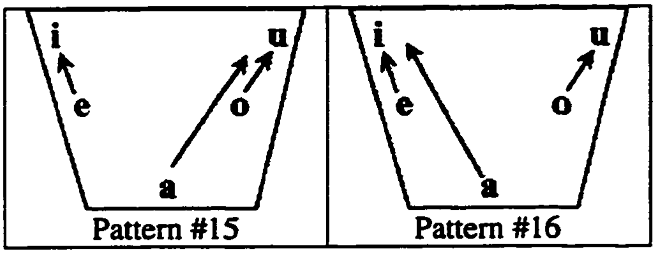
(62) Indirect Attestations of 11 Predicted Reduction Patterns

Unattested Pattern	Similar Attested Pattern(s)
#2: only /a/ reduces (/a/ > [ə])	#4, Pavlikiankski Bulgarian: only /i/ reduces (/i/ > [ə])
#3: only /u/ reduces (/u/ > [ə])	#4, Pavlikiankski Bulgarian: only /i/ reduces (/i/ > [ə])
#5: only /i,u/ reduce *in a 5-vowel language*(/i,u/ > [ə])	#79, Upper Carniolan Slovene: only /i,u/ > [ə] *in a 7-vowel language*
#6: only /e/ lowers to [a] (/e/ > [a])	#22, Russian with [e]-reduction: only /o/ lowers to [a] (/o/ > [a])
#9: only /e/ reduces (/e/ > [ə])	#4, Pavlikiankski Bulgarian: only /i/ reduces (/i/ > [ə]); #98, Sadzhava Ukrainian: only front mid vowels reduce (/e,ɛ/>[ə])
#10: only /e,a/ reduce (/e,a/ > [ə]), *in a 5-vowel language*	#103, Balear Catalan: only /e,ɛ,a/ > [ə] *in a 7-vowel language*
#13: /e/ lowers and /o/ raises, *in a 5-vowel language* (/e/ > [i], /o/ > [u])	#117, Algueres Catalan /e,ɛ/ lower to [a], and /o,ɔ/ raise to [u]
#28: only /o/ reduces (/o/ > [ə])	#4, Pavlikiankski Bulgarian: only /i/ reduces (/i/ > [ə]); #98, Sadzhava Ukrainian: only front mid vowels reduce (/e,ɛ/>[ə])
#29: only /o,a/ reduce (/o,a/ > [ə])	#19, Rossellenes Catalan: only /e,a/ reduce (/e,a/ > [ə])
#30: only /u,o/ reduce (/u,o/ > [ə])	#11, Shirokolushki Bulgarian: only /i,e/ reduce (/i,e/ > [ə])
#42: all vowels but /a/ reduce, *in a 5-vowel language* (/i,u,e,o/ > [ə])	#234, Northern Italian: all vowels but /a/ reduce in 7-vowel lang.

4.2.3.2 Unattested Patterns

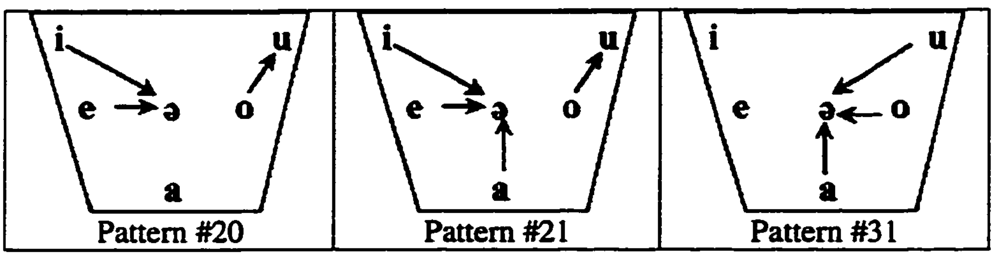
Finally, there were also 20 patterns that are not attested, and which bear only passing resemblance to any attested pattern. These patterns are presented and discussed in small groups in the following paragraphs.

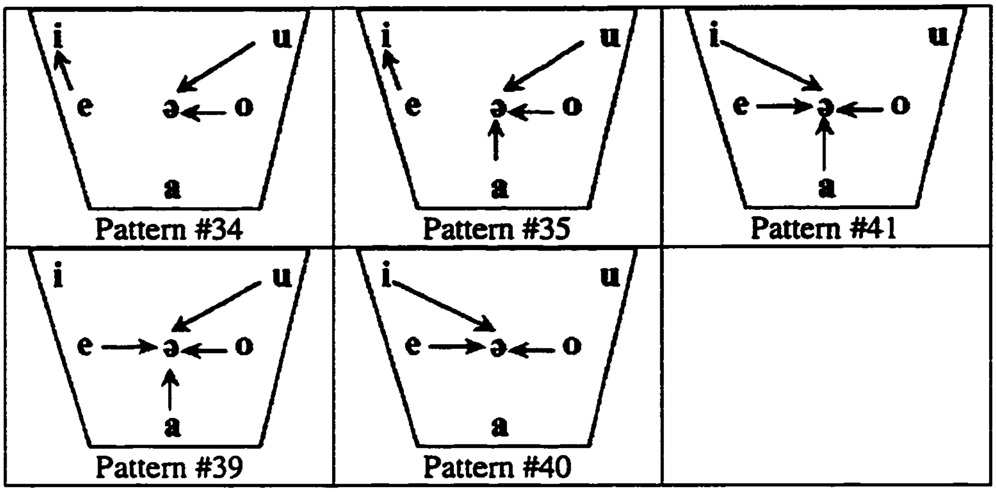
(63) Unattested Patterns #15 and #16: Reduction of /a/ to a color-bearing vowel



These two unattested patterns are unusual in that the vowel /a/ is never seen to reduce to a color-bearing vowel (such as /e/ or /o/) in any attested reduction pattern. These two patterns result from a ranking which favors insertion of vowel feature specifications, and where it is simultaneously very important to avoid sonorous unstressed vowels as well as to avoid unstressed nonperipheral vowels (included [ə]). The end result is that the sonorous unstressed vowel /a/ is replaced by a low-sonority vowel that is also peripheral (i.e., either [i] or [u]). Either this pattern of reduction is not very common (and therefore, difficult to find attestation for), or it is universally preferable to avoid insertion of color features such as [round] or [+front] than it is to avoid high-sonority unstressed vowels (i.e. Dep[round], Dep[+front] universally outrank *Unstressed/[-high]). Due to lack of evidence pertaining to this question, I leave it unanswered for the time being.

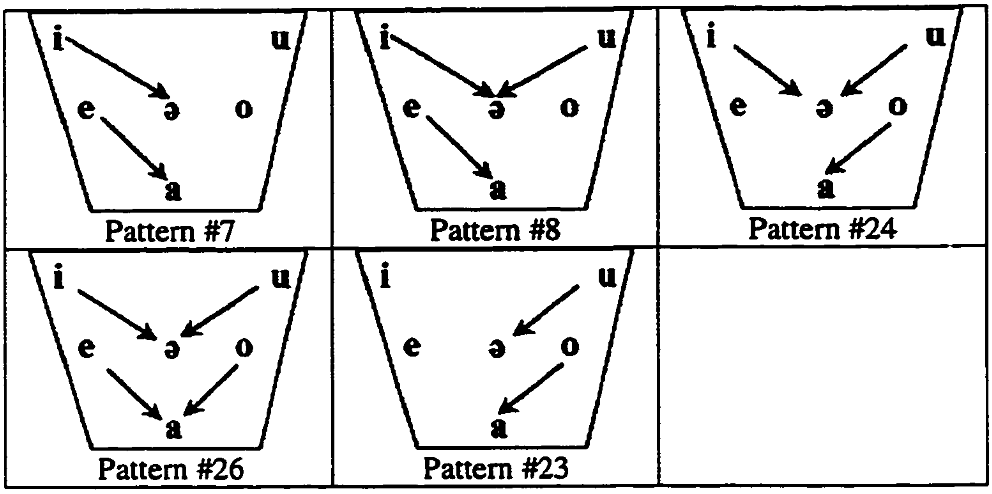
(64) Unattested patterns with centralization of high vowels





The eight patterns illustrated above are all unattested, and all involve centralization of a high vowel to [ə]. Since centralization of high vowels is somewhat uncommon cross-linguistically, it might at first glance appear possible to rule these patterns out by somehow barring or limiting centralization of high vowels. However, this approach proves to be untenable, since there are some patterns in which high vowels do undergo centralization. Notable examples include the Upper Carniolan Slovene reduction pattern (#79), in which only the high vowels /i,u/ reduce to [ə], as well as the Pavlikianski Bulgarian reduction pattern (#4), in which only the high vowel /i/ undergoes reduction to [ə]. The vowel reduction pattern seen in Shirokolushki Bulgarian (pattern #11, /i,e/ > [ə]) is also pertinent here, demonstrating that reduction patterns in which one high vowel and one mid vowel simultaneously centralize to [ə] cannot be ruled out.

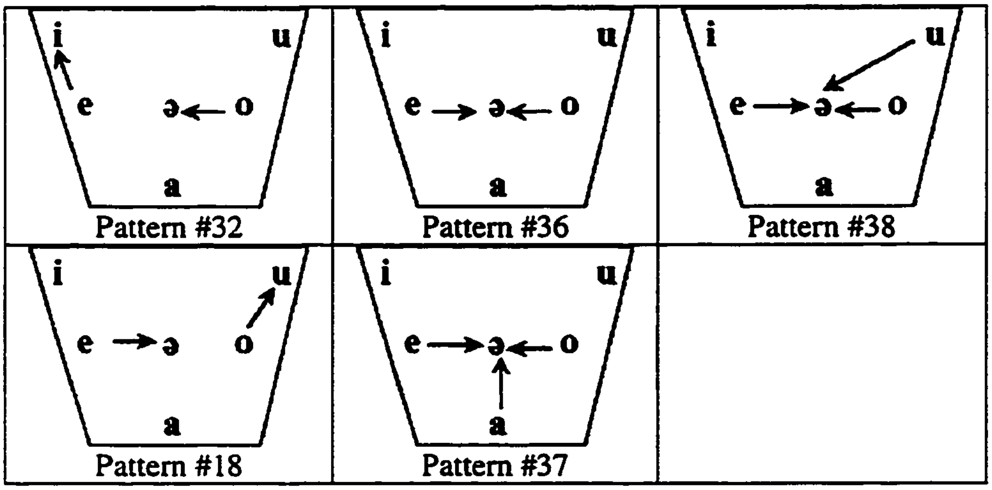
(65) **Unattested Patterns With "Double Lowering"**



The five unattested patterns shown above all involve "double lowering"—that is, one or both high vowels lower via centralization to [ə], while one or both mid vowels lower to [a]. As noted above, centralization of high vowels is not common cross-linguistically, but is attested—therefore, the 5 unattested patterns cannot be ruled out simply because they involve centralization of high vowels. It may at first glance appear strange for high vowels to reduce to [ə] while other vowels of higher sonority are either immune to reduction, or reduce in a different way. One might suppose (incorrectly) that if the high vowels reduce to [ə], then all other vowels must *also* reduce to [ə]. However, this approach again gives incorrect results. Consider, for example, the reduction pattern seen in Northern Italian dialects (#234), in which all vowels *except /a/* reduce via centralization to [ə] in syllables preceding the stress. This provides a very striking case in which the high vowels /i,u/ undergo centralization to [ə], while the highly sonorous vowel

/a/ is immune. The reduction pattern seen in Lower Carniolan Slovene also provides an example of centralization of high vowels in conjunction with a non-centralizing reduction of other vowels. In this language, the high vowels /i,u/ centralize to [ə], while the lax and tense mid vowels /e,ɛ,o,ɔ/ undergo neutralization for tenseness (producing mid vowels that are either lax or unspecified for lax/tense, see chapt. 2). Based on these examples, it does not seem possible to rule out "double lowering" in principle.

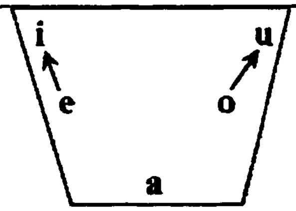
(66) Unattested patterns with centralization of mid vowels



Finally, the last five unattested reduction patterns involve centralization of mid vowels. These three patterns are illustrated above. Again, it does not seem possible to rule out these three patterns in any principled way. For example, reduction of mid vowels to [ə] is observed in many attested reduction patterns, although it is usually accompanied by reduction of /a/ to [ə]. One might (incorrectly) hypothesize that mid vowels cannot reduce to [ə] unless the low vowel /a/ concomitantly centralizes. However, the reduction pattern observed in Sadzhava Ukrainian (#98) provides a counteraxample to this hypothesis. In this language, the front mid vowels /e,ɛ/ undergo reduction to [ə] while the low vowel /a/ is immune to reduction.

4.2.3.3 Attestation Rate by Number of Strata

In the preceding paragraphs, we've seen that although the unattested reduction patterns for 5-vowel languages seem to fall into certain groups of patterns, we cannot in principle rule these patterns out as impossible—attempts to do so would incorrectly rule out attested patterns. What accounts for the fact that precisely these patterns are empirically unattested? I believe that the answer lies in frequency. Recall that the number of rankings for *n* constraints is *n!*. Furthermore, if two constraints do not conflict in a given grammar, their rankings can be reversed without affecting an input pattern. Output patterns that rely on fewer set rankings between constraints will have greater flexibility in terms of the number of possible constraint re-rankings they allow. For example, pattern #14 (illustrated below) is a rather frequent reduction pattern.

<table>
<tr>
<td>

Pattern #14</td>
<td>Attested in: Gabrielino, Asia Minor Greek, dialectal Polish, Horjulj Slovene, Ecuadorian Spanish</td>
</tr>
</table>

In order to achieve this pattern of reduction, the constraints under consideration need to be arranged into only 2 *strata*. A stratum is a group of constraints which may be freely re-ranked among themselves, but which as a group must outrank some other group of constraints. This is illustrated below for reduction pattern #14:

Stratum 1			Stratum 2
Lic-Nonperiph	Max +front	Dep –low	Dep +high
Dep round	Max –front	Max +low	Max -high
Max round	Dep –high	Max –low	*Unstressed[-high]
Dep +front	Max +high		Lic-[F]
Dep –front	Dep +low		

In other words, reduction pattern #14 will result so long as the two reduction constraints *Unstressed/-high and Lic-[F] and the two faithfulness constraints Dep +high and Max –high are ranked at the bottom of the constraint hierarchy. All other constraints can be freely re-ranked with respect to one another. However, not all of the patterns predicted by the factorial typology have only two constraint strata—some have as many as 5 strata. Not surprisingly, there is a strong correlation between the complexity of a predicted reduction pattern and the number of constraint strata it requires: more complex patterns require more strata. Increasing the number of strata is the same as increasing the number of rankings that crucially need to be specified in a grammar, which simultaneously decreases the number of constraints that can be freely re-ranked within a grammar. The 43 reduction patterns predicted by the factorial typology include: eight 2-stratum patterns, twenty-six 3-stratum patterns, five 4-stratum patterns, and four 5-stratum patterns. They break down as follows:

(67) **Attestation Rate By Strata: 5-Vowel Languages**

	total number	attested	indirectly attested	unattested
2-stratum patterns	**8**	5 (62.5%)	0	3 (37.5%)
3-stratum patterns	**26**	6 (23%)	12 (46%)	8 (31%)
4-stratum patterns	**4**	0	0	4 (100%)
5-stratum patterns	**5**	0	0	5 (100%)

These figures show that the highest rate of attestation (62.5%) is found in the 2-stratum grammars, while the lowest attestation rates (0%) are found in the 4- and 5-stratum grammars. An intermediate attestation rate (23%) is found in the 3-statum grammars, with a high rate of indirect attestion (46%). If we assume that the grammar of an actual language is not arranged in terms of strata, but in terms of a total ranking of constraints, this means that there will be more possible languages (i.e., total rankings) that are consistent with a 2-stratum pattern than there are that are consistent with a 3-stratum pattern, etc. Therefore, we might plausibly expect the 2- and 3-stratum patterns to be more frequent in the world's languages than 4- and 5-stratum grammars. This could account for the observed attestation patterns. In other words, unusual unattested patterns such as "double lowering" and centralization of high vowels to [ə] could be unattested in the current survey simply because these patterns only result from certain, very particular rankings of constraints which have a low relative frequency empirically. This hypothesis is supported by the fact that similar attestation rates are found for the 7-vowel typology.

Attestation rates by strata for the entire 235-pattern typology (i.e., including both 5-vowel and 7-vowel typologies) are provided below:

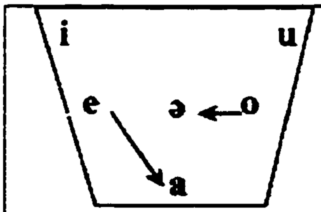
(68) Attestation Rate By Strata: All 235 Predicted Patterns

	total number	attested	indirectly attested	unattested
2-stratum patterns	**21**	11 (52.3%)	3 (14.3%)	7 (33.3%)
3-stratum patterns	**127**	16 (12.5%)	46 (36.3%)	65 (51.2%)
4-stratum patterns	**55**	0	0	55 (100%)
5-stratum patterns	**32**	0	0	32 (100%)

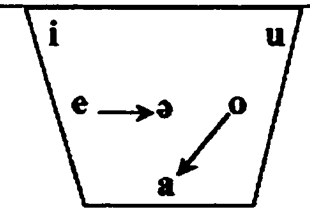
4.2.4 Some Impossible Vowel Reduction Patterns

Although the factorial typologies produced for 5- and 7-vowel languages included over 200 predicted reduction patterns, it is worth emphasizing that there are certain logically-possible reduction patterns that are **not** predicted as possible by the typologies. For example, the reduction pattern illustrated below is not included in the factorial typology:

(69) Not Predicted: Centralization plus Lowering



(unattested)



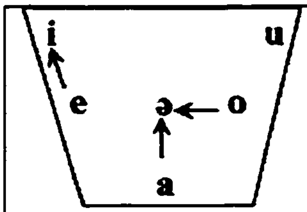
(unattested)

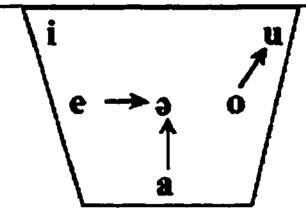
Impossible: lowering of one mid vowel with centralization of the other in a 5-vowel system.[26]

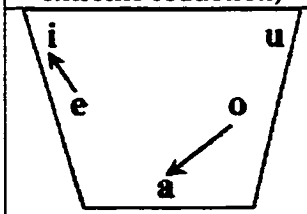
[26] Combination of lowering of one mid vowel with centralization of another is predicted, however, for 7-vowel languages, where tense and lax mid vowels can reduce differentially. The typology does not, however, predict 7-vowel reduction patterns where centralization and lowering are combined within a single ATR class (i.e., no patterns with /ɛ/ > [ə] while /ɔ/ > [a] or vice versa).

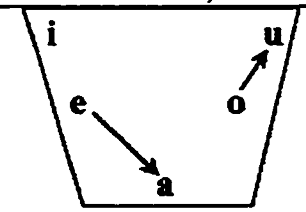
This type of pattern is ruled out because if reduction to [a] is possible for one mid vowel, it should also be possible for the other. Under my approach, the only plausible reason for the second mid vowel to be immune to lowering is in order to preserve its color features (i.e., rounding and palatality). Since centralization does not preserve color features, it is not predicted that the second mid vowel would centralize while the first lowers. This is an interesting prediction, since superficially similar patterns of asymmetrical vowel reducton are predicted by the typology, and many of these patterns are attested. For example, patterns with centralization of one mid vowel and raising of the other are both predicted by the typology and attested empirically, as are patterns with lowering of one mid vowel and raising of the other:

(70) Predicted Patterns: Asymmetrical Raising w/ Centralization/Lowering

<table>
<tr>
<td>

Pattern #33 (Russian, extreme reduction)</td>
<td>

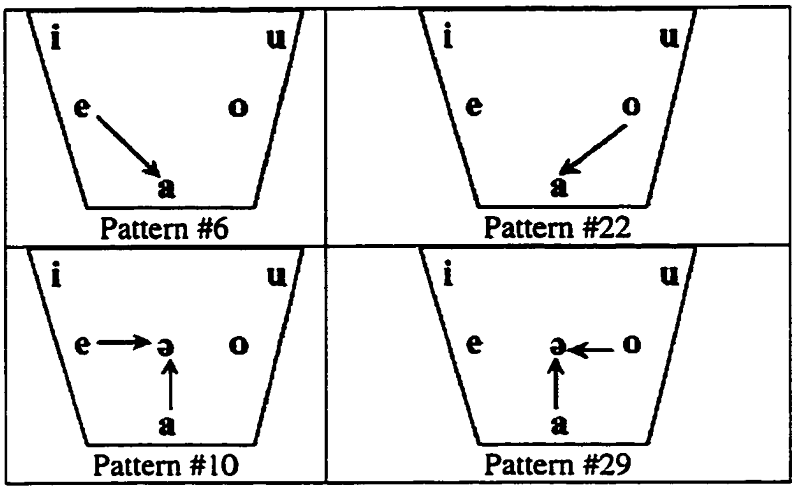
Pattern #19 (Rossellenes Catalan)</td>
<td>Attested: raising of one mid vowel with centralization of the other.</td>
</tr>
<tr>
<td>

Pattern #27 (Russian, moderate reduction)</td>
<td>

Pattern #13 (Algueres Catalan)</td>
<td>Attested: lowering of one mid vowel and raising of the other.</td>
</tr>
</table>

In these cases, the different behavior of the front and back mid vowels is caused by different rankings for faithfulness constraints pertaining to color features. That is, these patterns can be seen as basically centralization patterns (top two, #33 and #19) or basically lowering patterns (bottom two, #27 and #13), but this "default" neutralization pattern of either centralization or lowering is blocked by a high ranking Max[F] constraint such as Max[+front] or Max[round]. The high-ranking Max[F] constraint forces one or the other mid vowel to raise rather than lower/centralize. Variants on these asymmetrical patterns involving lack of vowel reduction are also predicted.

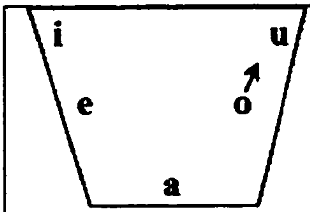
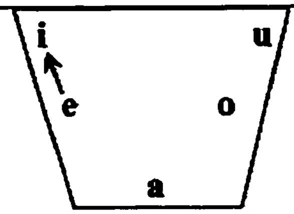
(71) **Predicted Patterns: One Mid Vowel Remains Unreduced**



Of these three patterns, one is attested in the five-vowel variant illustrated above (#22—Russian [e]-reduction.) In addition, pattern #10 is highly similar to the 7-vowel reduction pattern observed in Balear Catalan (/e,ɛ,a/ > [ə]). The two remaining patterns, #6 and #29, are the front-back inverses of patterns #10 and #22. In these four asymmetrical patterns, high ranking of a Max[F] constraint pertaining to vowel color blocks either lowering or centralization of one mid vowel only. The vowel that cannot lower/centralize is further blocked from raising by high ranking of Dep +high, which effectively blocks raising.

In the same vein, the typology does not predict assymetrical reduction patterns where one mid vowel raisies, while the other mid vowel remains unreduced:

(72) Not Predicted: Raising of Only One Mid Vowel, Nonreduction of the Other

 (unattested)	 (unattested)	Impossible: One mid vowel raises, the other remains unreduced.

Again, this pattern is predicted to be impossible since the raising of one mid vowel indicates that Dep +hi and Max –hi must be dominated by the relevant vowel reduction constraint(s). This in turn would imply that the second mid vowel can also undergo raising. The only plausible reason why a vowel would not raise in this situation would be to satisfy faithfulness for vowel height—however, since the front and back mid vowels have identical height specifications, blocking vowel reduction to maintain the vowel's underlying height specifications would be expected to apply equally to both mid vowels.

4.3 Conclusion

In this chapter, I have considered and rejected the possibility that reduction patterns can be predicted based on language-specific phonetic similarity between vowels. I have also tested the alternative hypothesis that reduction patterns result simply from the ranking of vowel reduction constraints relative to featural faithfulness constraints. A factorial typology based on this approach fares well both with respect to the questions of empirical adequacy and overgeneration: all known attested 5- and 7-vowel reduction patterns were predicted by the typology (except those that were specifically excluded from the model), and all gaps in the predicted typology are plausible accidental gaps with the highest non-attestation rates weighted towards those patterns that require a higher number of crucial rankings. Furthermore, this approach does make claims about possible asymmetrical vowel redution patterns, and these claims do seem to be supported empirically.

Chapter 5
Contextual Blocking of Vowel Reduction

"When you aim for perfection, you discover it's a moving target."

—GEORGE FISHER

5.0 Introduction

In this chapter, I will investigate some of the ways in which vowel reduction can interact with other phonological processes. In particular, I will consider phonological processes that can block the regular application of vowel reduction. This type of case will be illustrated with examples taken from Portuguese, Russian, and Catalan, as well as from other languages.

5.1 Phonotactic Blocking Effects

In many languages, vowel reduction is blocked for vowels in specific phonotactic contexts, including absolute-word-initial position and hiatus position.

5.1.0 Hiatus Blocking

For example, in standard Catalan, unstressed /e,ɛ,a/ normally reduce to [ə], and unstressed /o,ɔ/ normally reduce to [u]. However, the reduction of /e/ and /ɛ/ to [ə] is blocked if the unstressed vowel is immediately followed by [a] or [ə]. Examples are taken from Mascaró (1978):

(73) **Hiatus Blocking in Catalan** (Mascaró 1978)

[teátrə]	*[təátrə]	'theatre'
[reəlitát]	*[rəəlitát]	'reality'
[meándrə]	*[məándrə]	'meander'
[əsteárik]	*[əstəárik]	'stearic'
[useənɔ́grəf]	*[usəənɔ́grəf]	'oceanographic'
[pəruneál]	*[pərunəál]	'tibular' (< peruné + al)
[lineál]	*[linəál]	'linear' (< line + al)
[kreərá]	*[krəərá]	'he'll create'
[kur̄eá]	*[kur̄əá]	'to cultivate'
[kur̄eərá]	*[kur̄əərá]	'he'll cultivate'

The phenomenon of hiatus blocking does not affect unstressed /a/, as shown by the examples [səárik] 'Saharan' (> /saara + ik/, cf. [sáərə] 'Sahara') and [bəál] 'Baal' (Mascaró 1978). If hiatus blocking applied here, we would expect the incorrect surface forms *[saárik] and *[baál].

A similar hiatus blocking effect is seen in Russian, where the reduction of unstressed /o,a/ to [ə] after a non-palatalized consonant is blocked when an underlying /o,a/ is immediately adjacent to another underlying /o,a/. Recall that /o,a/ neutralize to [ə] in Russian unstressed syllables, except in the syllable that immediately precedes the stress.

(74) **Hiatus Blocking in Russian**

	Underlying	Surface	Gloss
o>a	/pootʃʲerʲódnoj/	paatʃʲirʲódnəj	'in turn' (*cf. [ótʃʲirʲitʲ] 'line, queue'*)
	/koalʲítsija/	kaalʲítsija	'coalition'
a>a	/zaalʲétʲ/	zaalʲétʲ	'to turn pink' (*cf. [áləj] 'pink'*)
	/proanalʲizʲírovatʲ/	praanəlʲizʲírəvətʲ	'to analyze' (perfective)

It should be noted that not all hiatus situations block [ə]-reduction in Russian. For example, hiatus with high or mid vowels does not block vowel reduction—consider the following representative examples: /pauká/ 'spider' (gen. sg.) > [pəuká], /bóa/ 'boa' > [bóə].[27] Hiatus blocking also does not affect underlying /e/ (cf. /vnʲeot͡ʃʲerʲednój/ 'out of order' > [vnʲiət͡ʃʲirʲidnój], *[vnʲeət͡ʃʲirʲidnój], *[vnʲeat͡ʃʲirʲidnój]—from [vnʲé], 'outside', and [ót͡ʃʲirʲidʲ] 'line, queue').

So in summary, hiatus blocking in both Catalan and Russian works to avoid double-schwa (*əə) and sequences of schwa + low vowel (*əa). In both languages, only reduction to [ə] is affected—reduction of /e/ to [i] in Russian and reduction of /o,ɔ/ to [u] in Catalan are not affected. Furthermore, reduction of underlying /a/ to [ə] is not blocked by hiatus in Catalan, but is blocked by hiatus in Russian. I believe that both phenomena derive from constraints on the distribution of targetless vowels (schwa). However, before discussing this approach, first let's consider an alternative that won't work.

At first glance, it may seem that the effects of hiatus blocking should be built into the overall formulation of vowel reduction constraints themselves. That is, my overall approach to the Russian and Catalan type of prominence-reducing vowel

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[27] It should be noted that hiatus environments in which a mid vowel is preceded by an unstressed /o,a/ without an intervening consonant are irrelevant here—since mid vowels only occur in Russian when under stress, a preceding hiatal vowel would necessarily be in the immediately pretonic syllable. As discussed at length in chapter 3, the immediately pretonic syllable in Russian does not use reduction to [ə] for independent reasons.

reduction is that certain sonorous vowels require too much articulation time to appear in certain low-duration contexts. For example, sonorous low and mid vowels cannot occur in nonmoraic positions because the low-duration environment of nonmoraicity does not mix well with the high inherent duration of low and mid vowels. However, in cases where no consonant intervenes between vowels of the same or similar height, isn't it possible that the combined duration of two vowel slots (even two unstressed or nonmoraic slots) would provide enough duration to allow those vowels to escape prominence reduction effects? This could be represented through the formal mechanism of feature-sharing. For example, perhaps we might say that [-high] is not licensed unless (a) it is linked to at least one mora (Russian version) or one stressed vowel (Catalan version), *or* (b) it is linked to at least two vocalic root nodes. In other words, the underlying [-high] specification of an unstressed /a,e,ɛ/ in Catalan or an unstressed /a,o/ in Russian would be able to survive in a reduction context just in case it is in hiatus with another [-high] vowel: they would share a single [-high] feature specification, and this "extension" of that single feature specification through the duration of two vowel slots would serve to protect it from prominence-reducing vowel reduction.

This approach is untenable, for two basic reasons. First, only reduction to schwa is blocked—reduction of /e/ to [i] in Russian and reduction of /o,ɔ/ to [u] in Catalan is not blocked. The feature-sharing approach would predict that the underlying [-high] of Russian /e/ and Catalan /o,ɔ/ should be able to undergo the same salvage-via-extension process. This is not the case (cf. Russian [vnʲiətʃʲirʲidnój] 'out of order' and Catalan [káus] 'chaos'). Second, only hiatus with [a] (surface or derived) will block reduction, not hiatus with a mid vowel (cf Russian [bóə] 'boa', Catalan [rəó] 'reason'). Under the feature-sharing approach, an unstressed [-high] vowel would escape reduction by sharing its [-high] specification with another vowel of the same height. Since mid vowels are [-high], they should be able to fulfill this role, and therefore should be expected to trigger hiatus blocking, but they don't.[28] So, if the extra duration of hiatus position isn't the deciding factor, how is hiatus blocking to be accounted for?

I suggest that hiatus blocking results from constraints that bar certain types of schwa-hiatus. In particular, double-schwa is not allowed to occur, and schwa is not allowed to occur in hiatus with /a/. Although these restrictions may sound unusual at first, upon closer examination they are quite natural, and work to avoid two somewhat unusual phonological strings.

First comes the case of double schwa. It should be noted that long schwa is avoided cross-linguistically. For example, in many Yupik dialects (cf. Krauss 1985), stressed vowels in open syllables normally undergo iambic lengthening—but this process fails to occur if the stressed vowel is [ə]. Given a featureless representation for schwa,

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[28] Note that a feature-sharing approach based on linking [+low] to two V slots does not improve the situation since (1) the vowels that would undergo reduction are not always underlyingly [+low]—hiatus blocking predominantly affects unstressed *mid* vowels, and (2) hiatus blocking in Catalan produces [ea], not [aa], so sharing [+low] is not possible in these cases.

this seems reasonable. We can assume that featureless segments are somewhat dispreferred—segments should be at least partially specified featurally. Without feature specifications to translate into articulatory targets, the articulators start operating in a completely interpolate fashion—a targetless segment can be thought of, for example, as an articulatory transition from the preceding segment and into the following segment. A ban on double [ə] simply expresses a dispreference for extended periods of vocalic interpolation. I propose the following constraint:

> ***Interpolation/*x***: The phonological string *x* may not be wholly interpolative.

In the case of the ban on double [ə], the appropriate string to substitute for *x* is that of hiatus: *Interpolation/[VV]. In other words, the articulators may not be left in a wholly interpolative state for the duration of two adjacent vocalic slots. For clarity of exposition, I will use the abbreviation *əə to refer to the constraint *Interpolation/[VV].

The ban against hiatus between [a] and [ə] is also a fairly reasonable thing. My claim is that any disyllabic sequence containing adjacent heterosyllabic [a] and [ə] will be easily misinterpreted as a monosyllabic sequence.[29] Consider, for example, that the vowel /a/ is plausibly unspecified for color features such as [front] and [round], as suggested at the end of chapter 4. This means that /a/ is only specified for height features: [+low, -high]. Since [ə] is also not specified for color features, the vowels [a] and [ə] are not easily distinguished featurally—they are distinguished featurally only in terms of height. However, this difference is phonetically obscured in hiatus situations. Acoustic cues for vowel height include the frequency of the first formant (F1), as well as duration: lower vowels have higher frequency values for F1, and they are longer. Thus, [a] has a higher-valued F1 than does [ə], and [a] is longer in duration than [ə]. However, in hiatus situations both cues are obscured. First, the F1 value for [ə] might easily be lowered due to coarticulation with [a]. Second, without an intervening consonant, the durational difference between [a] and [ə] is difficult to identify: Since [ə] is a rather short vowel, and [a] is a rather long vowel, it would be easy to misinterpret [a+ə] or [ə+a] as a slightly longer-than-usual [a]. As a result of these factors, without an intervening consonant or changes in vowel color, it is difficult to resolve surface [a+ə] or [ə+a] into the intended heterosyllabic two-vowel sequence. Thus, vowel reduction that results in [a+ə] or [ə+a] hiatus runs the risk of obscuring the syllable structure of the intended output because a two-syllable string may be interpreted as monosyllabic. This approach is supported by native speaker judgments—for example, Avanesov (1984, p. 107) emphasizes that the [aa] sequences produced by Russian hiatus-blocking are pronounced as two separate sounds, and warns non-native and/or dialect

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[29] It would be tempting to posit a *Interpolation constraint that dealt specifically with color features—"at least one vowel in a hiatus situation must bear color features", for example. However, this would incorrectly rule out [aa] hiatus, which is an allowable hiatus type in Russian.

speakers to avoid incorrect pronunciation of [aa] as a single vowel. I will represent the dispreference for [ə]~[a] hiatus using the following constraint:

***Hiatus([a], [ə]):** The featureless vowel [ə] may not occur in hiatus with [a].[30]

In effect, the *Hiatus([a], [ə]) constraint is a type of licensing constraint—the vowel [ə] may not occur in output positions where its presence might be overlooked by a listener.

High placement of the *Hiatus([a], [ə]) constraint has the effect of blocking reduction to [ə] when adjacent to a surface [a]. In Russian, *Hiatus([a], [ə]) must be outranked by Lic-Nonperiph, since reduction of unstressed /o/ to [a] still occurs in hiatus positions, as shown in the following tableau.

(75) **Use of *Hiatus([a], [ə]) in Russian**

/koalitsiónnij/	LIC-NONPERIPH	*Hiatus ([a], [ə])	*əə	*NONMORAIC-HIGH
☞ kaalitsiónnij				
kəəlitsiónnij			*!	
kəalitsiónnij		*!		
koalitsiónnij	*!			

As shown in the last row of the tableau, non-reduction of the hiatus /o/ is disallowed, since the *Hiatus([a], [ə]) constraint is still outranked by one reduction constraint—

[30] Note that the constraint is not direction specific—it applies equally to [əa] and to [aə].

Lic-Nonperiph. However, the ranking of *Hiatus([a], [ə]) above the other reduction constraint—*Nonmoraic/-high, forces reduction of the hiatus /o/ to [a] rather than [ə]. Also note that reduction of both the hiatus vowels to [ə] avoids violation of the *Hiatus([a], [ə]) constraint, but this option is ruled out by the *əə constraint.

The implementation of *Hiatus([a], [ə]) in Catalan is slightly different. In Catalan, the effect of *Hiatus([a], [ə]) is to totally block reduction for unstressed /e/, and to cause unstressed /ɛ/ to reduce to [e] rather than [ə]. The *Hiatus([a], [ə]) constraint does not affect unstressed /a/ in Catalan. Both details can be accounted for by deconstructing the Catalan reduction constraint similar to the way Prince and Smolensky (1993) deconstruct their prominence-alignment constraint H-Nuc into a family of related constraints. Recall that prominence-reducing vowel neutralization of the sort seen in Catalan and similar languages is accounted for here using prominence-reduction constraints such as *Unstressed/-high, which are based on prominence-alignment constraints families of the sort utilized in Prince and Smolensky (1993) and Kenstowicz (1994). The Catalan reduction constraint can be expanded into several component members. Each member refers to the same structure, but at a different level of sonority or prominence. For example, recall the Prominence Alignment constraint family *μμ/X used in chapter 5 to account for Russian "dissimilative" vowel reduction dialects. This constraint family has the following inherently ranked members:

*μμ/i: Vowels with [i]-sonority should not be bimoraic.
*μμ/e: Vowels with [e]-sonority should not be bimoraic. ↑ *higher-ranked*
*μμ/ɛ: Vowels with [ɛ]-sonority should not be bimoraic. ↓ *lower-ranked*
*μμ/a: Vowels with [a]-sonority should not be bimoraic.

Prominence reduction constraints that cause vowel neutralizations can also be broken down into their constituent members. For example, the *Unstressed/X constraint active in Catalan has the following constituent members

*Unstressed/a: Vowels with [a]-sonority should not be unstressed.
*Unstressed/ɛ: Vowels with [ɛ]-sonority should not be unstressed. ↑ *higher-ranked*
*Unstressed/e: Vowels with [e]-sonority should not be unstressed. ↓ *lower-ranked*
*Unstressed/i: Vowels with [i]-sonority should not be unstressed.

The *Unstressed/-high constraint can be thought of as convenient shorthand for a block of constraints consisting of the first four members listed above. However, the behavior of [ə]-reduction in hiatus situations as observed in Catalan now requires that a different constraint—namely, *Hiatus([a], [ə])—be interleaved among the constituent sub-parts of this constraint family. Specifically, in order to derive the correct results, *Hiatus([a], [ə]) must be ranked below *Unstressed/a, but above *Unstressed/e. In other words, the desire to avoid [əa] and [aə] hiatus situations in Catalan is strong enough that the language tolerates an unstressed [e] (with medium sonority), but not so strong as to tolerate an unstressed [a] or [ɛ] (both with high sonority). This situation is demonstrated in the following tableaux:

(76) **Hiatus Blocking in Catalan**

/saárik/	*UN-STRESSED/a	*UN-STRESSED/ɛ	*Hiatus ([a], [ə])	*UN-STRESSED/e	*UN-STRESSED/i
☞ səárik			*		
saárik	*!			*	

/teátr/	*UN-STRESSED/a	*UN-STRESSED/ɛ	*Hiatus ([a], [ə])	*UN-STRESSED/e	*UN-STRESSED/i
☞ teátr				*	
təátr			*!		

In the first tableau, the non-reduced variant *[saárik] is ruled out because it fatally violates *Unstressed/a—there is a highly sonorous unstressed vowel in the first syllable. In the second tableau, the input form has an underlying mid vowel [e] in unstressed position. Since the *Hiatus([a], [ə]) constraint outranks *Unstressed/e, the presence of an unstressed mid vowel is tolerated in order to avoid an unfavorable form of hiatus. The deconstruction of the Catalan prominence reduction constraint into its constituent members can also account for the fact that unstressed /ɛ/ emerges as [e] in hiatus situations: when reduction of highly-sonorous /ɛ/ to low-sonority [ə] is not possible, the vowel nonetheless is realized as a somewhat less sonorous vowel, reducing to [e]. This is because a violation of *Unstressed/e is preferable to a violation of the more highly ranked *Unstressed/ɛ. As in the Russian case discussed in chapter 5, reduction in Catalan is limited by high ranking of Dep[+high], which rules out reduction via raising[31]. Thus, the even more beneficial reduction of /ɛ/ to [i] in hiatus position—which would violate only *Unstressed/i—is blocked by Dep[+high].

(77) Deconstructing Vowel Reduction and *əə in Catalan

/krɛará/	*əə	*UNSTRESSED/a	*UNSTRESSED/ɛ	*UNSTRESSED/e	*UNSTRESSED/i
☞ kreərá					
krɛərá			*!		
krəará		*!			
krəərá	*!				

In this form, underlying /ɛ/ and /a/ are in hiatus together, and neither one is stressed. The deconstruction of the prominence-reduction constraint into its component parts correctly predicts for this case that the more sonorous unstressed vowel, /a/, undergoes reduction as normal—non-reduction of sonorous /a/ would violate the high-ranking *Unstressed/a constraint. The other unstressed vowel, being of lower sonority, is allowed to surface with partial vowel reduction to [e].

Note that the precise ranking of *[əə] cannot be determined at this time—all we know is that it must outrank *Unstressed/e, which is shown by the fact that *[əə] can motivate violation of *Unstressed/e, as in the tableau above. However, this tableau does not give us the necessary evidence to decide whether *[əə] should be ranked immediately above *Unstressed/e or at some higher point in the hierarchy. In

[31] Except, of course, when reduction via raising is necessary to preserve labiality—the mirror-image of the

the case of *Hiatus([a], [ə]), we could tell that this constraint needed to be ranked immediately above *Unstressed/e, because the other *Unstressed/x constraints needed to outrank it—presence of an unstressed /a/, for example, can force a violation of *Hiatus([a], [ə]) (cf. [səárik]). This does not seem to be the case with *[əə], although information on this point in scarce. Echevarria (p.c.) reports that the Catalan form /baalísme/ 'Baalism' would be pronounced [bəalízmə], not *[bəəlízmə]. Based on this form, it seems as though a violation of *[əə] is worse in Catalan than a violation of *Unstressed/a, indicating the ranking *[əə] » *Unstressed/a. This is the ranking shown in the tableau above.

5.1.1 Word-Initial Blocking

Another position where vowel reduction is blocked is absolute word-initial position—this type of blocking is found in Russian (both standard and dialectal variants). Some example forms are given below:

(78) Word-Initial Blocking in Russian

	Underlying	Surface	Gloss
o>a	/obʃː^{j}onaródnoj/	[apʃː^{j}inaródnəj] (*cf. ópʃ^{j}ij 'common'*)	'of all the people'
	/ogn^{j}ovój/	[agn^{j}ivój] (*cf. ógn^{j}innəj 'ablaze'*)	'fiery'
a>a	/am^{j}er^{j}ikánskoj/	[am^{j}ir^{j}ikánskəj]	'American'
a>a	/azbukóvn^{j}ik/	[azbukóvn^{j}ik] (*cf. ázbukə 'primer'*)	'beginning reader'

As shown above, word-initial blocking only affects the reduction of unstressed /o,a/. Although unstressed /e/ is rare word-initially, it nonetheless undergoes reduction (cf.

Russian case.

/etáʒ/ > [itáʃ] 'floor, storey', /ekzámʲen/ > [igzámʲin] 'exam'). Also, it should be noted that vowel reduction is not blocked in *word-internal* onsetless syllables (unless they happen to fall into one of the hiatus categories discussed above). For example, the onsetless final syllable of *períod* 'period of time' undergoes the usual sort of vowel reduction: compare correct [pʲirʲíət] with the incorrect blocked form *[pʲiríat]. If word-internal onsetless syllables followed the same pattern, it would be possible to credit the blockage of vowel reduction to the absence of a preceding homosyllabic consonant: a vowel in a CV sequence is usually slightly shortened due to gestural overlap with the preceding consonant. Since blocking is only noted in word-initial onsetless syllables, this does not seem to be a tenable approach.

According to Zlatoustova (1981) absolute word-initial [a] has a duration that is similar to immediately-pretonic [a]. I propose that both the word-initial blocking effect and the increase in phonetic duration result from a alignment constraint that requires the segment at the left edge of the word to be moraic:

Align-μ: The left edge of every word must align with some mora.

If this constraint dominates *Struc-μ, the correct Russian facts will result: word-initial vowels in Russian will always be moraic, regardless of stress. As such, they are immune to the prominence-reducing type of vowel reduction that causes the reduction of /a,o/ to [ə].

5.2 Morphological Blocking

In some languages, vowel reduction is blocked not by phonological factors, but by morphological factors. The two types of morphological blocking that I have identified for vowel reduction are analogical blocking and homophony avoidance. These types of blocking are discussed below.

5.2.0 Analogical Blocking

In some languages, vowel reduction does not work as expected when the vowel in question is contained within a morphological ending. For example, in Russian, vowel reduction is partially blocked in certain desinences (Avanesov 1984), including the endings for feminine nom. sg. nouns, masculine and neuter gen. sg. nouns, masculine and neuter nom. pl. nouns using the suffix -a, and a series of others (cf. Avanesov 1984, pp. 99-101). All of these exceptional desinences have an underlying low vowel or mid back vowel (/o,a/) that invariably reduces to [ə], even when the preceding consonant is palatalized, as shown in the following chart. For each grammatical category that shows partial vowel reduction blocking, two forms are provided. The first form is a stem-stressed word of the given category, and the second is an end-stressed form. (The end-stressed forms demonstrate the underlying quality of the vowel in the desinence.) (Note: this table depicts a conservative type of pronunciation ("Old Muscovite"). More contemporary variants will be discussed presently.)

(79) **Partial Vowel Reduction Blocking in Russian Desinences** (cf. Avanesov 1984:99-100)

grammatical category	stem-stressed forms		end-stressed forms	
fem. nom. sg.	káplʲə	'drop'	zimlʲá	'earth'
masc./neut. gen. sg.	mórʲə	'sea'	plʲit͡ʃʲó	'shoulder'
masc./neut. pl. in -a	górʲə	'misfortunes'	palʲá	'fields'
dat., instr., and loc. plurals (all genders)	a káplʲəx	'about drops'	a daskáx	'about boards'
-mʲa neuters, nom. sg.	vrʲémʲə	'time'	n/a	
masc./neut. instr. sg.	kámnʲəm	'stone' (instr. sg.)	katóm	'cat' (instr. sg.)
masc. gen. pl.	brátʲjəf	'brothers' (gen.)	katóf	'cats' (gen.)
masc./neut. adjectivals in the gen., dat., or loc. sg.	préʒnʲəvə	'former' (gen. sg.)	balʲʃóvə	'big' (gen. sg.)

As shown above, these endings have underlying /o,a/ but always reduce to [ə] in stem-stressed forms, even if the preceding consonant is palatalized. The ə-reduced forms are possible only in desinences, not in stems or derivational endings—cf. [t͡ʃʲélʲidʲ] from underlying /t͡ʃʲélʲadʲ/ 'servants' (*[t͡ʃʲélʲədʲ]). It should be emphasized that this sort of blocking cannot be explained as homophony avoidance (which is discussed below in section 5.2.1). For example, although *some* of cases shown in (79) above have near homophones in [i] (cf. [káplʲə] 'drop, nom. sg.' vs. [káplʲi] 'drop, nom. pl./gen.sg.'), this is not the case for all of them. For example, there are no nearly homophonous forms *[vrémʲi], *[brátʲjiʃ], *[a kápʲlʲix][32] that could cause the occurrence of ə-reduced forms for purposes of homophony avoidance. Furthermore, with only a few exceptions[33], the blocking phenomenon illustrated in (79) is found only in vowel-initial desinences that can occur with stems ending in either palatalized or non-palatalized consonants. For example, the –a fem. sg. nom. ending (shown in the first row of (79) above) can be added to stems with a final palatalized consonant, as in [kápʲlʲə] 'drop', [zimlʲá] 'earth', as well as to stems with a final non-palatalized consonant, as in [daská] 'board', [kóʃkə] 'cat'.

Based on these observations, it is possible to explain the partial reduction blocking shown in (79) as a type of paradigm uniformity (Steriade 1996). The reduced form of these affixes has been standardized—the palatality of a stem-final consonant is not allowed to cause variation in the surface form of these affixes. The type of constraint I propose to account for this phenomenon is given below:

> **PU(-a/front)**: All surface occurrences of the morpheme -a 'FEM. NOM. SG.' must have the same feature specification for [front].

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[32] Neuters that end in -mʲa in the nom. sg. add –on– to the stem in oblique cases: [vrʲémʲinʲi] 'time, gen. sg.', [vrʲimʲón] 'time, gen. pl.'. Pronunciations like [brátʲjiʃ] are attested, but only as optional pronunciations for [brátʲjəʃ], as discussed below.

[33] The exceptions are: -mʲa neuter nouns, gerundives in –aja, and the fem./neut. adjectival endings –aja/-oje. The -mʲa neuters are a closed class of neuters with 10 current members. Although the final vowel is usually considered to be /a/ underlyingly, it is never stressed, and therefore underlying /o/ is also possible. In this case, -mʲa neuters can be grouped with the regular neuter and masculine nom. sg. forms listed in the text. In the case of the gerundives and adjectivals, the irregularity is that the final /a,e/ does not reduce to [i] after the preceding [j]—instead, it reduces to [ə]. It may be that the effects of a preceding palatalized consonant simply do not affect word-final unstressed vowels. However, even if this is the case, several of the cases listed in (79) in the text remain unexplained.

By ranking the PU(-a/front) constraint above the C^j/[+front] constraint (which motivates occurrence of front vowels after palatalized consonants—see chapter 3), a preceding palatalized consonant will fail to affect the reduction pattern of a following unstressed vowel if doing so would violate paradigm uniformity. Note that the PU(-a/front) constraint is non-directional—it does not give precedence to the desinence forms that are found after non-palatalized consonants. That is, it is also logically possible that this type of constraint could cause analogical blocking of the opposite sort; it could force reduction of /a,o/ to [i] even when there wasn't a preceding palatalized consonant—either way would cause all unstressed tokens of the –a morpheme to have the same surface realization. I assume that the directionality of analogy seen in the Russian case is due to the fact that these morphemes can also appear stressed. Since the stressed allomorphs contain [-front] vowels ([ó] or [á]), the [-front] reduced form in [ə] is the one that is generalized through paradigm uniformity.

This approach to analogical blocking in Russian predicts that this behavior need not necessarily be found for all vowel-initial desinences containing /a,o/. This is because PU constraints like the one discussed above are morpheme-specific. For example, the PU constraint just discussed was specific for the -a ending that marks feminine nominative singular nouns. The fact that this particular PU constraint causes an effect in the language is due to it's ranking with respect to the C^j/[+front] constraint. If a given PU constraint was ranked below C^j/[+front], it would not cause analogical blocking, leading to a system where analogical blocking affects some morphemes of the appropriate type, but not others. This explains, for example, why the Russian feminine instrumental singular endings -oj and -oju[34] are not subject to analogical blocking of vowel reduction (cf. Avanesov 1984, p. 101). Both endings can attach to stems of various types, and its underlying /o/ reduces to [i] if the preceding consonant is palatalized but reduces to [ə] otherwise. Examples are given below:

(80) Reduction of Russian Instr. Sg. Fem. Endings -oj/-oju

	Nom. Sing.	Instr. Sg.	Gloss
end-stressed	daská kasá	daskój, daskóju kasój, kasóju	'board' 'braid'
stem-stressed	kóʃka káplʲə	kóʃkəj, kóʃkəju káplʲij, káplʲiju	'cat' 'drop'

As shown above, although both endings can occur stressed, and can occur after non-palatalized stems, they do not display analogical blocking based on these facts (*[kaplʲəj]). This pattern can be generated simply by ranking the PU(-oj/front) and PU(-oju/front) constraints below the C^j/[+front] constraint, but ranking the remaining PU(front) constraints above C^j/[+front].

Finally, this approach also allows for morpheme-by-morpheme changes in this pattern. The analogical blocking pattern shown in (79) above is described by Avanesov as a conservative form of pronunciation that was typical of the "Old Muscovite" dialect (a pre-revolutionary literary pronunciation norm). At the time Avanesov wrote, a subset of

[34] The instrumental singular of Russian feminine nouns can be formed using either ending. The –oju ending is more archaic, and is stylistically marked in the contemporary language.

the desinences that show analogical blocking in (79) also allowed optional pronunciations with [i]. Since then, this subset has grown larger, and most younger speakers now allow alternate pronunciations in [i] and [ə] for most grammatical endings. This ending-by-ending change of analogical blocking in Russian is consistent with a situation where different PU(front) constraints individually move into a tied position with the constraint C^j/[+front]. Following Antilla (1995), I assume that tied constraints result in more than one winning output in an Optimality-Theoretic analysis. Presumably, this language change could proceed via the further demotion of PU constraints to lower positions in the constraint hierarchy until such time as, one-by-one, these desinences no longer allow the [ə]-reduced allomorphs whatsoever. This situation is depicted schematically below:

(81) Possible Formalization for Loss of Analogical Blocking in Russian Endings

[illegible]	[illegible]	[illegible]	
PU(-a/front)	PU(-a/front)	PU(-a/front)	↑ *higher ranked*
PU(-ov/front)		C^j/[+front]	
C^j/[+front]	PU(-ov/front), C^j/[+front]	PU(-ov/front)	
PU(-oju/front)	PU(-oju/front)	PU(-oju/front)	↓ *lower ranked*

In the situation represented above, Stage I represents a grammar where analogical blocking occurs obligatorily for the fem. nom. sg. ending <u>-a</u> and the masc. gen. pl. ending <u>-ov</u>, but where analogical blocking never occurs with the fem. instr. sg. ending <u>-oju</u>. Stage II corresponds to a system where analogical blocking is obligatory for the suffix <u>-a</u>, optional for the suffix <u>-ov</u>, and impossible for the suffix <u>-oju</u>. Finally, Stage III corresponds to a system where analogical blocking is obligatory for <u>-a</u>, but impossible for both <u>-ov</u> and <u>-oju</u>.

This analysis of analogical blocking provided in this section never predicts blockage of reduction of underlying /e/ in desinences. There are two reasons for this. First, underlying /e/ reduces to [i] regardless of the palatality of the preceding consonant. Therefore, reduction of underlying /e/ to [ə] would never be motivated for reasons of analogy. Second, desinences with underlying /e/ in Russian usually require the morphophonemic palatalization of the preceding consonant: cf. [daská] 'board', [na dask^{j}é] 'on the board'—therefore it is *not* the case that such endings could occur either after palatalized or non-palatalized stem consonants.

For the Russian data under discussion, analogical blocking is caused by a correspondence constraint targeting suffixes. In Catalan, a similar type of blocking is seen with stems. For example, in compounds and certain other derived environments, previously stressed vowels are immune to vowel reduction, as shown by the following forms:

(82) Analogical Blocking in Catalan Compounds (Mascaró 1978)

[sɛmi séntrə]	'semi-center'
[rentə pláts]	'dishwasher'
[kɔr ágrə]	'heartburn'
[sensə gánə]	'without hunger'
[kap rəó]	'no reason'

In these forms, it is clear that vowel reduction *in toto* is not blocked—the final vowels of [séntrə] and [rentə] still undergo reduction, for example. Mascaró, a native speaker of Catalan, also denies the possibility that the unreduced vowels bear any degree of stress—

he explicitly states that all of the lexical items shown above contain only one stress, as marked. This suggests that the unreduced vowels in these forms are subject to blocking due to the fact that they correspond to *stressed vowels* in the related simplex forms. This could be caused by the following constraint:

> **Ident-Base/Compound:** For α a vocalic segment of some compound form and its correspondent β in the related base form:
> If β is [γ ATR, δ high], α must be also be [γ ATR, δ high].

This constraint will effectively block reduction in compounds for those vowels that were previously protected from the effects of vowel reduction due to the presence of stress. In other words, destressed vowels in compound words may not undergo reduction in Catalan, since this would cause them to have surface specifications for [ATR] and [high] that are different from those of the corresponding vowels in non-compounded forms.

5.2.1 Homophony Blocking

Another sort of morphological blocking effect that can affect vowel reduction involves homophony-blocking (Crosswhite 1997), which is discussed briefly in this section.

The quintessential quality of vowel reduction is a loss of vowel contrasts—underlying vowel distinctions are lost in unstressed positions. Sometimes this very fact can block the application of vowel reduction under circumscribed conditions. Namely, if vowel reduction would cause two underlyingly distinct lexical items to become homophonous, and if those two items are morphologically related, vowel reduction can be blocked. In some cases, this type of homophony-blocking arrests vowel reduction altogether (i.e., leading to an unstressed nonreduced vowel), and in other cases it simply causes an unexpected reduction pattern (i.e., reduction occurs according to a neutralization pattern other than that generally observed in the language). Based on evidence from standard Russian and dialectal Bulgarian, I argue that this type of vowel-reduction blockage results from an anti-Identity correspondence constraint. The major points illustrated by these two languages are discussed below.

An example of the complete blockage of vowel reduction due to homophony-avoidance is found in the Trigrad dialect of Bulgarian (Stoikov 1963). In this dialect, unstressed /o,ɔ/ reduce to [a].[35] However, this process is completely blocked just in case application of vowel reduction would create a homophone with a morphologically related word. Examples are given below of both the reduction process and the homophony-blocking process:

[35] In addition, unstressed /ɛ/ becomes [e]. Unstressed /e/ does not reduce. This pattern of vowel reduction can be derived by ranking the Max[+front] and Dep[+high] constraints above the vowel reduction constraint, thus blocking both raising and lowering for unstressed front mid vowels. For analysis of a similar case, see the "ekan'e" pattern of Russian described in chapter 4.

(83) **Homophony Blocking in Trigrad Bulgarian** (Stoikov 1963)

	singular	plural	gloss
underlying singular –o undergoes reduction to [a]	varˈzala	varzaˈla	*mooring point*
	vlaˈt͡ʃila	vlat͡ʃiˈla	*[gloss not given]*
	kaˈpita	kapiˈta	*hoof*
	ˈklɔba	klaˈba	*globe*
	ˈpera	peˈra	*pen*
	ˈrebra	reˈbra	*rib*
underling sg. –o does not reduce	ˈzɔrno	ˈzɔrna	*grain*
	ˈpetalo	ˈpetala	*horseshoe*
	ˈblago	ˈblaga	*good, blessing*
	t͡sigaˈrilo	t͡sigaˈrila	*cigarette*

In the Trigrad dialect of Bulgarian (as well as generally in Bulgarian), neuter singular nouns are marked with the ending –o. The plural is formed from neuter nouns by replacing the –o suffix with –a. In the first six forms listed in the table above, the singular and plural suffix markers are homophonous because of vowel reduction—both are pronounced [-a]. However, in those six forms, there is also a stress shift that can serve to retain the sg./pl. distinction for those words: cf. for example kapíta sg. and kapitá pl. 'hoof'. This stress shift is not predictable; shifts in stress from the stem to the ending must be lexically specified. In the last four forms listed in the table, no stress shift occurs—simultaneously, vowel reduction in the singular is blocked: cf. for example blágo sg. and blága pl. 'benefit'. That is, vowel reduction of underlying –o has been blocked in just those cases where its application would cause two underlyingly distinct forms to become homophonous. In this dialect, a similar pattern is noted with other morphemes that involve underlying /o/.[36]

It is important to note, however, that homophony blocking is strictly delimited in its application. In the Trigrad dialect, for example, only intra-paradigmatic homophones are blocked: the forms involved in homophony blocking must be morphologically related. This is clearly the case, since vowel reduction cannot be blocked to avoid non-morphologically-related homophones. For example, the following lexical homophones are reported in the Trigrad dialect:

(84) Lexical Homophones in Trigrad Bulgarian

	noun			adjective	
a.	'blago	'benefit'	c.	'blago	'sweet' (predicative)
b.	'blaga	'benefits'	d.	'blaga	'sweet' (attributive)

Here, we have two words that are pronounced ['blago]--one is a noun that means "benefit" (singular), and one is an adjective that means "sweet" (predicative). There are also two words that are pronounced ['blaga]--one being a plural form of "benefit" and the other being the attributive form of "sweet". Note that, significantly, within each paradigm, homophony is avoided—the two forms for "benefit" are both distinct, and the two forms for "sweet" are distinct. These are both cases of homophony-blocking. In a case like this, one might say that homophony is unavoidable—every

[36] Such morphemes include the –o suffix for marking predicative adjectives (which contrasts in this dialect with the –a suffix, used for feminine attributive adjectives; gender is not marked predicatively in this dialect); and the –o suffix used to mark names for male humans, which contrasts with the –a suffix used to mark the accusative case for male animate nouns. However, with these morphemes there are no stress shifts

candidate output will be homophonous with another form. Since this is the case, you might expect that the winners would be those candidates that faired the best on phonotactic constraints. However, this is clearly not the case since the phonotactics predict vowel reduction.

Both the homophony-blocking phenomenon and its morphological limitation are addressed by use of the following Correspondence constraint:

ANTI-IDENT: For two forms, S_1 and S_2, where $/S_1/ \neq /S_2/$,
$\exists\, \alpha, \alpha \in [S_1]$, such that $\alpha \neq \Re(\alpha)$.

The Anti-Ident constraint is formulated in terms of Correspondence Theory (McCarthy & Prince 1993, 1995). This constraint says that two forms that are *underlyingly* distinct must possess some item (presumably a segment) that is not identical to it's correspondent. In the Trigrad case, non-identity of near-homophones can be achieved either through featural differences (i.e., the difference between [o] and [a]), or prosodic differences (i.e., the difference between stressed [á] and unstressed [a]). The use of Correspondence Theory for the analysis of homophony blocking also makes it possible to explain the morphological limitation observed with homophony blocking. The general assumption in the literature on Correspondence Theory is that a correspondence relation ($\Re$) may be set up between different types of forms, such as input~output forms, base~reduplicant forms, or normal~argot forms. In Crosswhite (*to appear*), I argue that Correspondence is actually strictly limited by

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such as those discussed above for the plural/singular distinction. Resultantly, vowel reduction is always blocked for these morphemes.

these relationships—i.e., that a correspondence relation cannot be set up between two forms unless there is some sort of lexical relationship between them. This being the case, it is clear why Anti-Ident can only prevent morphological homophones: prevention of lexical homophones would require setting up a correspondence relation between unrelated lexical items—something that is beyond the scope of correspondence in general.

By ranking the Anti-Ident constraint above the vowel reduction constraint, the proper homophony-blocking effect is achieved. This is demonstrated in the following tableaux:

(85) Use of Anti-Ident Constraint in Trigrad Bulgarian

cf. plural: zɔ́rna 'grains'

/zɔ́rno/	ANTI-IDENT	Dep[+high]	Lic-Mid/Stress
☞ zɔ́rno			*
zɔ́rnu		*!	
zɔ́rna	*!		

cf. plural: klabá 'globes'

/klɔ́bo/	ANTI-IDENT	Dep[+high]	Lic-Mid/Stress
☞ klɔ́ba			
klɔ́bo			*!

In the first tableau, there is no stress shift to preserve the distinction between singular and plural, and homophony blocking therefore takes place. That is, the vowel-reduced form *[zɔ́rna] is ruled out because it violates the Anti-Ident constraint. In addition, a second incorrect candidate, *[zɔ́rnu] is also ruled out. This candidate displays an unexpected form of reduction—reduction via raising, rather than the expected pattern of reduction via lowering. However, since this option is not actually attested in homophony-blocking situations, we can assume the ranking Dep[+high] » Lic-Mid/Stress.[37] In the second tableau, an example is presented where there *is* a shift stress: in the singular the stem is stressed, while in the plural the ending is stressed. In this case, the Anti-Ident constraint is irrelevant. Since prosodic differences are adequate to satisfy the Anti-Ident constraint, homophony blocking for vowel reduction is unnecessary in this case.

In another case of homophony blocking, from Russian, homophony avoidance can cause partial suspension of the expected vowel reduction patterns. Recall from section 5.2.0 that Russian desinences with underlying /o,a/ show partial blocking of vowel reduction if unstressed and preceded by a palatalized consonant—in this environment, unstressed underlying /o,a/ reduce to [ə] rather than to [i], despite the preceding palatalized consonant. As explained above, this behavior is principally found only with endings that can occur either after palatalized or non-palatalized consonants. Endings that require the palatalization of the preceding consonant are immune. For example, –oʃ '2nd person singular', which requires palatalization of the preceding consonant, reduces to [-iʃ] instead of [-əʃ]. There is one datum that is not accounted for in this analysis, however. The 3rd person plural verbal desinence –at

[37] The standard dialect of Bulgarian would presumable use the opposite ranking. In standard Bulgarian, reduction via raising is the standard neutralization pattern.

also requires paltalization of the preceding consonant, but does not show reduction to [i]. Instead, it uses a [ə] reduced form when unstressed: [-ət]. This occurrence cannot be explained analogically, but it can be explained as homophony avoidance. If the –at ending were to reduce to [-it], it would be homophonous with the 3rd person singular ending, which is *underlyingly* –it. Examples are provided below:

(86) Homophony Avoidance in Russian 3rd Person Verbs

infinitive	**3rd. sg.**	**3rd. pl.**	**gloss**
gəvarʲítʲ	gəvarʲít	gəvarʲát	'speak'
stávʲitʲ	stávʲit	stávʲət	'place'
pómnʲitʲ	pómnʲit	pómnʲət	'recall'
lomʲítʲ	lómʲit	lómʲət	'break'

In the first row of the table above, I have provided an end-stressed verb of the same class in order to demonstrate the underlying vowel qualities used in the infinitive, 3rd sg. and 3rd pl. endings, respectively. As shown, the 3rd singular ending is /–it/, and the 3rd plural ending is /–at/. In addition, this class of verb always has a palatalized final consonant preceding the 3rd person endings. In this environment, we would expect underlying /a/ to reduce to [i], thus causing the 3rd sg. and 3rd pl. endings to be homophonous in unstressed positions. However, as shown in the last three rows of the table, this does not happen: in the 3rd plural, the unstressed /a/ of the verbal desinence reduces to [ə], despite the presence of a preceding palatalized consonant.

This result can be derived by inserting the Anti-Ident constraint in a position dominating the C^j/[+front] constraint discussed in chapter 4. This is demonstrated in the following tableau:

(87) Use of Anti-Ident in Russian

cf. 3rd singular *pómnit*

/pómnʲat/	*NONMORAIC/-HI	ANTI-IDENT	Cʲ/[+ft]
☞ pómnʲət			*
pómnʲit		*!	
pómnʲat	*!		*

The constraint-based approach to anti-homophony in Russian is also useful in explaining why certain homophones are allowed to occur. For example, recall that the reduction of unstressed /a/ to [i] is analogically blocked in the nominative singular of words like n̲ʲ̲i̲d̲ʲ̲é̲l̲ʲ̲ə̲ 'week' (*[nʲidʲélʲi] for the nom. sg.). However, it should be noted that homophones are produced elsewhere in this very same paradigm. For example, the locative singular, genitive singular, and nominative plural of 'week' are all homophonous—[nʲidʲélʲi]:

(88) Occurring Grammatical Homophones in Russian

Grammatical Form	Underlying Form	Surface Form
nom. pl.	/nʲedʲelʲ + i/	[nʲidʲélʲi]
gen. sg.	/nʲedʲelʲ + i/	[nʲidʲélʲi]
loc. sg.	/nʲedʲelʲ + e/	[nʲidʲélʲi]

As shown above, two of the forms (the nom. pl. and the gen. sg.) are underlyingly identical. Given the formalization of Anti-Ident presented above, we would not expect this sort of "underlying" homophony to be avoided—the Anti-Ident constraint does not avoid homophony generally, it only acts to preserve the distinctiveness of forms that are not underlyingly identical (i.e., $/S_1/ \neq /S_2/$). However, the last form listed—the locative singular—*is* underlyingly distinct from the other two. We might think that this would lead to blocking of vowel reduction, but in fact it does not. In fact, homophony blocking in Russian never applies in such a way as to preserve the /e/~/i/ distinction—grammatical homophones that result from the obliteration of /e/~/i/ distinctions are quite common. This can be accounted for using the Anti-Ident constraint simply by installing the ranking Max[+front] » Anti-Ident. Recall that in the analysis of Russian vowel reduction already developed in chapter 5, the raising of unstressed /e/ was derived via the high-ranked position of Max[+front]—the same ranking can be used here to explain why the reduction of /e/ to [i] is not affected by homophony blocking:

(89) Limitation of Homophony Blocking due to Max[+front] » Anti-Ident

cf. gen. sg. and nom. pl. *n^{j}id^{j}él^{j}i*

/n^{j}ed^{j}él^{j}e/	*NON-MORAIC/-HI	MAX [+FRONT]	ANTI-IDENT	C^j/+ft
☞ n^{j}id^{j}él^{j}i			*	
n^{j}id^{j}él^{j}ə		*!		*
n^{j}id^{j}él^{j}e	*!			

It should also be noted that homophony blocking in Russian does not ever affect the reduction of /o,a/ to [ə]. There are several instances where grammatical homophones result from the neutralization of unstressed /o/ and /a/. For example, the neuter past tense and feminine past tense verbal endings –o and –a are often neutralized. For example, the surface form igrálə can be either 'she played' (from igrá+l+a), or 'it played' (from igrá+l+o). In order to avoid generating homophonous forms in this case, it would be necessary to completely arrest vowel reduction in one form or the other, similar to the homophony-blocking effect seen in Trigrad Bulgarian.[38] However, this does not occur in Russian. Recall that in the Trigrad Bulgarian case, it was necessary to rank Anti-Ident above the vowel reduction constraint, thus allowing unreduced mid vowels to appear in stressless syllables. The reverse ranking in Russian explains why vowel reduction does not affect the reduction of unstressed /o,a/ when not preceded by a palatalized consonant.[39]

Finally, the homophony-blocking phenomenon in Russian also displays the same morphological restrictions observed in Trigrad Bulgarian: only morphological homophones can be blocked. In fact, non-morphologically-related homophones are quite frequently produced via vowel reduction. Two examples are provided below:

(90) Non-Morphological Homophones in Russian

mʲátʃʲ	'ball', sg.	mʲitʃʲí	'balls'
mʲétʃʲ	'sword', sg.	mʲitʃʲí	'swords'
tʃʲástə	'frequently'	tʃʲistatá	'frequency'
tʃístə	'cleanly'	tʃʲistatá	'cleanliness'

Here, the singular forms for 'ball' and 'sword' are distinct: [mʲátʃʲ] and [mʲétʃʲ]. However, their plural forms are identical, due to a stress shift: [mʲitʃʲí]. Based on the

[38] That is to say, the context after a palatalized consonant has one additional option not available here: either follow the expected pattern for the Cʲ__ environment (i.e., reduce to [i]), or use the default pattern (i.e., reduce to [ə]).

[39] It should be noted that in a number of cases, the type of homophony discussed apropos of igrálə is avoided in Russian, but not in a way that involves vowel reduction. Instead, many verbs show stress shifts in the past tense—for example, bilá 'she was' vs. bílə 'it was'. However, not all verbs show this phenomenon, and it is not straightforwardly predictable which ones will shift stress and which ones won't.

homophony-blocking effects we saw above with verbs like [pómnʲət] 'understand' 3rd plural, we might expect the plural form of 'balls' to be *[mʲətʃí] in order to block homophony, but this is not the case. A similar case holds for the adverbial and nominal forms for 'clean' and 'frequent', shown above. As already discussed with respect to Trigrad Bulgarian, this limitation is an expected result due to the nature of Correspondence.

5.2.2 Blockage of Vowel Reduction in Loan Words

In a number of languages, vowel reduction is blocked in non-nativized loan words. There are two different forms of loan-word blocking:

1. non-nativized loan words do not display vowel reduction at all
2. non-nativized loan words show a reduction pattern that is different from that seen in native words

The first type of pattern is found, for example, in standard Russian (data from Kalenchuk & Kasatkina 1996):

(91) Loanword Blocking in Russian

Form	Gloss
[flʲordaránʃ]	'navel orange'
[boleró]	'bolero'
[sʲekvéstr]	'sequester'
[tsetsé]	'tsetse fly'
[ʒalʲuzí]	'jalousie'

The behavior of the words listed above contrasts with older loan words, such as [itáʃ] 'storey' (> French *étage*) and [paét] 'poet' (> French *poète*), where vowel reduction does occur (cf. older Russian pronunciations [etáʃ] and [poét], which are no longer used (Shvedova 1982)).

The second type of pattern is found, for example, in standard Catalan. In native words, unstressed /ɛ,e/ reduce to [ə], while unstressed /ɔ,o/ reduce to [u]. In non-nativized loan words, this reduction does not occur. Instead, unstressed [e,o] can occur, but unstressed [ɛ,ɔ] cannot. Examples include the following, from Mascaró (1978):

(92) Loanword Blocking in Catalan

[kláse]	*[klasə]	'class'
[bóston]	*[bóstun]	'Boston'
[sopráno]	*[supránu]	'soprano'
[báter]	*[bátər]	'bathroom'
[kátedrə]	*[kátədrə]	'university chair'
[ɔ́perə]	*[ɔ́pərə]	'opera'
[deskártes]	*[dəskártəs]	'Descartes'
[kɔ́lerə]	*[kɔ́lərə]	'cholera'

Note that the reduction /a/ > [ə] does take place, as expected. However, the reductions /e/ > [ə] and /o/ > [u] are absent. Unstressed /ɛ,ɔ/ also seem to be subject to reduction in this type of non-nativized loan, since they never occur in unstressed position in such words. (Note, however, that these vowels can occur in non-nativized loans in stressed position: kɔ́lera, ɔ́pera.)

It has been suggested by Mester and Itô (1993, 1995, *to appear*) that this sort of loan-word blocking effect should be handled using a grammar consisting of several *co-phonologies*. A co-phonology is an OT grammar, and as such consists of a set of (universal) constraints and the rankings between them. In this view of phonology, different words are stored in different lexical groups or layers. One of these layers is identified as the core layer, and contains the majority of native lexical items. Other lexical items are assigned to other, specific lexical layers. Each of these layers is associated with its own co-phonology. In particular, Mester and Itô claim that one of the co-phonologies—the one associated with the core lexical layer—is the basis for all remaining co-phonologies in a very explicit manner. Their hypothesis is that the co-phonologies of a language can only differ with respect to constraint *rankings*, and further that peripheral co-phonologies can only differ from the core co-phonology with respect to the ranking of faithfulness constraints: the peripheral co-phonologies will be characterized by a higher ranking of one or more faithfulness constraint(s), while the core co-phonology will be characterized by higher relative ranking of phonotactic constraints. For example, Ito and Mester analyze Japanese as having (at least) three co-phonologies—"Yamato" (for native words and fully-nativized loans), "Foreign", and "Assimilated Foreign". Here, the Yamato co-phonology is core, and the other two are peripheral. Lexical items assigned to these three co-phonologies show different behavior with respect to the following three constraints:

(93) Itô and Mester's (1993, 1995) Use of Co-Phonologies in Japanese

*P:	Single [p] is prohibited
*NT:	Post-nasal obstruents must be voiced
*DD:	Voiced geminate obstruents are prohibited

Stratum	Definition	Examples
Foreign	*DD necessarily violated	*beddo* 'bed'
Assimilated Foreign	*DD necessarily obeyed; at least one of *NT, *P necessarily violated	*peepaa* 'paper', *hantai* 'opposite'

Words in the Yamato group obey all three phonotactics. Words in the "Assimilated Foreign" group allow violations of *P and/or *NT, but not *DD[40]; words in the "Foreign" group allow violation of *DD. Note that the difference between the Foreign and Assimilated Foreign co-phonologies is based on degree of nativization, not on etymological origin—the loanwords shown above for both co-phonologies are all from English. Itô and Mester assign different Japanese words to one of these three co-phonologies, which have the following constraint rankings:

(94) **Ranking of FAITH in Core vs. Peripheral Co-Phonologies** (Itô & Mester 1993, 1995)

Yamato	*COMPLEX	»	*DD	»	*NT	»	*P	»	FAITH
Assimilated Foreign	*COMPLEX	»	*DD	»	FAITH	»	*NT	»	*P
Foreign	*COMPLEX	»	FAITH	»	*DD	»	*NT	»	*P

As shown, the faithfulness constraint FAITH has the lowest ranking in the Yamato (core) co-phonology. It is more highly ranked in the Assimilated Foreign co-phonology, and achieves its highest ranking in the Foreign co-phonology.

In dealing with co-phonologies, it is assumed that different words are assigned to different lexical strata, based on morphological considerations. For example, native

[40] The definition provided by Itô and Mester that "Assimilated Foreign" words violate *at least one* of *NT and *P is due to the fact that foreign words that don't happen to break either phonotactic are included in the Yamato co-phonology.

vocabulary might be assigned to the core co-phonology, while different types of loanwords are assigned to peripheral co-phonologies. However, peripheral co-phonologies are not limited to housing borrowings. Inkelas *et al.* (1996) discuss a case where some native words are assigned to a peripheral co-phonology. In Turkish, an irregular but productive type of stress assignment referred to as Sezer stress (Sezer 1981) affects native place names as well as most foreign words. Interestingly, in the Turkish case, words can be transferred from one co-phonology to another morphologically. When a native word is zero-converted to a place name, it takes on the Sezer stress pattern—the morphological process of conversion can transfer lexical items from the core co-phonology to the Sezer-stress co-phonology.

In Russian, native vocabulary items and nativized loan words (such as <u>itáʃ</u> and <u>paét</u>) will be assigned to the core co-phonology, a partial grammar for which is shown below. Non-nativized words such as those shown in (91) will be assigned to a second co-phonology characterized by a higher ranking of the Max[-high] and Dep[+low] faithfulness constraints, as shown below:

RUSSIAN CORE CO-PHONOLOGY
Applies to:
Native words, Nativized Loan Words

Dep+hi	»	*Non-moraic[-hi], Lic-Mid/Stress	»	Max[-hi], Dep[+lo]

PERIPHERAL CO-PHONOLOGY #1
Applies to:
Non-Nativized Loan Words

Dep[+hi], Max[-hi], Dep[+lo]	»	*Non-moraic[-hi], Lic-Mid/Stress

In Peripheral Co-Phonology #1, the higher ranking of the Max[-high] and Dep[+low] faithfulness constraints prevents vowel reduction of any sort: the ranking of Max[-high] above the two vowel reduction constraints will prevent raising/centralization of unstressed /o,a/ to [ə], and will also prevent raising of unstressed vowels to [i]; the ranking of Dep[+low] above the vowel reduction constraints will prevent lowering of unstressed /o/ to [a].

The Catalan loan-word pattern can also be accounted for using the co-phonology approach to loan words. However, in this case the promoted faithfulness constraints do not come to dominate all the vowel reduction constraints. Recall that in section 5.1.0, I demonstrated how a prominence-reduction constraint can be broken down into its component members. In the loan-word co-phonology of Catalan, faithfulness constraint for Max[-high] will be promoted above some members of the *Unstressed/X constraint family, but not all, as illustrated below:

CATALAN CORE CO-PHONOLOGY
Applies to:
Native words, Nativized Loan Words

*Unstressed/a, *Unstressed/ɛ, *Unstressed/e	»	Max[-hi]

PERIPHERAL CO-PHONOLOGY #1
Applies to:
Non-Nativized Loan Words

*Unstressed/a, *Unstressed/ɛ	»	Max-hi	»	*Un- stressed/e

As illustrated above, the faithfulness constraint Max[-hi] has been promoted above the vowel reduction constraint *Unstressed/e, but remains dominated by the vowel reduction constraints *Unstressed/a and *Unstressed/ɛ. In the core co-phonology, loss of an underlying [-high] specification through either raising (for underlying /o,ɔ/) or raising/centralization to [ə] (for underlying /ɛ,e,a/) is always justified (barring hiatus), since all of the *Unstressed/X constraints motivating vowel reduction dominate the faithfulness constraint Max[-high]. However, in peripheral co-phonology #1, raising to /u/ for underlying /o/ and centralization to [ə] for underlying /e/ are both ruled out because Max[-high] dominates *Unstressed/e. On the other hand, losses of ATR features for underlying unstressed /ɔ,ɛ/ and raising/centralization of unstressed underlying /a/ are still motivated by the constraint rankings found in the peripheral co-phonology. The vowel reduction blocking found in the peripheral co-phonology is illustrated by the following three tableaux.

/kláse/	*UN-STRESSED/a	*UN-STRESSED/ɛ	MAX [-HIGH]	*UNS-TRESSED/e	*UN-STRESSED/i
☞ klase				*	
kláse			*!		

In this tableau, the input has an underlying mid vowel that remains unreduced in the correct surface output form. Actually, it should be noted that we cannot tell whether the correct input segment is [+ATR] or [-ATR]. For the time being, I will assume that the input segment is [+ATR]. However, the correct result would also be predicted under the opposite assumption (as will be demonstrated in the next tableau). The correct surface form, kláse, is chosen as optimal because it avoids deleting the underlying [-high] specification of the underlying mid vowel. The unsuccessful candidate *[klásə] is ruled out because it fatally violated the Max[-high] constraint.

In the following tableau, I will consider the same lexical item, but this time I will assume that the input mid vowel is [-ATR]:

/kláse/	*UN-STRESSED/a	*UN-STRESSED/ɛ	MAX [-HIGH]	*UN-STRESSED/e	*UN-STRESSED/i
☞ klase				*	
klásə			*!		
kláse		*!			

In this tableau, the incorrect output candidate *[kláse] is ruled out because the unstressed vowel [ɛ] is too sonorous, thus fatally violating the *Unstressed/ɛ constraint. As in the previous tableau, the incorrect output form *[klásə] cannot surface because of its fatal violation of Max[-high]. The remaining output form, the correct kláse, only violates the lower-ranked *Unstressed/e constraint.

The last tableau, below, demonstrates that the loan-word co-phonology does not block reduction of unstressed /a/ to [ə]. As seen for Catalan hiatus blocking, [a] is too sonorous to be tolerated as an unstressed vowel.

/kátedra/	*UNSTRESSED/a	*UNSTRESSED/ɛ	*UNSTRESSED/e	*UNSTRESSED/i
☞ kátedrə			*	
katedra	*!		*	

According to Mascaró, Catalan loanword blocking of the sort described above displays a *derived environment effect*. Loanword blocking only effects unaffixed loans, or affixed loans that do not undergo a stress shift. In other words, if a loanword is affixed with one of several stress-shifting affixes, vowel reduction applies as usual. For example, the form *Bóston* does not undergo vowel reduction: [bóston]. The suffixed form *Bostoniá* 'Bostonian' (note stress shift) *does* undergo vowel reduction: [bustunjá] (cf. incorrect *[bostonjá]). According to Mascaró, affixes in Catalan are either unstressed, stressed, or prestressed[41]. (The unstressed affixes do not affect stress placement in the derived words they form, but the other two groups do.)

This situation is similar to that discussed by Inkelas *et al.* (1996) for Turkish Sezer stress. Recall that in the Turkish case, native words that are zero-converted for use as place names acquire the Sezer stress pattern—a phenomenon that Inkelas et al. analyze as the transfer via morphological modification of certain lexical items from one co-phonology to another. Based on examples like [bustunjá], it seems that the inherently-stressed affixes of Catalan have a similar behavior—attaching these suffixes to a lexical item assigned to Catalan Co-Phonology #1 causes that lexical item to be transferred to Catalan's core co-phonology. The assignment of words containing stress-shifting affixes to the core co-phonology seems reasonable since these words are guaranteed to show a native-like stress pattern. This leads to the following revised picture of Catalan's co-phonologies:

[41] Prestressed suffixes cause the preceding syllable to surface with a stress.

(95) **Catalan Co-Phonologies, Revised**

CATALAN CORE CO-PHONOLOGY *Applies to:* *Native words, Nativized Loan Words, Words in –njá, etc.*	**PERIPHERAL CO-PHONOLOGY #1** *Applies to:* *Non-Nativized Loan Words*
*Unstressed/a, *Unstressed/ɛ, *Unstressed/e » Max[-hi]	*Unstressed/a, *Unstressed/ɛ » Max-hi » *Unstressed/e

5.3 Conclusion

In this chapter, I have presented analyses for several different types of exceptions to vowel reductions. These analyses are summarized in the table below:

TYPE OF EXCEPTION:	ANALYZED AS:
Hiatus Blocking	Phonotactic constraints on allowable V-V sequences outrank reduction constraints.
Word-Initial Blocking	Alignment constraints bar nonmoraic vowels in word-initial position.
Analogical Blocking	Paradigm Uniformity constraints for specific desinences outrank reduction constraints.
Homophony Blocking	The result of the Anti-Ident Correspondence Constraint
Loan-Word Blocking	Promotion of faithfulness constraints above (a subset of) vowel reduction constraints in non-core lexical layers

These analyses demonstrate, first of all, that the overall approach to vowel reduction taken in this survey easily admits of treatment for these blocking phenomena. Inasmuch as these exceptional cases occur in more than one language each, it is important for an analysis of vowel reduction to deal with them in a manner that can easily be generalized to other languages. As has been demonstrated in the preceding sections, the approaches to the exceptional cases presented in this chapter are all applicable to a range of similar phenomena.

Secondly and more importantly, the treatments developed here for the analysis of exceptional cases underscore that the analysis of vowel reduction requires the multi-faceted, constraint-based motivation for vowel reduction that I advocate. For example, the partial blocking of vowel reduction seen in Catalan loan words and hiatus situations requires a multi-membered vowel-reduction motivation such as that provided by the *Unstressed/X family. Similarly, the partial blocking of vowel reduction in Russian hiatus situations and homophony blocking requires a treatment for Russian vowel reduction that allows different elements of the overall neutralization pattern to be manipulated separately. For example, the use of Faithfulness constraints to determine the neutralization patterns used by a particular language easily allows a blocking factor to affect a subset of the vowel reduction processes (such as /a,o/ > [i]), while leaving others intact (such as /e/>i or /o,a/>[a/ə]

Chapter 6
Moraicity, Reduction, & Stress-Timing

"No one can escape stress, but you can learn to cope with it."

–ADELE SCHEELE

6.0 Introduction

In the preceding chapters, I presented an approach to vowel reduction within Optimality Theory. Some of the case studies discussed here depend on the idea that vowel reduction phenomena can be specifically aimed towards *nonmoraic* vowels. In this chapter, I will discuss the concept "nonmoraic vowel" in greater detail. The idea of the nonmoraic vowel is not a novel one—several researchers have posited nonmoraic vowels in a number of languages. These includes both languages with lexical (underlying) nonmoraic vowels (Dutch (Ellis & Kager 1984), Mari and Chuvash (Hyman 1985)) and languages with derived nonmoraic vowels (English (Hammond 1997), Tohono O'odham[42] (Hill and Zepeda 1992)). I will review some of these cases of nonmoraic vowels, discuss how nonmoraic vowels can be implemented in current theories of phonology, and further explore the link between moraicity, reduction, and language rhythm.

[42] Some readers may know this language under the name "Papago", which is the ethnonym used by the Navajo to refer to the Tohono O'odham.

6.1 Previous Uses of Nonmoraic Vowels

As mentioned above, several previous researchers have used the idea of nonmoraic vowels in a variety of languages. In this section, I will review some of the evidence that has been advanced for these analyses. The point to be made here is that a theory that makes allowance for the existence of nonmoraic vowels is more explanatory than one that does not. First, I will discuss work on languages with lexical nonmoraic vowels, then I will discuss previous work on languages that have actual demorification processes.

6.1.0 Work on Languages without Reduction Processes

A number of languages have been described as possessing "reduced" vowels that do not occur as the result of any (synchronic) reduction process. Such languages include Chuvash, Mari, Dutch, and Au, to name a few. In these languages, at least one vowel occurs with a somewhat indistinct quality and short duration, and is referred to as "reduced". Oftentimes, this vowel has special prosodic qualities, such as repelling stress, or acting as if it were nonsyllabic. Several different authors have proposed that these types of vowels be treated as nonmoraic. In this section, I will review some of these proposals and the evidence for the nonmoraicity of lexical reduced vowels.

In Chuvash and Mari (both discussed, for example, by Hyman 1985), the vowel [ə] is called a reduced vowel, although it is an unpredictable, underlying vowel quality of these languages. The stress placement patterns of both Chuvash and Mari is similar: main stress falls on the rightmost "non-reduced" vowel. If a word contains only "reduced" vowels, stress falls on the leftmost vowel. Hyman (1985) proposes, *apropos* Chuvash, that such languages possess an underlying distinction between vowels with 1 mora and vowels with 0 moras.[43] In this respect, Chuvash would be similar, although not identical, to languages like Czech or Hungarian which have an underlying distinction between vowels with 1 mora and vowels with 2 moras. Under this approach, stress placement in Mari and Chuvash can be handled in a manner similar to the unbounded stress systems with an "opposite side default" discussed by Hayes (1994). Examples include Classical Arabic (McCarthy 1979a) and Huasteco (Larsen and Pike 1949), both of which stress the rightmost heavy syllable, else the leftmost syllable, where "heavy syllable" means CVV or CVC for Classical Arabic, and CV: for Huasteco. Hayes (1994) in fact groups Mari and Chuvash with Classical Arabic and Huasteco, reanalyzing the reduced vowel [ə] as monomoraic and the "nonreduced" vowels as bimoraic. However, an approach using bimoraicity does not seem phonetically motivated. Gruzov (1960) performed an instrumental analysis of Mari reduced and non-reduced vowels. He finds that the difference between these two groups is, as expected, one of length—but his measurements for the average duration of Mari reduced vowels are not in line with those we would expect for monomoraic vowels. Some of his findings are shown below.

[43] In fact, Hyman does not use the term "mora", referring instead to "weight units".

(96) Average Vowel Duration (in ms.) in Two Dialects of Mari (Gruzov 1960)[44]

Vowel Duration in Standard Mari: Pretonic Syllables

	Before fricatives		**Before voiced stops**		**Before voiceless stops**	
	open σ	*closed σ*	*open σ*	*closed σ*	*open σ*	*closed σ*
a	122	108	126	118	114	98
e	122	102	103	103	89	81
o	105	101	115	108	93	90
i	116	101	107	87	97	76
y	116	100	112	90	94	76
ø	95	82	129	116	94	87
u	97	82	109	92	84	75
ə	67	69	65	59	65	62

Vowel Duration in Volga Mari: Stressed Syllables (in ms.)

	Before fricatives		**Before voiced stops**		**Before voiceless stops**		**Word-final position**
	open σ	*closed σ*	*open σ*	*closed σ*	*open σ*	*closed σ*	
i	167	133	168	124	127	125	176
e	198	170	166	155	159	145	190
a	190	165	196	168	157	151	157
o	160	149	169	157	154	134	181
u	129	121	141	135	126	118	135
ə	87	62	50	62	55	53	100

As shown above, the reduced and non-reduced vowels in these two dialects of Mari do vary with respect to their duration: the reduced ones can be described as "short" and the non-reduced ones as "long". However, it should be noted that the average duration for reduced vowels in these two dialects hovers around 50-60 milliseconds, even when stressed (second table). (This behavior is reminiscent of the behavior of Yupik [ə]

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[44] Measurements are from kymographs. Isolated words, word combinations, and short sentences were

discussed in Hayes 1994, which fails to lengthen under stress (cf. Krauss 1985).) The durational range observed for Mari [ə] is quite short, even for phonemically short (monomoraic) vowels. In fact, the duration of the Mari reduced vowels seems to be approximately intermediate between the 40 ms. duration identified by Chistovish et al. (1976) needed for a listener to reliably identify the *presence* of a vowel in the speech stream and the 70 ms. duration needed for it's *quality* to be identified reliably. Gruzov also notes that the reduced vowels were sometimes completely absent, especially when found adjacent to a sonorant or fricative, and that the presence of reduced vowels in certain words sometimes goes unnoticed by inexperienced researchers. Therefore, although it does seem to be the case that Mari employs a length distinction in its vowel system that is plausibly based on underlying moraic distinctions, this distinction is not on the same footing as familiar long vs. short distinctions in languages like Czech or Finnish.

Hyman's analysis can also be extended to cases like Au (Scorza 1985). In this language, the vowels [ʌ] and [ɨ] repel stress: In general, stress falls on the initial syllable of the word, unless this syllable contains the vowel [ʌ] or the vowel [ɨ]. In this case, stress falls on the first non-[ʌ,ɨ] vowel of the word. If a word only contains [ʌ] or [ɨ] vowels, stress falls on the first syllable. Under the Hayesian approach, we could say that Au [ʌ,ɨ] are monomoraic and that all the other vowels of Au are bimoraic. However, Au

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elicited for each phonetic environment.

also possesses a phonemic distinction between [a] and [a:][45]. Since the short vowel [a] does not show the stress repelling characteristic, a monomoraic analysis for [ʌ,ɨ] will not explain their stress-repelling behavior (or wrongly predicts the same behavior for [a]). Hyman's approach can easily account for these facts, however: Au [ʌ,ɨ] are nonmoraic, [a:] is bimoraic, and the remaining vowels are monomoraic ([a, i, u, o]).

The idea that some languages allow not only nonmoraic vowels but nonmoraic *syllables* at the surface levels has been suggested, among others, by Piggott (1995, 1998). This assumption allows Piggott to account not only for the familiar stress-repelling behavior of certain vowels (similar to the case seen in Au, for example), but also other, more subtle effects. For example, Piggott (1998) discusses the case of Mohawk (Michelson 1988, 1989), where /e/ is arguably nonmoraic (or, in Piggott's terms, *weightless*) and repels stress. In addition, according to Piggott's (1998) analysis, Mohawk uses trochaic feet that are preferentially uneven (Heavy-Light as opposed to Light-Light). To achieve the desired uneven foot form, stressed vowels undergo lengthening if they are in an open syllable ([CV́.CV] > [CV́:.CV]). However, this sort of lengthening does not occur if the weak member of the foot is a syllable containing the weightless vowel /e/. For example, the form *wakeras* surfaces as *[wá.ke]ras* instead of

[45] According to Scorza, [a:] is realized in the Eastern dialect simply as a long vowel, while in the central dialect it is realized as an interrupted vowels: [aʔa]

[wá:ke]ras. Piggott accounts for this fact by noting that if /e/ is nonmoraic as argued, the foot [wá.ke] is already uneven, and lengthening is therefore unnecessary.

In an analysis of sonority-based stress systems, Kenstowicz (1994) hypothesizes that the low phonetic duration of vowels like Mari [ə] is itself the basis for the stress-repelling properties of certain vowels. He discusses data from languages such as Mordvin, where both high vowels *and* schwa repel stress in a manner similar to Mari and Chuvash [ə]. Using Prince and Smolensky's (1993) prominence alignment constraint families, Kenstowicz suggests that languages prefer to place stress on vowels that are *phonetically* (but not necessarily phonemically) longer than others—an approach that obviates use of moraic distinctions in such languages. He uses constraint families such as those shown below in (97).

(97) Peak Prominence for metrical feet (Kenstowicz 1994)
$*P_{foot}/X$ = "X should not be a foot-peak"

$*P_{foot}/ə >> *P_{foot}/i,u >> *P_{foot}/e,o >> *P_{foot}/a$

Although this analysis is appealing in its simplicity and its ability to be extended to other phenomena (and is, in fact, based on the same mechanism I use to formalize prominence-reduction), it should be recognized that, to a certain extent, this general approach simply reassigns part of the original puzzle to the phonetic component of language. For example, the fact that [a] is phonetically longer than [e,o] or [i,u] is explained by phonetic universals: vowels that preferentially have lower jaw positions generally have longer articulation times. It is not *a priori* clear, however, why [ə] would be phonetically shorter than [i,u] (Pettersson and Wood (1987a,b), for example, find Bulgarian [ə] to have about the same jaw depression as Bulgarian [i,u]). The fact that [ə] *is* phonetically shorter than other vowels could be due to its nonmoraic status, a suggestion that is investigated in greater detail in section 6.3.0.

Finally, it should be noted that a nonmoraic interpretation of [ə] and other lexical "reduced" vowels has also been suggested for other languages, including Dutch (Ellis and Kager 1984) and French (Anderson 1982). For the most part, these analyses crucially rely on rule ordering: some vowel (such as [ə]) starts off as nonmoraic, but acquires a mora at some point in the derivation through application of a mora-insertion rule. By ordering certain rules that are sensitive to syllable structure (such as stress-placement, for example) before the mora-insertion rule, [ə] surfaces with properties not shared by the other vowels of the language. For example, Dutch word-final Cə is skipped in determining stress placement, and many consonants preceding [ə] undergo phonetic modifications that otherwise affect only coda consonants.

6.1.1 Work on Languages with Vowel Reduction Processes

The examples of Mari, Chuvash, Au, and Mohawk have all involved cases where some vowel or other seems to display nonmoraic behavior, but where the distribution of this vowel is unpredictable. In these cases, the nonmoraic vowels in question have been considered by various researchers to be lexically weightless. There are also languages that have been analyzed as possessing nonmoraic vowels whose distribution is predictable. These languages, then, can be interpreted as depriving certain vowels of moras according to a predictable pattern. This type of approach has been proposed by Hill and Zepeda (1992) for Tohono O'odham, for example. In addition, English has been analyzed as a language possessing mora-deletion as well (Hammond 1997).

Hammond (1997) investigates the combinatorial possibilities of different English vowel qualities with different syllable structures and syllable positions (word final, unstressed, etc.). In order to account for the different patterns, he adopts the familiar position that English tense vowels are underlyingly bimoraic, and that English lax vowels are underlyingly monomoraic. Furthermore, surface unstressed [ə] is treated as nonmoraic.

Hammond's nonmoraic interpretation of [ə] in English basically rests on the fact that this approach provides a unified analysis of vowel reduction in English, which can be extended to account for the distributional restrictions on stressed lax vowels. Hammond also points out that a featural characterization of English vowel reduction is problematic, since his nonmoraic vowels can have varying phonetic realizations,[46] including: [ə], as in [ˈtapək] 'topic', syllabic liquids and nasals as in [ˈrænsm̩] 'ransom', and [ɨ] as in [ˈrænsɨd] 'rancid'. Therefore, Hammond represents

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[46] It should be pointed out that the phonetic realization of a nonmoraic reduced vowel can vary from person to person, so the transcriptions of reduced vowels that are about to be given will not match every individual's pronunciation. For example, I say [tapɨk] instead of [tapək].

English vowel reduction as a prosodic process, whereby a mora is removed from an underlyingly monomoraic vowel. The featural content of the vowel, apparently, is not changed, although neither is it fully realized (perhaps due to the low duration of a nonmoraic vowel). This allows vowel reduction of the type just described to be formally unified with two other stress-dependent phenomena in English: tensing and laxing.

First, Hammond derives the non-occurrence of stressed lax vowels prevocalically via mora addition. That is, although stressed tense vowels can occur before another vowel ([bó̱ə] 'boa', [brú̱ən] 'bruin', [gé̱əti] 'gaiety', [àjdí̱ə][47] 'idea'), lax vowels cannot occur in this position. That is, *[brʊ̱́ən] and *[àydɪ̱́ə] are not possible words of English. A constraint requiring syllables to be bimoraic forces a monomoraic vowel in this type of coda-less syllable[48] to undergo lengthening—in Hammond's system, adding a mora to an underlyingly monomoraic lax vowel transforms it into a bimoraic tense vowel. Then, a similar analysis is used to explain the absence of both lax vowels and tense [e, a, ɔ] in one particular environment—i.e., unstressed word-final open syllables. Under Hammond's analysis, vowels in this position may not be monomoraic. The more sonorous lax vowels [æ, ɛ, a] lose their

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[47] Speakers who have a disyllabic pronunciation for this word do in fact use a pronunciation similar to this: [aj.dɪ͡ə]. The generalization discussed here pertains to hiatus, so the starred form shown here is necessarily trisyllabic: *[aj.dɪ.ə]

one underlying mora due to a type of prominence reduction constraint (they surface as [ə]), while the less sonorous lax vowels [ʌ, ɪ, ʊ] undergo tensing to produce [o, i, u]. Thus, [o, i, u] can occur in word-final unstressed open syllables (as the surface realization of [ʌ, ɪ, ʊ]), but [e, a, ɔ], which are the tense counterparts of the more sonorous lax vowels [ɛ, æ, a], cannot.

Based on this analysis of nonmoraic reduced vowels, Hammond proposes the following cross-linguistic generalization:

> **Reduction Generalization** (Hammond 1997): If a vowel α exhibits reduction (zero moraicity) in some language L, then any vowel β in L that is more sonorous than α must also exhibit reduction in L.

This generalization is consistent with the behavior of prominence-reduction. For example, there are languages like Sri Lankan Portuguese creole (Smith 1978) where only low vowels undergo prominence reduction, and there are also languages like Bulgarian (Lehiste & Popov 1970, Scatton 1984, Pettersson & Wood 1987a, 1987b; Groen 1987) and Catalan (Recasens 1991, Mascaró 1978), etc., where all non-high vowels undergo prominence reduction. Thus, Hammond's analysis of the English facts provides a precedent for treating at least some cases of vowel reduction as prominence reduction phenomena, either moraic prominence reduction (as in Hammond's case), or segmental prominence reduction (as in the cases I discuss).

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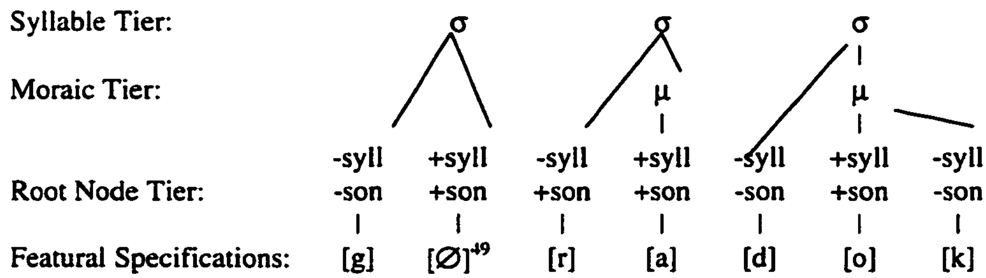
[48] If the following syllable had an onset, this would be geminated to provide a coda consonant, thus generating the famous "ambisyllabic" consonants of English.

6.2 Nonmoraicity and Syllable Structure

In the preceding section, I have reviewed a number of cases that are profitably analyzed using a phonological theory that allows for not only nonmoraic vowels, but nonmoraic syllables. Given widespread assumptions about prosodic structures, the existence of such structures may seem alien. For example, one traditional view is that moraicity and syllabicity mutually imply one another. Under this assumption, [i] is monomoraic, and [j] is not; similarly, [l] is not moraic while [l̩] is—in other words, the notion of a non-moraic syllabic segment would be a contradiction in terms. Therefore, the idea that some languages possess nonmoraic vowels, and furthermore that these vowels are syllabic, is incompatible with the traditional view on moraicity and syllabicity. In particular, the existence of nonmoraic syllables is in direct conflict with Zec's (1994a) claims about possible cross-linguistic patterns concerning sonority and prosodic structure. Before addressing this issue, I will provide some general discussion on the link between moraicity and syllabicity. Then, I will consider the more specific claims made by Zec (1994a) and how they can be reconciled with the claim that certain vowel-reduction languages possess nonmoraic syllables.

First, I start off by pointing out that the equivalence between moraicity and syllabicity was belied early on in the development of contemporary moraic theory. For example, Hayes (1989) and Hyman (1985) both point out that Central Alaskan Yupik contrasts short high vowels with featurally-identical glides of the same quality. Importantly, the glides in this language can be moraic in coda position *without* becoming syllabic, leading Hayes and Hyman to suggest that, at least in some languages, the feature [syllabic] can be underlyingly specified and form the basis of a phonemic contrast. McCarthy (1988) suggests that syllabicity and sonority be encoded on the root node tier, which also encodes linear order of segments and serves to anchor segmental feature specifications (in frameworks utilizing feature-geometry, for example). The separation of moraicity from syllabicity is also emphasized in Hyman's (1985) analysis of Gokana, in which he suggests that vowels can project moras without also projecting syllables (he argues that there is no evidence for the syllable tier in this language, just a weight tier). As mentioned above, Hyman also allows vowels to project syllables without first projecting moras, as in Chuvash or Mari. By separating syllabicity from moraicity, it is possible for segments to be underlyingly either syllabic or non-syllabic. The feature specification for [syllabic] can also be altered for purposes of syllabification: changing an underlying /i/ to a [j], for example. For clarity, I present an example of the type of structure that I assume for a language like Russian, where under my analysis unstressed, non-footed syllables are nonmoraic. The word illustrated below is /gorodók/ 'little city', which is pronounced [gəradók]:

(98) Prosodic Structure of a Word With a Nonmoraic Syllable



Here, I assume that onset consonants attach directly to the syllable node, while coda consonants are adjoined to the vowel's mora. Note that in nonmoraic syllables such as [gə], there is no moraic distinction between the syllable nucleus and margins—syllabicity is represented only by the [+syllabic] specification of the [ə] root node. This might help to explain the pattern observed by Bondarko et al. (1966) in which Russian C-V coarticulation is at its most extreme in those syllables interpreted in the present work as nonmoraic: since the vowel does not possess its own timing unit (mora), it's timing relation with respect to the surrounding segments is not as clearly defined as it would be, for example, in a moraic context. This may in turn lead to greater gestural overlap between a nonmoraic vowel and the surrounding segments.

A second hypothesis concerning the relationship between syllabicity and moraicity is not that syllabicity *equals* moraicity (as discussed above), but that syllabicity *implies* moraicity. This hypothesis is investigated in detail by Zec (1994a). Zec's theory

[49] I use the symbol ∅ to represent the featural specifications of [ə] below the root node in keeping with my analysis of schwa as featureless.

relies on the ideas of Strict Layering (Selkirk 1984) and Prosodic Licensing (Itô 1986). Both of these concepts rely on the idea of the prosodic hierarchy, according to which the following prosodic units are universal, and show the following hierarchical arrangement:

(99) The Prosodic Hierarchy

Prosodic Word
|
Foot
|
Syllable
|
Mora

This hierarchical arrangement is often interpreted as not only encoding the idea of prosodic "size", but as an implicational hierarchy: the existence of some prosodic word implies the existence of some constituent foot. In other words, words are made up of feet, feet are made up of syllables, and syllables are made up of moras. Under this interpretation, referred to as the *Strict Layering Hypothesis* (Selkirk 1984), it is impossible to have a syllable without also having at least one mora somewhere inside that syllable, or to have a foot that directly governs moras without an intervening syllable. As a result, segments that cannot be parsed into some syllable might be subject to *stray deletion*—since they cannot be incorporated into the prosodic hierarchy in accordance with strict layering, they are simply deleted. Zec utilizes this idea to explain certain cross-linguistic patterns concerning moraicity and prosodic structure. For example, Zec observes the following cross-linguistic generalization:

Segmental Inventory $\supseteq$ Moraic Sub-Inventory $\supseteq$ Syllabic Sub-Inventory

Thus, the set of all segments of a language includes the set of all moraic elements—in other words, the set of moraic elements of a language can either be coextensive with the set of segments (all segments can be moraic), or it might be a proper subset (only certain segments are moraic). Furthermore, Zec claims that the syllabic elements of a language are a subset of the moraic segments. In other words, a language might allow nasals, liquids, and vowels to be moraic, but only allow the vowels (a proper subset of moraic elements) to be syllabic. Zec explains this regularity as a consequence of a strictly-layered prosodic hierarchy which contains the mora as it's fundamental unit—in order to be syllabic, you must also be moraic. Therefore, a syllabic element must meet any prerequisites imposed on moraic elements, as well as those imposed on syllabic elements. In recent work (Zec 1999), these ideas have been expressed as optimality-theoretic constraints that set sonority threshholds for different levels of the prosodic hierarchy. An example of the sonority threshold constraints that a particular language might employ are demonstrated below:

SON-μ[+son]: Moraic elements must be [+sonorant]
SON-σ[-cons]: Syllabic elements must be [-consonantal]
SON-φ[-cons]: Stressed elements must be [-consonantal]

Furthermore, Zec hypothesizes that the implicational hierarchies discussed in her earlier work are due to the existence of conjoined constraint. That is, a segment that is both moraic and segmental will be subject to a highly-ranked constraint that requires satisfaction of both mora-level threshold requirements and syllable-level threshold requirements simultaneously.

The proposed analysis of Russian and similar vowel-reduction languages relying on the presence of nonmoraic vowels is not compatible by Zec's original (1994a) theory of sonority threshholds, since a syllabic element ([ə]) is never moraic—thus, the set of syllabic elements is a *superset* of the moraic ones (moraic={i,u,a,e,o}, syllabic={i,u,a,e,o,ə}). However, by framing sonority threshholds as optimality theoretic constraints, Zec allows the possibility that these threshholds requirements are violable. Thus, although languages will be motivated to obey sonority threshold requirements in a way that makes the cross-linguistic observations of Zec (1994a) the likely outcome, it is possible that some other constraint, ranked highly enough in the grammar, could subvert this otherwise exceptionless process. This phenomenon has been referred to by Smolensky (1993) as *Emergence of the Marked*: A non-harmonic (i.e., marked) structure may be allowed to surface if all more-harmonic competitors are excluded by a more highly ranked constraint. In this case, the structure avoidance constraint *Struc-μ must outrank the SON-family of constraints, thus forcing the emergence of a nonmoraic syllabic vowel, in violation of sonority threshold constraints.

It should be noted that a very similar situation has been discussed by Prince & Smolensky (1993), regarding yet another aspect of the strict layering hypothesis. Prince and Smolensky (1993) suggest that extrameticality be equated with a violation of strict layering: an extrametrical consonant or syllable is parsed into the prosodic hierarchy at some level, having bypassed lower levels. That is, an extrametrical syllable—a syllable, for example, that is not counted for purposes of assigning stress—might be analyzed as being connected directly to the prosodic word, bypassing the prosodic level of the foot. This allows an extrametrical element to be prosodically licensed (i.e., incorporated into the prosodic structure of some phonological word), but it does so at the expense of strict layering. Thus, stress might fall on the rightmost or leftmost *foot*—a designation that excludes an extrametrical syllable from being counted for purposes of stress placement. Similarly, an extrametrical consonant might be connected directly to a syllable, having bypassed the prosodic level of the mora: such consonants would not be counted in calculations of prosodic weight, even if they are structurally in coda position. Thus, the violability of strict layering observed in cases of extrametricality prompt Prince & Smolensky to suggest that strict layering is implemented via optimality-theoretic constraint. Thus, it seems to be the case that languages prefer to follow the prosodic hierarchy in the manner expressed via strict layering, but that it is possible for them to do otherwise if warranted. In particular, violations of strict layering will only occur when very particular constraint rankings hold—a constraint motivating violation of strict layering must be very highly ranked. This makes strict layering a general (but not inviolable) pattern cross-linguistically.

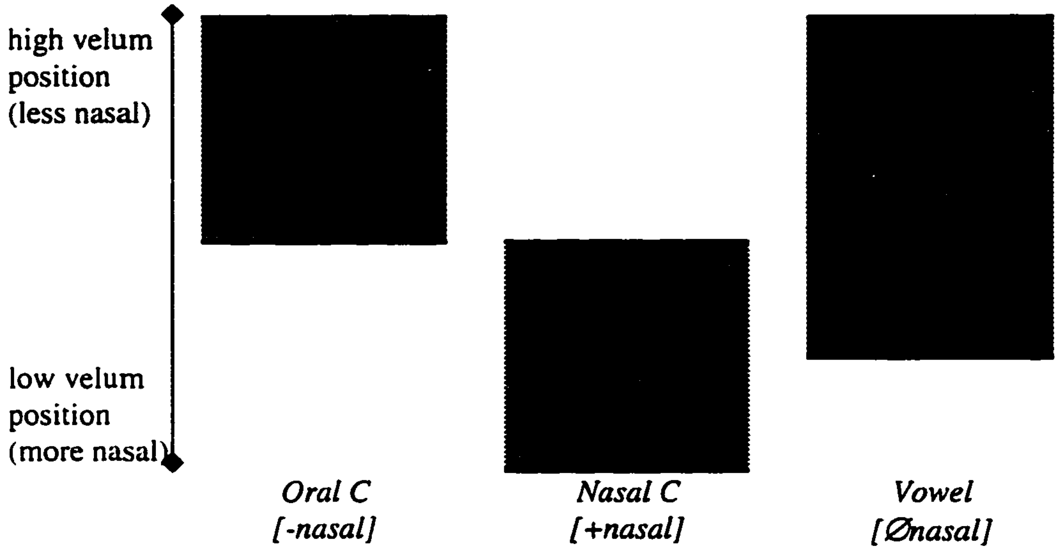
6.3 Moraicity and Timing

In the preceding section, I suggested how nonmoraic vowels can be incorporated into current theories of prosody within Optimality Theory. In this section, I will discuss what "nonmoraic vowel" means in more detail—i.e., how is nonmoraicity phonetically interpreted? It should be pointed out, however, that a full and satisfactory explanation of the concept "nonmoraic vowel" depends on a full and satisfactory explanation of what a mora is, and how a mora is phonetically interpreted. A complete investigation of these issues is beyond the scope of the present study. Rather, in this section I provide a first approximation towards a model that could, if fully developed, shed some light onto these and other questions involving linguistic duration.

6.3.0 Durational Windows

I hypothesize that moras are interpreted phonetically using idea of a durational window. The idea of a durational window is based on Byrd's (1996) phase window model, and (therefore) also on Keating's (1988, 1990) articulatory window model. The basic window concept expresses the fact that a given phonological category (such as a feature specification) is consistent with a range of highly-similar phonetic implementations. For example, a [+nasal] segment must have an articulation that falls into a specific range of acceptable velum-lowering gestures—this "acceptable articulatory range" is the [+nasal] articulatory window. Thus, a unitary lexical specification like [+nasal] is allowed to correspond to an infinite number of highly-similar phonetic implementations that fall within certain bounds. The exact value chosen from the window on any given occasion is determined contextually—if the following segment has a velum-lowering window that is more towards the "low velum" end of the continuum, then a value towards the "low velum" end of the [+nasal] window will be chosen. This is shown schematically below:

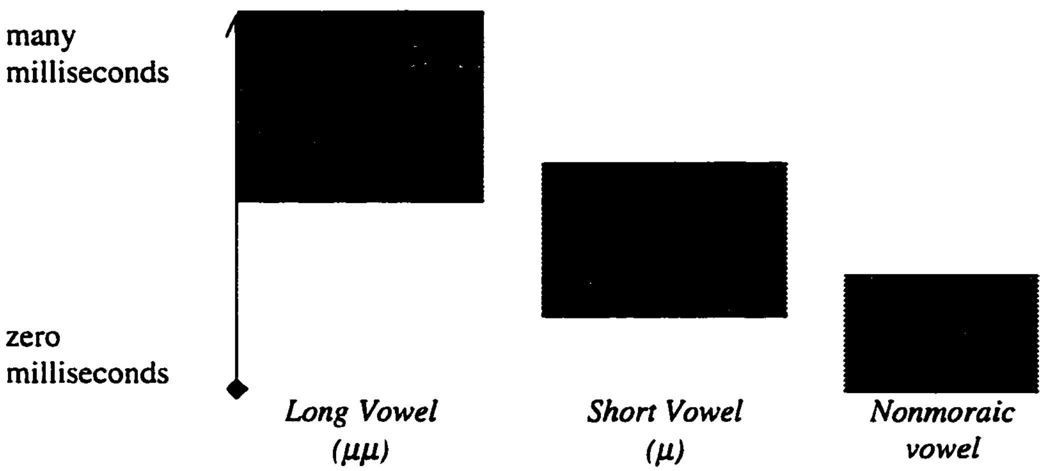
(100) Articulatory Windows for [-nasal], [+nasal], and [∅nasal] (based on Keating 1988)



Byrd's (1996) phase windows extend this idea to account for the acceptable range of variation observed with gestural timing relations: a phase window defines the acceptable range of articulatory overlap that two adjacent gestures (or segments) may display. Byrd's research on phasing relations suggests that windows can be *contextually weighted*: The actual value that is chosen from a window on any specific occasion will be influenced by various contextual factors. For example, a casual speech register may increase the likelihood that a value will be chosen from the "more overlapped" end of a window, while a formal speech register increases the likelihood of choosing a value from the "less overlapped" end.

I propose that phonological timing units like moras are interpreted phonetically using durational windows. A durational window defines the range of temporal variation that is acceptable for a segment belonging to a given phonological durational category. For example, a segment associated with one mora will have a window that is located towards the 'short' end of the durational continuum, while segments associated with two moras will have windows located near the 'long' end of the durational continuum. An example of 1-μ and 2-μ durational windows is provided below:

(101) Durational Windows for Vowel Length



Note that I also assume that nonmoraic vowels have a durational window. In keeping with previous windows-based models, the exact size and location of these windows will vary cross-linguistically, although I also propose that there are some cross-linguistic tendencies affecting the placement of window boundaries. These are as follows:

<u>Nonmoraic Vowels</u>: Lower bound of 0 ms.
<u>Monomoraic Vowels</u>: Lower bound must be above 50 ms., the duration needed to accurately identify the presence of a vowel (Chistovich, et al. 1976). Upper bound determined on a language-specific basis.
<u>Bimoraic Vowels</u>: Lower bound must be above 70 ms., the duration needed to accurately identify a vowel's quality. Upper bound determined on a language-specific basis.

In effect, we can view this model as assigning a certain (minimal) duration to segments possessing a [+syllabic] root node (the nonmoraic window). This window moves slightly higher on the durational continuum if a segment has a vocalic root node and is *also* linked to a mora. Finally, if a second mora is additionally present, the window is raised even higher along this continuum. Segments that are non-syllabic will not normally receive any durational window at all (although this might be subject to cross-linguistic variation, especially in languages where consonants can be moraic). Instead, the duration of a consonantal segment will be determined in the manner suggested by Browman and Goldstein (1986) for the timing of articulatory gestures in general: intrinsic timing[50]. They point out that any linguistic gesture will take up a certain amount of time for its completion—the duration that is necessary for the completion of a gesture is the intrinsic duration of that gesture. Thus, the duration of a segment that lacks a durational window will be determined in a task-specific manner—the duration will be determined by the type of gesture, and the stiffness of the articulator (cf. Browman and Goldstein 1986).

This interpretation of nonmoraic vowels allows us to account for certain aspects of durational variation. For example, the fact that nonmoraic vowels are realized variously as "short-ish" (approaching normal duration for a 1-μ vowel), ultra short, or not there at all results from the fact that all of these instantiations are licit durational values

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[50] It should be noted that in Browman and Goldstein's theory of phonology (Articulatory Phonology), only intrinsic duration exists. The use of durational windows is a departure from their model.

from the 0-µ window. Furthermore, the fact that short (monomoraic) vowels vary in duration according to their degree of jaw lowering is easily accommodated in this framework: vowels with lower jaw positions will tend to use values from the "high duration" end of that 1-µ window, while vowels with higher jaw positions will use values more from the "low duration" end. Thus, Kenstowicz' (1994) observation that [i,u] as well as [ə] can have stress-repelling characteristics is seen to fall out: [i,u] will use values from the "low duration" end of the 1-µ window, while [ə] will use values from the 0-µ window. Therefore, the class [i,u,ə] represents a class of vowels with very short duration. In fact, some language may utilize constraints that say [i,u,ə] are too short to carry stress (i.e., Mordvin (Kenstowicz 1994)). Other languages may be less particular: they might only single out [ə] as being too short to carry stress (i.e., Mari, Chuvash (Hyman 1985)). The point being made here is that the lower duration (and therefore, lower sonority) of [ə] results from the fact that it belongs to a different durational category (choosing phonetic values from the 0-µ window). If [ə] were assigned to the 1-µ window, it is not clear what would force this vowel quality to consistently choose low-duration values. A similar point can be made concerning the lack of lengthening under stress observed with Mari [ə]—recall that Gruzov's (1960) data on Mari indicate that [ə] tops a duration of 60ms. only under conditions of extreme lengthening (i.e., stressed, word-final position). In contrast, stressed [i,u] show durations over 100 ms in all contexts investigated by Gruzov. If both [ə] and [i,u] belonged to the same durational category, it is difficult to see why they would display such markedly different durational behavior. By assigning [ə] to a nonmoraic category in languages such as this one, we can account for this and similar facts.

Another area where the window-based approach for interpreting phonological duration is helpful involves the existence of different strategies for tempo acceleration in languages with different speech rhythms. This topic is explored in more detail in the next section, where the idea of nonmoraicity and language rhythm are discussed.

6.3.1 Moraicity and Stress-Timing

The languages analyzed here as possessing vowel reduction in nonmoraic syllables are generally thought of as stress-timed languages. According to Pike (1945), stress-timed languages are ones in which stresses fall at regular (or isochronous) intervals in the speech stream. Although this rather simple description of stress-timing does not hold up under instrumental investigation (cf. Lehiste 1977), researchers have discovered some verifiable differences in the prosody of languages traditionally referred to as stress-timed and syllable-timed. Bertinetto (1989) provides a summary of some of these characteristics, a subset of which are listed in (102) below:

(102) Characteristics of Stress-Timing and Syllable-Timing (based on Bertinetto 1989)

Stress Timed Languages	Syllable Timed Languages
Have vowel reduction	Have full articulation of unstressed vowels
Tempo acceleration via compressing unstressed syllables	Tempo acceleration via proportional compression of *all* syllables
Complex syllable structure with relatively uncertain syllable boundaries	Simple syllable structures with well-defined boundaries
Tendency of stress to attract segmental material in order to build up heavy syllables	No such tendency
Native speakers are not good syllable-counters; presence of stress-counting versification	Native speakers are better at syllable-counting; presence of syllable-counting versification

In addition, some authors postulate that the choice between syllable-timing and stress-timing is can vary within a given language. For example, languages such as French might be stress-timed at the "deep level", but syllable-timed at the "surface level" (Brakel 1985b), and languages like Brazilian Portuguese might use stress-timing for post-tonic syllables and syllable-timing for pretonic syllables (Major 1992). Of course, without a good definition of stress-timing and syllable-timing, these hypotheses are difficult to interpret.

I suggest that the distinction between syllable-timing and stress-timing is dependent, at least in part, on surface moraic distribution: stress-timed languages are those that allow some subset of vowels to surface without a mora, and therefore allow vowels with durational windows at the very short end of the durational continuum. The more nonmoraic vowels that a language allows, the more strong is the impression of stress-timing. Languages like Russian or European Portuguese, where almost all unstressed syllables are nonmoraic, are strongly stress-timed. Languages like Brazilian Portuguese, where unstressed vowels are nonmoraic only in certain environments (such as word-finally, see 3.4.0.2), are weakly stress-timed. Thus, the suggestion on the part of authors like Major (1992) that languages might be syllable-timed in one context but stress-timed in another becomes easier to interpret: in these languages, the instances where stress-timing is described are the ones where nonmoraicity is more likely to occur. In the following paragraphs, I discuss how the mora-based approach to stress-timing can also help to explain two of the other characteristics associated with stress-timing: vowel reduction, and a particular strategy for speech tempo acceleration.

Presence vs. Absence of Vowel Reduction:

As discussed in several of the preceding chapters, nonmoraic syllables are a prime target for extreme vowel reduction, which is based on the idea that sonorous vowels should not occur in non-prominent positions. Therefore, assuming that Dauer (1987) is correct in her observation that the so-called stress-timed languages tend to emphasize stressed syllables through a number of phonetic means (duration, amplitude, pitch), it is precisely this sort of language that would be expected to show stress-based licensing effects: It is in this sort of a language that the structural position of "stressed syllable" would entail a favorable perceptual environment for vowel features.

Methods of Tempo Acceleration

According to Bertinetto (1989), stress-timed languages achieve faster speech tempos mainly through compression of unstressed syllables, while syllable-timed languages compress all syllables (including the stressed ones). Given the window-based interpretation of moras as durational units, this is not surprising. For example, Byrd (1996) hypothesizes that the statistical probability that a given point within a window will be chosen on any given occasion as the actual phonetic instantiation of some phonological entity is open to contextual influence. For example, increasing speech tempo can weight a phase window towards the "more overlapped" end of the continuum. It seems probable that similar influencers affect durational windows: increased speech tempo would weight a durational window towards the low-duration end of the continuum, for example. Since the lower end of the nonmoraic durational window is much lower than for other vowels (extending, in fact, down to zero), it is not surprising that these vowels would undergo the most significant shortening during fast speech. In addition, it may be possible that the *size* of the durational windows can be manipulated to achieve changes in speech rate: at faster speech rates, the upper and lower bounds of each durational window might be lowered. In stress-timed languages, the extreme shortening of nonmoraic vowels may be adequate to achieve a desired speech rate without having to re-size durational windows, whereas in syllable-timed languages window resizing may be more commonplace—thus explaining why even the stressed vowels of syllable-timed languages undergo compression at faster speech tempos.

6.4 Conclusion

In this chapter, I have summarized work by previous authors showing that the formal analysis of certain linguistic phenomena requires reference to nonmoraic vowels and nonmoraic syllables, thus requiring that phonological theory incorporate such structures. I also discussed the relationship between moraicity and syllabicity in order to make it clear how the suggested nonmoraic structures can be accomodated in current phonological theories. A window-based approach to phonological durational categories was suggested in order to help explain both the various phonetic implementations of nonmoraic vowels as well as different types of tempo acceleration. Finally, I discussed some aspects of the idea "stress-timed language" that might be correlated with the presence of surface nonmoraic vowels in a language—although some of these hypotheses are currently somewhat speculative, the suggested link between surface nonmoraic vowels and the percept of stress-timing promises to be an interesting avenue for further research.

Chapter 7
Previous Approaches to Vowel Reduction

"The most exciting phrase to hear in science, the one that heralds the most discoveries, is not 'Eureka!' (I found it!) but 'That's funny...'"

~ISAAC ASIMOV

7.0 Introduction

In the preceding seven chapters, I have laid out an approach to vowel reduction that relies on a non-unitary, phonetically based understanding of stress-dependent vowel neutralizations. In this final chapter, I compare my approach with various other methods that have been suggested by other researchers for analyzing vowel reduction. As will be seen, many of these analyses share certain characteristics with my approach to vowel reduction, however, none of them is capable of handling the full range of attested vowel reduction patterns.

7.0.0 The Jakobsonian Approach

One of the first principled accounts of vowel reduction provided in the literature is that of Jakobson (1929), which in part discusses the development of the Russian vowel inventories (both standard and dialectal). To a large extent, many of the basic principles underlying the analysis in this dissertation can be viewed as the Optimality-Theoretic formalization of concepts discussed in Jakobson (1929).

For example, one of the primary thrusts of Jakobson's analysis is the idea that Russian vowel reduction resulted from prosodic change: the previous pitch-accent system was adandoned for a stress-system. Under the new stress-based prosody, it became important to realign vocalic amplitude, namely, in order to increase "the contrastiveness between stressed and unstressed vowels, there is a tendency to strengthen the first and weaken the second" (Jakobson 1929). It seems clear that this analysis of vowel reduction in Russian is a pre-OT instantiation of the idea of prominence reduction.

Furthermore, Jakobson also formalizes the tie between CSR [a]-reduction and the so-called 'dissimilative' [a]-reduction patterns. Jakobson describes the 'dissimilative' pattern thus (note: here "strong" and "weak" refer to sonority: strong vowels = high sonority vowels (i.e., nonhigh vowels) and weak vowels = low sonority vowels (i.e., high vowels)):

> There [*in the immediately pretonic syllable -KC*], if the stressed syllable has a strong vowel, the preceding syllable has a reduction analogous to that seen for strong vowels in other unstressed syllables, while if the stressed syllable has a weak vowel, the preceding syllable maintains the strong vowel. But the range of possible strong vowels of the preceding syllable is simplified to [a] because there is not enough intensity to maintain the contrastiveness of three strong vowels. (Jakobson 1929)

Clearly, this analysis is almost parallel to that presented in chapter 3: high-sonority vowels are avoided in the very short unstressed syllables (prominence reduction), but not in the immediately pretonic syllable, which does allow the occurrence of high-sonority vowels. However, the immediately pretonic syllable is still not capable of maintaining contrastive mid vowels, so a different form of reduction (constrast-enhancement) neutralizes both /e,o/ in this position.

The main departures from the Jakobsonian approach in the current work include:

1. Introduction of feet and moras to formally represent the contexts where different forms of reduction take place
2. Reference to duration as the primary phonetic factor driving reduction, not amplitude
3. 'Dissimilative' [a]-reduction is viewed as a variation in foot form and limitation on vowel lengthening, whereas Jakobson views it as a relationship of "equilibrium of intensity" between the stressed and immediately-pretonic vowels

The Optimality-Theoretic approach to vowel reduction also shares another characteristic with Jakobson's analysis. Although Jakobson did not coonsider many languages other than Russian (except for brief consideration of related Slavic languages), he does consider a number of different dialects of Russian, and their respective reduction systems—many of which produce the same atonic vowel sub-inventories, but do so via different neutralization patterns. One suggestion that he makes is that these various dialectal neutralization patterns result from the fact that individual dialects "assimilated only the general principles of the generalization and the rest was reserved for local efforts", where the generalization referred to here is the "reduction of atonic vowels to three phonemes, the cleanest and most characteristic in terms of timbre, the 3 'points of the vowel triangle'". In effect, this proposal is fully parallel with the proposal investigated in more detail here—namely, that vowel reduction constraints identify the vowels to be eliminated, but language-specific factors such as the relative ranking of vocalic faithfulness constraints determine the neutralizations used to achieve vowel reduction. As discussed in chapter 4, this general concept seems to provide a good model of the possible vowel reduction patterns observed not only in Russian dialects, but in a number of languages that have vowel reduction phenomena.

7.0.1 Rule-Based Approaches to Vowel Reduction

Many subsequent approaches to the analysis of vowel reduction rely on the SPE-type of phonological rule. This is the approach adopted, for example, by Halle (1959, 1965), Lightner (*undated*), and Nelson (1974) (among others) for Russian, or by Mascaró (1978) for Catalan. These types of analyses frequently rely on rule ordering to achieve the correct results. Furthermore, asymmetrical reduction patterns (such as the one seen in Catalan) are commonly derived through the use of special notational devices, such as angled brackets. For example, the rules used by Mascaró for Catalan vowel reduction are given below ("CP" stands for "constricted pharynx" and is similar in usage to [-ATR]: the Catalan vowels /ɛ,ɔ,a/ are [-CP]):

(103) Vowel Reduction Rules in Catalan (Mascaró 1978)

$$\begin{array}{l} \text{+syll} \\ \text{-hi} \\ \text{-str} \end{array} \quad \rightarrow \quad \text{+ATR}$$

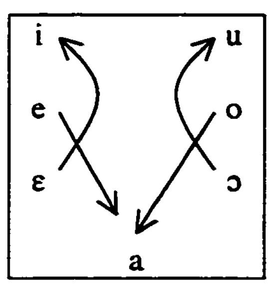
$$\begin{array}{l} \text{+syll} \\ \text{-hi} \\ \text{-CP} \\ \text{-str} \\ \langle\text{+back}\rangle \end{array} \quad \rightarrow \quad \begin{array}{l} \text{+back} \\ \langle\text{+hi}\rangle \end{array}$$

In fact, the choice of notational devices (alpha, angled brackets, and braces) to be used in formally describing Catalan vowel reduction in a rule-based approach was a topic for discussion in *Linguistic Inquiry* during the early 70's (Phelps 1972, Vogt 1972).

A more recent version of this approach to vowel reduction is found in Dukes (1993). In her analysis of Brazilian Portuguese vowel reduction, Dukes utilizes filters such as *[-ATR, -stress] to trigger the deletion of certain underlying feature specifications during the derivation of a surface form. Through the use of underspecification, these deletions result in the correct pattern of vowel neutralizations.

Although this type of rule-based approach can adequately capture the neutralization patterns observed in vowel reduction languages, it also has a number of drawbacks. For example, simply by changing the feature specifications mentioned in these rules, we can describe impossible forms of reduction—such as a system where stressed vowels become [ə] but unstressed vowels retain their underlying qualities. Even if we allow for some sort of additional mechanism that rules out reductive processes in stressed positions, certain logically possible but unattested patterns could still be described. For example, the following reduction pattern is unattested, and is predicted by my factorial typology of vowel reduction to be impossible, but it can be derived using the SPE-style rules shown:

(104) An Impossible Form of Reduction, and The Rules Deriving It



-ATR, -high, -stress	→	+high, +ATR
+ATR, -high, -stress	→	+low, -round, -front

7.0.2 Markedness-Based Approaches to Vowel Reduction

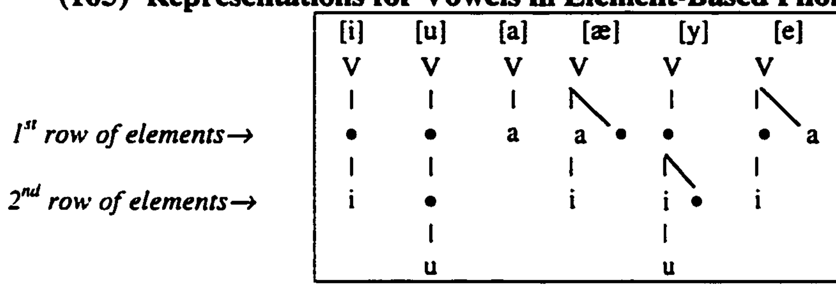
An improvement over the unconstrained rule-based approach discussed briefly above relies on the idea of markedness. By relying on markedness (to be defined), a rule-based approach can be constrained in certain ways. For example, Miller (1972) presents an analysis of several vowel reduction phenomena in the framework of natural phonology. Her basic approach regards the schwa position as unmarked, both literally and figuratively: Miller uses a set of features in which [-] specifications all correspond to the schwa-like configurations: the quality [ə] is therefore represented by Miller as a vowel with a [-] specification for all features ([-palatal], [-labial], [-high] [-low]). Different types of vowel reduction are analyzed in this approach as the deletion of at least some [+] feature specifications. In this way, Miller's view of vowel reduction is that unstressed (or otherwise reduced) vowels become more similar to schwa in some appropriate way as a result of vowel reduction.

Although Miller's approach accounts for many types of vowel reduction, especially those utilizing reduction to schwa, it is ill-suited to account for non-schwa-based reductions. For example, Miller's analysis of vowel reduction in Russian relies on a step-wise reduction process: first all non-high unstressed vowel are reduced to [ə], then certain of these schwas are fronted and raised to [i] (i.e., after palatalized consonants), or are lowered to [a] (i.e., in immediately pretonic position). As pointed out in chapter 5, however, the reduction of Russian /e/ to [i] is not dependent on the presence of a preceding palatalized consonant—therefore, Miller's analysis cannot account for the pronunciation of Russian /etáʒ/ as [itáʃ], for example. This approach to vowel reduction is also problematic for the type of reduction found in standard Italian, where /ɛ,ɔ/ neutralize in favor of /e,o/ in unstressed positions: it is unclear in what way /e,o/ could be claimed to be more similar to [ə] than are /ɛ,ɔ/. Furthermore the lax vowels /ɛ,ɔ/ are usually differentiated from the tense vowels /e,o/ by a [-] specification: the lax vowels are usually [-ATR] or [-constricted pharynx] (only rarely [+RTR])—this means that tensing of unstressed vowels might have to correspond to deleting or replacing a [-] specification for some vowel feature.

7.0.3 Particle-Based Approaches to Vowel Reduction

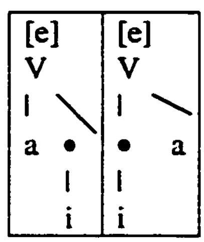
A newer and more widely applicable approach to vowel reduction using the ideas of particle phonology (and similar frameworks) has been explored by Kamprath (1991), Anderson (1996) and Harris (1997). The basic idea behind particle phonology is that all vowels consist of three basic particles or elements: I, U, and A. These particles can be combined, much likes water-colors, to derive different vowel qualities. For example, a vowel that is mostly [I] with a touch of [A] would correspond to [e], while a vowel that is mostly [A] with a touch of [I] would correspond to [ɛ] or [æ] (depending on the particular version of the theory being used). There are a number of different phonological schools that utilize this basic idea, and therefore the exact representation of a vowel quality in terms of particles is subject to variation. However, they are all reminiscent of one another. One particular representational system for some familiar vowels is shown below. This system is that of van der Hulst (1988), repeated here from illustrations in Kamprath (1991):

(105) Representations for Vowels in Element-Based Phonology



In these representations, the structures shown descending straight down from the V node represent the main quality of the vowel—these are referred to as the "head" of the vowel's representation. The structures that are shown branching off to the right of the V node represent modifications to the main quality of the vowel, and are referred to as "dependents". The symbol "•" represents a high tongue body position if it occurs in the first row of elements, and represents velarity if it occurs in the second row of elements. Kamprath utilizes this system of vowel representations to provide a unified account for vowel reduction in several different languages. In her approach, vowel reduction corresponds to the pruning (deletion) of dependents. Therefore, all unstressed vowels neutralize to the vowel quality corresponding to the "head" of their underlying representation. For example, if the non-head dependent branch of the representation for [e] provided in (105) above were removed, the remainder of the structure would correspond to the representation for [i]—this is the formal analysis of the vowel reduction process /e/ > [i]. Formally, this approach to vowel reduction corresponds to a structural simplification of unstressed vowels: complex vocalic structures (those involving both a head and a dependent) are limited to occurring in stressed positions. Kamprath's approach also offers an explanation for the different types of neutralization processes that are observed in languages with similar vowel inventories. Specifically, Kamprath points out that identical vowel qualities can have different representations in an element-based approach such as the one she adopts. For example, the vowel [e] can have either of the two representations shown below:

(106) Two Element-Based Representations for [e] (Kamprath 1991)



In a language that has /e/ > [a] reduction, the underlying representation for /e/ is as shown in the left-hand column: an [a]-based head with an [i]-dependent. In a language that has /e/ > [i] reduction, the underlying representation for /e/ is as shown in the right-hand column above: an [i]-based head, with an [a] dependent. A similar story applies for the variable reduction of /o/ to either [a] or [u], etc.

A similar approach to vowel reduction is explored by Anderson (1996) and Harris (1997). Both use a slightly different element-based representational system, in which elements are simply listed, rather than organized into trees. For example, Anderson (1996) gives the following underlying representations for the Bulgarian vowel system:

(107) The Bulgarian Vowel System (Anderson 1996)

Qualities		
i		u
e		o
	ʌ	
	a	

Representations		
{i}		{u}
{a,i}		{a,u}
	{ }	
	{a}	

So, for example, the Bulgarian vowel /e/ consists of the elements {a,i} (here, the ordering of elements within curly braces indicates which is the predominant quality—the first element listed would correspond to the "head"). In Anderson's theory of vowel reduction, a certain element or combination of elements is excluded from appearing in the reduced vowel sub-inventory. In the case of Bulgarian vowel reduction, the element {a} is excluded. By deleting the {a} element from all the vowel representations given above in (107), the correct results are derived: /e/ merges with /i/, /o/ merges with /u/, and /a/ merges with /ʌ/.

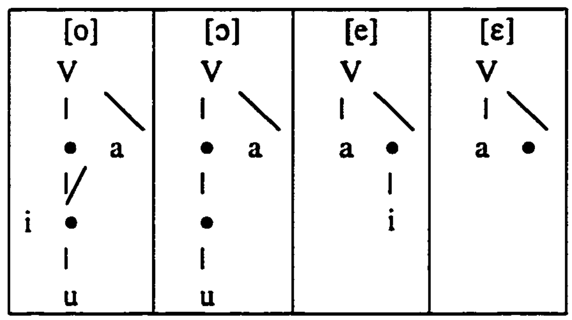
In Harris' (1997) account of vowel reduction, non-dominant (i.e., unstressed) vowels have limited licensing ability, which may have the effect of limiting the articulatory complexity of that vowel's representation. In this sense, Harris' approach to vowel reduction is very similar to Kamprath's in that vowel reduction is seen as a limitation of the complexity of vocalic representations. In an analysis similar to Kamprath's, Harris postulates that only single-element vowels can occur in the weakly-licensed positions of some languages, and that complex (i.e., multi-element) vowels must be simplified to one or fewer elements when found in unstressed position. In other words, under Harris' view, a reduced vowel sub-inventory can contain the single-element qualities [i,u,a] or the no-element quality [ə].

Although all three of the element-based accounts of vowel reduction are appealing in certain aspects, it has to be noted that they do not provide a full account for vowel reduction phenomena. The allure of these accounts are mirrored by the two different approaches that exploit the element-based systems: either certain elements are banned altogether from unstressed syllables (as in Anderson's (1996) analysis), or the complexity of element combinations is limited in unstressed syllables (as in Kamprath's (1991) and Harris' (1997) analyses). In both cases, reduction is simply and elegantly modeled as the subtraction of some object from a more complex underlying structure: either subtraction of a specific element, or of a specific type of structure. However, this elegance of analysis does not extend to other types of vowel reduction. Some of the cases that are problematic for element-based approaches are outlined below:

Reduction targeting high vowels: As described in chapter 2, high vowels are sometimes singled out for reduction due to their low inherent duration. In Slovene, this results in the neutralization of /i,u/ to [ə] in short positions (Lencek 1982). The Slovene case can be modeled as a form of element deletion: the elements {i} and {u} are not allowed to occur in unstressed positions. However, note that this statement only effects the elements {i} and {u} when they occur in isolation—vowels such as /e/ and /o/ which contain the {i} and {u} elements in combination with an {a} element are not subject to reduction. In other words, the Slovene case could be summed up by barring the elements {i} and {u} from occurring in isolation in unstressed syllables—combining these elements with another (such as {a}) protects them. This is problematic for the approaches advanced by Kamprath (1991) and Harris (1997) because this represents a case in which a given element must be considered to be *more* marked when found in isolation as part of a simple structure, and considered to be *less* marked when found as part of a more complex structure.

Reduction based on [ATR]: Another problematic type of reduction is that seen in standard Italian or Brazilian Portuguese moderate vowel reduction—this type of reduction based on [ATR] neutralization is not handled elegantly in an element-based approach to vowel reduction. Recall that in this type of reduction, the vowels /ɛ,ɔ/ reduce to [e,o] in unstressed position. The distinction between tense and lax vowels has various representations in element-based theories. In earlier frameworks, such as the framework developed by van der Hulst (1988) and adopted by Kamprath (1991), tenseness is indicated by adding an additional {i}-particle to some dependent branch of the vowel's representation (in this framework, the particle {i} represents both palatality and ATR-ness). Therefore, the differences between /e,o/ and /ɛ,ɔ/ might be as shown below:

(108) Representations for Tense/Lax Mid Vowels (van der Hulst 1988)



In more recent theories of element-based phonology, the lax vs. tense distinction is seen as one of headedness: tense vowels are headed, while lax vowels are headless. In the element-based framework used by Harris (1997), for example, headedness is indicated via underlining the predominant element in a vowel's representation. For example, the vowel /e/ would be represented by Harris as <$\underline{\text{I}}$,A>, which indicates that this vowel is predominantly *I* with a little bit of *A* mixed in. Similarly, the vowel /ɛ/ would be represented as <A,I> (sans underlining), which indicates that this vowel is an equal mixture of *A* and *I*. Neither of these representations for tenseness/laxness lend themselves to explaining the standard Italian or Brazilian Portuguese reduction of lax vowels via tensing. For example, in the framework depicted in (108), this type of vowel reduction would have to be modeled as addition of an {i}-particle as a dependent member of the representation of an underlying lax vowel. This approach is inconsistent with the idea of reduction-as-simplification, since vowel reduction must now be modeled as the addition of some element. Furthermore, in the case of /ɔ/ > [o], not only is an additional element added, but an additional dependent branch must be added to the vowel's representation to house this additional particle (cf. the illustrations in (108))—thus reduction in this case corresponds both to addition of elements and increase in complexity. The situation is a little better using the more recent representations of tenseness/laxness as headedness. In this case, Italian vowel reduction simply boils down to adding a specification of headedness: the representation <I,A> must become <$\underline{\text{I}}$,A>. This in itself is only a moderate improvement—Italian vowel reduction is now modeled only as an increase in complexity (an indication of the predominance of one element over the other is added), but no actual particles are added. However, it is unclear how we are to know where the underlining should go: if a headless vowel truly does not possess any indication as to whether one element is dominant over the other, why wouldn't <I,A> become <I,$\underline{\text{A}}$>? (The representation <I,$\underline{\text{A}}$> would correspond to [æ], presumably.)

Sri Lankan Vowel Reduction: Finally, a third thorny case for vowel reduction in element-based phonology is the vowel reduction process observed in Sri Lankan

Portuguese Creole (Smith 1978), where the low vowels /æ,a,ɒ/ raise to the corresponding mid vowels /e,ə,o/ when they become unstressed. Although the change of /a/ to [ə] could be modeled in element phonology as the pure loss of an element (the *a* element, presumably), the same is not true for the others. Following Harris' representation of /e,o/ as $\langle \underline{I},A \rangle$ and $\langle \underline{U},A \rangle$, respectively, I will assume that /æ,ɒ/ are represented as $\langle \underline{A},I \rangle$ and $\langle \underline{A},U \rangle$, respectively. In this case, then, Sri Lankan Creole vowel reduction is a process of headedness flip-flop: the dominant element becomes recessive, and the recessive element becomes dominant. Although the overall complexity of the vowel's representation has remained the same, this analysis is problematic because it eliminates the possibility of formally uniting this vowel reduction phenomenon with that of Bulgarian. Although these processes appear very similar on the surface (unstressed sonorous vowels become less sonorous in a stepwise fashion), they are modeled in element-based approaches as completely different: Bulgarian requires deletion of the [a]-particle in unstressed syllables, while Sri Lankan Creole requires a headedness reversal in unstressed syllables.

In the three cases discussed above (reduction targeting high vowels, [ATR] neutralizations, and Sri Lankan Creole reduction targeting low vowels), the idea that vowel reduction corresponds elegantly to either a decrease in complexity or the elimination of a single element in unstressed syllables is contradicted. These three patterns require vowel reduction to target simplex structures (i.e., high vowels), require increases in complexity (i.e., adding an element or adding a headedness specification), or require a change in structural description (i.e., headedness flip-flop). However, having said this, I would like to emphasize that these examples do not invalidate the use of element-based representations for vowels in general—it merely invalidates the claim that vowel reduction is *more elegantly* accounted for using such a representation. It is entirely possible to model a problematic reduction pattern, such as the Sri Lankan Creole pattern, using the element-based representations. For example, we could say that the element {a} may not occupy the head position in unstressed syllables in Sri Lankan Creole. Therefore, underlyingly {a}-headed vowels will have to undergo some change in their surface representation—either the {a}-element will be deleted (for underlying /a/), or a dependent element will become the head (for underlying /æ, ɒ/). Similarly, the Slovene (/i,u/ > [ə]) reduction case can be represented in an element-based theory by banning isolated {i} and {u} in unstressed syllables. However, statements such as "{a} may not occur as a head" or "{i} and {u} may not occur in isolation" are more like phonotactic constraints than constraints on complexity, and it is not clear that they are superior to constraints discussed in previous chapters, such as *Unstressed/X and Lic[+high].

Finally, it should also be pointed out that element-based approaches to vowel reduction do not fair as well as it might appear at first glance with respect to predicting either the pattern of neutralization or its conditioning environment. Recall, for instance, that element-based approaches account for different patterns of neutralization by positing different underlying structures for the vowels of different languages—a language with the reduction /e/ > [i] has an [i]-headed front mid vowel, while a language with the reduction /e/ > [a] has an [a]-headed front mid vowel. However, recall that the mid vowels can show variable reduction patterns ***within the same language***. Such is the case, for example, in the Rhodope dialects of Bulgarian, where unstressed /e,o/ reduce to [a] in syllables that precede the stress, but reduce to [i,u] (respectively) in syllables that follow the stress (Miletich 1936, Stoikov 1968). This vowel reduction pattern can be handled in the style proposed by Kamprath (1991) only by assuming that Rhodope Bulgarian /e/ has two different underlying representations: it is [a]-headed in some syllables, and [i]-headed in other syllables. A similar argument can be made for Russian dialects with *a-reduction*, in which unstressed /e/ reduces to [a] in the immediately pretonic syllable, and reduces to [i] elsewhere. Also, recall that some vowel reduction neutralizations are conditioned not by stress or its absence, but by the length of the vowel: for example, Slovene mid and lax vowels contrast when bimoraic, but neutralize when monomoraic (even if stressed). In Harris' (1997) account, vowel reduction is viewed as a limitation on licensing: vowels that are the head of some domain can license more complex vocalic structures than can the non-dominant vowels of the same domain.[51] However, it is not clear how a main-stressed monomoraic vowel in Slovene is any less the head of its domain than is a main-stressed bimoraic vowel. This same point has been made by

[51] Harris analyzes the non-dominant unstressed vowels as governed by the head vowel. The unstressed vowels receive their licensing ability through inheritance from the stressed vowel.

Steriade (1994a) with respect to licensing-by-position accounts of laryngeal neutralizations. As she correctly points out, a given structural position does not license the presence of additional phonological materials unless such a position logically entails a more robust phonetic deployment of this extra material, such as by providing additional time for the execution of fine phonological contrasts. Under this account, it is clear that Slovene long vowels are better licensers simply because they are longer, not because they have some special structural position.

7.0.4 Positional Faithfulness and Vowel Reduction

Positional faithfulness (Beckman 1998, Alderete 1995) is perhaps the most successful previous approach to vowel reduction I have encountered. It is quite similar in form to the Licensing and Prominence Reduction constraints I use to analyze vowel reduction, but with a different mode of deployment. Both licensing constraints and prominence reduction constraints can be thought of as "positional markedness" constraints—certain marked elements (such as certain vowel qualities) are considered to be *more marked* in certain positions (such as unstressed syllables). In contrast, positional faithfulness allows certain faithfulness requirements to be stronger in certain positions (such as in stressed syllables). Therefore, in a "positional markedness" approach to vowel reduction such as the one I develop, neutralizations target only a subset of vowels—usually, those that are unstressed or otherwise non-prominent. In a positional-faithfulness approach, however, neutralizations target all syllables, and are blocked *only* in certain prominent contexts via the action of position-specific faithfulness constraints. As an example of how this approach works, I will briefly describe Beckman's (1998) positional-faithfulness account of the vowel reduction process seen in certain dialects of Catalan (cf. Valencian and Northwestern dialects, in the terminology used by Recasens 1981). In these dialects of Catalan, vowel reduction works in a way similar to that seen in standard Italian: the lax mid vowels /ɛ,ɔ/ become tense when unstressed. Beckman accounts for this use a context-free markedness constraint banning the combination of the features [-ATR, -low]—a combination which, as pointed out in chapter 2, combines mutually opposing acoustic cues. If this constraint were undominated, it would lead to the tensing (or lowering) of all underlying lax mid vowels—indeed, Beckman claims that this ranking results in vowel inventories that lack lax mid vowels. However, in the language systems under consideration, this constraint is dominated by a positional-faithfulness constraint that requires all stressed vowels to maintain their underlying specifications for [ATR]. This means that unstressed lax mid vowels are free to shed their problematic [-ATR] specification, thus ridding themselves of an awkward feature combination, while the stressed lax mid vowels are constrained by positional faithfulness to forego this option. This situation is demonstrated in the following tableau:

(109) Beckman's (1998) Analysis of Valencian Catalan Vowel Reduction

Ident-σ́-ATR: Don't change [ATR] specifications of stressed vowels
Ident-ATR: Don't change [ATR] specifications for any vowels.
NonLo/ATR: Non-low vowels must be [+ATR]

/pɛz /	IDENT-σ́-ATR	NONLO/ATR	IDENT-ATR
☞ pɛ́s			
pés	*!		

/pɛz-et/	IDENT-σ́-ATR	NONLO/ATR	IDENT-ATR
☞ pezét			
pɛzét		*!	

The definitions of the constraints used in Beckman's analysis are provided above the first tableau shown in (109) above—basically, she uses one position-specific faithfulness constraint that bans changing the ATR-quality of a stressed vowel, and a context-free markedness constraint that demands all non-low vowels be [+ATR]. As shown in the first tableau, the ranking of the positional faithfulness constraint IDENT-σ́-ATR over the markedness constraint NonLo/ATR prevents tensing of a stressed lax mid vowel: the positional faithfulness constraint blocks an otherwise general phonotactic of the language. In the second tableau, a lax mid vowel occurs in an unstressed syllable. In this case, the positional faithfulness constraint cannot protect this vowel from quality changes, and it therefore undergoes tensing to satisfy NonLo/ATR.

In comparison, the same pattern is generated under my approach by using a Licensing constraint based on the same marked feature combination: Lic[-ATR, -low]/stress. In effect, this constraint can be thought of as a position-specific markedness constraint: whereas [-ATR, -low] is ordinarily a marked combination, when it is found in an unstressed syllable, it is even more marked. Under this approach, no positional faithfulness constraint is required, since the vowel reduction constraint is specific to unstressed syllables.

As Beckman points out, both of these approaches—Positional Faithfulness and Licensing—are capable of handling vowel reduction facts. However, researchers such as Zoll (1998) have recently demonstrated that although Licensing can account for all the phenomena covered by Positional Faithfulness, the reverse is not true. That is, there are alternations that can be accounted for via Licensing, but which are not compatible with an analysis in terms of Positional Faithfulness.

I have not identified any cases where this point can be demonstrated for vowel reduction as I have defined it for the current study. However, the point can be made using a very similar type of stress-dependent vowel neutralization—not a neutralization of vowel *quality*, but of vowel *quantity*. This example is taken from the Orlec dialect of Croatian (Houtzagers 1982, 1985). In this dialect, vowel length is contrastive in accented syllables only. This is demonstrated by the following minimal pairs and near minimal pairs:

(110) Minimal and Near-Minimal Pairs for Vowel Length in Orlec

Words With Long Vowels		Words With Short Vowels	
ú:sta	*'mouth'*	úski	*'narrow'*
tí:rat	*'pull'*	tírat	*'prod'*
tá:t	*'thief'*	ták	*'wooden chopping block'*
sé:st	*'sit down'*	ʃést	*'type of cooper's tool'*
blí:ʒu	*'near'*	sísa	*'nipple'*
muhí:ć	*'unidentified weed'*	miʃíć	*'muscle'*
zvoní:k	*'bell-tower'*	zvonít	*'ring, toll'*

However, unaccented vowels are uniformly short, and if accent moves off of a long vowel, that vowel concomitantly shortens. Instances of vowel shortening due to accent shift are illustrated below:

(111) Shortening Under Accent Shift in Orlec

Accented Long Vowel		Shortened Vowel (Unaccented)	
ʒú:j	*'blister'*	ʒují	*'blisters'*
nó:s	*'nose, spout'*	nosú	*'nose, spout' (loc.)*
tsvé:st	*'to bloom'*	tsvetú:ć	*'to bloom' (gerund)*
trú:t	*'duty' (nom.)*	trudá	*'duty' (gen.)*
bó:s	*'barefooted'*	bosá	*'barefooted' (fem.)*
frí:ʃ	*'stripe'*	friʒíć	*'stripe' (dim.)*
sné:h	*'snow' (nom.)*	snehú	*'snow' (loc.)*

I account for this length neutralization using the following prominence-reduction constraint:

***Unaccented/μμ:** Unaccented vowels may not be bimoraic.

This constraint is similar to the prominence-reduction constraints that derive extreme vowel reduction: In extreme vowel reduction, certain vowel qualities are too prominent (i.e., too *sonorous*) to occur in unstressed positions. In Orlec, certain vowel lengths are too prominent (i.e., too *long*) to occur in unaccented positions. By ranking this constraint above a moraic faithfulness constraint, the correct pattern is derived:

(112) Tableaux Demonstrating Shortening Under Affix Shift

/sne:h/ 'snow' (nom.)	*UNACCENTED/μμ	MAX-μ
☞ sné:h		
snéh		*!

/sne:h + ú/ 'snow' (loc.)	*UNACCENTED/μμ	MAX-μ
☞ snehú		
sne:hú	*!	

As shown in the first tableau above, these two constraints have no effect on long vowels that occur in accented syllables—this is because the *Unaccented/μμ constraint is specific only to unaccented syllables. In the second tableau, the ranking *Unaccented/μμ » Max-μ is responsible for ruling out the incorrect candidate *sne:hú. With the opposite constraint ranking, the incorrect pattern would be predicted: it would be preferable to retain long vowels in unaccented syllables rather than delete an underlying mora.

The length neutralization just discussed could also be accounted for using a positional faithfulness approach. In this type of analysis, the following constraints would be used:

***V:** Long vowels are marked (long vowels do not occur in output forms).

Max-σ́-μ: Do not delete moras contained in accented syllables.

By ranking Max-σ́-μ above *V:, the correct pattern is accounted for: long vowels are eliminated in all but the accented syllables. This is demonstrated in the following tableaux:

(113) Shortening Under Affix Shift—Positional Faithfulness Approach

/sne:h/ 'snow' (nom.)	**Max-σ́-μ:**	***V:**
☞ snéːh		
snéh	*!	

/sne:h + ú/ 'snow' (loc.)	**Max-σ́-μ:**	***V:**
☞ snehú		
sne:hú		*!

In the first tableau, the constraint *V: militates towards eliminating the underlying long vowel, but this is over-ridden by the higher-ranked constraint Max-σ́-μ. In the second tableau, no such blocking occurs, since the long vowel in this form is in an unaccented syllable, and therefore outside the domain of Max-σ́-μ. In summary, the length neutralization found in Orlec Serbo-Croatian can be accounted for using two different theoretical approaches—one based on positional markedness (in this case, prominence-reduction), and one based on positional-faithfulness. However, the Orlec dialect also possesses vowel lengthening. In the phenomenon of presonorant lengthening, a vowel becomes long if it occurs in a syllable closed by a sonorant.

(114) Presonorant Lengthening in Orlec

Lengthening Does Not Apply		**Lengthening Does Apply**	
govoríla	*'spoke' (fem.)*	govorí:l	*'spoke' (masc.)*
kantát	*'to sing'*	kantá:l	*'sang' (masc.)*
ʒúɲa	*'July' (gen.)*	ʒú:ɲ	*'July' (nom.)*
terpét	*'to suffer'*	terpé:l	*'suffered' (masc.)*

In the data shown above, all accented vowels undergo lengthening if they occur in a syllable closed by a sonorant. Notice that lengthening only occurs if the accented vowel is followed by a *coda* sonorant—it does not occur if the accented vowel is followed by a heterosyllabic sonorant, as in *govoríla* 'she spoke' (*govorí:la).

Presonorant lengthening can be accounted for as a case of moraic sequencing. I assume that codas are obligatorily moraic if (and only if) they are sonorant. The vowels of such syllables then obligatorily lengthen if they are not already long in order to maintain their status as the most moraicly prominent element of their syllable. The following two constraints derive this situation:

Sonorant Coda: Sonorant codas are moraic.

Moraic Sequencing: The syllable nucleus is more prominent at the moraic level than non-nuclear elements of the same syllable.

The presonorant lengthening phenomenon found in Orlec is quite similar to the presonorant reduction-blocking discussed in chapter 4 with respect to European Portuguese. Recall that in that case, vowels found in syllables closed by a sonorant may not be nonmoraic, and as such are immune to vowel reduction. Therefore, we can say that in European Porgtuguese, there is a moraic sequencing constraints that requires syllable nuclei to be merely *as* sonorous as its margins; the variant found in Orlec Serbo-Croatian requires that the nucleus be *more* sonorous than its margins. It should also be mentioned that presonorant lengthening also effects the standard dialect of Serbo-Croatian, where it effects both accented and unaccented vowels that are found before a sonorant coda (cf. Zec 1994). In the standard dialect, however, only certain sonorants (such as /j,w/) condition this behavior. The two cases of European Portuguese and standard Serbo-Croation are important, since they show that presonorant lengthening of the type found in Orlec is not specific to accented syllables: in both standard Serbo-Croatian and in European Portuguese, this type of effect is found in unaccented syllables as well. To prevent this degree of generality from occurring in Orlec, it is necessary to merely rank the **Moraic Sequencing** constraint below *Unaccented/μμ. This is demonstrated in the tableaux shown below:[52]

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[52] One may wonder, given this description of presonorant lengthening, whether the Orlec dialect derives trimoraic syllables due to the process of presonorant lengthening. As pointed out by Christina Bethin, this is not necessarily the case—the accented vowel might simply "share" the mora associated with the coda. Thus, the vowel lengthens without requiring addition of a mora.

(115) **Tableaux Demonstrating Presonorant Lengthening**

/govorí + l/ 'he spoke'	*UNACCENTED/μμ	MORAIC SEQUENCING	DEP-μ
☞ govorí:l			
govoríl		*!	

/tombat/ 'to drop'	*UNACCENTED/μμ	MORAIC SEQUENCING	DEP-μ
☞ tombát			
to:mbát	*!		

As demonstrated in the first tableau, an accented vowel that is followed by a sonorant coda can undergo the lengthening required by **Moraic Sequencing**—that is, presonorant lengthening is not blocked in accented syllables. Presonorant lengthening is blocked in unaccented syllables, however, as demonstrated in the second tableau. There, the unaccented vowel of *tombát* 'to drop' is found in a syllable with a sonorant coda, but it does not undergo lengthening. This is due to the constraint ***Unaccented/μμ**--presonorant lengthening in this case would create a vowel that is too prominent for its position. Note that Moraic Sequencing must outrank the constraint Dep-μ ("do not insert moras").

This sort of approach cannot be extended to the positional-faithfulness account. If we add the Moraic Sequencing constraint to the positional faithfulness analysis sketched above, we will incorrectly derive presonorant lengthening in *all* syllables, regardless of accent:

/govori + l/ 'he spoke'	Max-σ-μ:	Moraic Sequencing	*V:	Dep-μ
☞ govorí:l				
govoríl		*!		

/tombat/ 'to drop'	Max-σ-μ:	Moraic Sequencing	*V:	Dep-μ
☹ to:mbát				
tombát		*!		

Here, the moraic sequencing constraint is shown dominating the *V: constraint. This ranking is necessary to allow presonorant lengthening to apply when appropriate—the opposite ranking would block presonorant lengthening in *all* positions since it would be preferable to forego lengthening in order to avoid creating a marked long vowel. However, this ranking also allows presonorant lengthening to apply in unaccented syllables, as shown in the second tableau. Here, an incorrect form with lengthening of an unaccented vowel (*to:mbát) is predicted to emerge as the winner. No re-ranking of these constraints will produce the desired effect simply because nothing specifically rules out lengthening in unaccented syllables: under positional faithfulness, a non-faithful phenomenon can only occur (a) in all syllables, or (b) in non-prominent syllables. Prominent syllables are specifically shielded from undergoing any change, which is the opposite of the attested pattern of presonorant lengthening in Orlec.

7.1 Concluding Remarks on Vowel Reduction

Throughout my examination of vowel reduction phenomena, one point stands out for emphasis—vowel reduction as defined here constitutes a highly diverse collection of stress-dependent vowel neutralization phenomena. As I emphasize in this chapter, attempts to formally account for vowel reduction in generative phonology without consulting a representative empirical sampling of attested vowel reduction phenomena almost uniformly fail to achieve adequacy. The approach adopted here allows for a full coverage of all the attested patterns by allowing a number of different underlying motivations for reduction: avoidance of highly sonorous vowels, avoidance of nonperipheral vowels, avoidance of counter-enhancing feature combinations, etc. This approach has the added benefit of providing a simple account for two-pattern vowel reduction phenomena. By focussing all the various vowel reduction constraints on non-prominent positions, vowel reduction can be formally united with other stress-dependent neutralizations, such as the length neutralization discussed above for Orlec Serbo-Croatian.

This is not to say, however, that the proposed account of vowel reduction lacks a unifying theme. On the contrary—vowel reduction is analyzed under this approach as an articulated system of phonetically natural phonological processes that either increase perceptibility by enhancing vowel contrasts or increase articulatory ease by eliminating vowels that make inefficient use of articulatory time. That is, we intuitively perceive vowel reduction as a unitary process not because it has a single type of formal representation, but because the different vowel reduction phenomena fulfill similar goals and produce similar types of results.

APPENDICES

APPENDIX A: ATTESTED PATTERNS OF REDUCTION, ALPHABETICALLY BY LANGUAGE

Language # 1	Basque, Bortzetierra
Phonemic vowels	i,u,e,o,a
Neutralizations	Not specified in source,but result in an [i,u,a] sub-inventory.
Comments	This dialect of Basque has a strong stress-based accent.
Sources	Hualde 1991

Language # 2	Bulgarian, Standard
Phonemic vowels	i,u,e,o,ʌ,a
Neutralizations	/e/>[i], /o/>[u], /a/>[ʌ]
Factorial Typology:	Output Pattern # 17
Comments	Bulgarian /ʌ/ is a phonemic mid central vowel which can bear stress. Not all dialects of Standard Bulgarian show all the neutralizations shown above, but there is an implicational hierarchy /e/>[i] → /o/>[u] → /a/>[ʌ]. This reduction pattern is also found in many Bulgarian dialects, such as those of the Balkan dialect group (cf. Stoikov 1968).
Sources	Lehiste & Popov 1970, Scatton 1984, Pettersson & Wood 1987a, 1987b; Groen 1987

Language # 3	Bulgarian, Rhodope
Phonemic vowels	i,u,e,o,a
Neutralizations	moderate: /e,o/>[a] extreme: /e/>[i], /o/>[u], /a/>[ə]
Factorial Typology:	Output Pattern # 25 (moderate); Output Pattern # 17 (extreme)
Comments	Moderate reduction occurs in unstressed syllables preceding the stress; extreme reduction occurs in unstressed syllables following the stress.
Sources	Miletich 1936, Stoikov 1968

Language # 4	Bulgarian, Shirokolushki
Phonemic vowels	i,u,e,o,a,ʌ
Neutralizations	/i,e/>[ə]
Factorial Typology:	Output Pattern # 11
Comments	This reduction process is blocked when preceded by a palatalized consonant—in which environment the surface quality [i] emerges. This process is also blocked by rounding of unstressed /i/ to [u] when followed by /x/ or /f/.
Sources	Stoikov 1968 (p. 91-92)

Language # 5	Bulgarian, Pavlikianski
Phonemic vowels	i,u,e,o,a,ʌ
Neutralizations	/i/>[ə]
Factorial Typology:	Output Pattern # 4
Comments	Similar to the reduction process described in Shirokolushki Bulgarian, but does not affect unstressed /e/.
Sources	Stoikov 1968 (p. 95)

Language # 6	Bulgarian, Trigrad
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations	/ɛ/ > [e], /o,ɔ/ > [a]
Factorial Typology:	Output Pattern # 161
Comments	This dialect of Bulgarian does not possess the phonemic /ʌ/ vowel of standard Bulgarian. Reduction can be blocked in this dialect to avoid homophony (see Crosswhite 1999).
Sources	Stoikov 1963

Language # 7	Catalan, Central (a.k.a. Eastern, East Central)
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations:	/e,ɛ,a/>[ə], /o,ɔ/>[u]
Factorial Typology:	Output Pattern # 148
Comments	Also found in the Catalan of Menorqui and Eivissenc. Reduction is blocked in certain unstressed hiatal positions, and in certain morphological contexts.
Sources	Recasens 1991, Mascaró 1978

Language # 8 Catalan, North-Eastern and Valencian
Phonemic vowels i,u,e,o,ɛ,ɔ,a
Neutralizations: /ɛ/>[e], /ɔ/>[o] **Factorial Typology:** Output Pattern # 47
Comments
Sources Recasens 1991

Language # 9 Catalan, Algueres
Phonemic vowels i,u,e,o,ɛ,ɔ,a
Neutralizations: /e,ɛ/>[a], /o,ɔ/>[u] **Factorial Typology:** Output Pattern # 117
Comments
Sources Recasens 1991

Language # 10 Catalan, Majorcan
Phonemic vowels i,u,e,o,ɛ,ɔ,a
Neutralizations: /e,ɛ,a/>[ə], /ɔ/>[o] **Factorial Typology:** Output Pattern # 104
Comments
Sources Recasens 1991

Language # 11 Catalan, Balear
Phonemic vowels i,u,e,o,ɛ,ɔ,a
Neutralizations: /e,ɛ,a/>[ə] **Factorial Typology:** Output Pattern # 103
Comments
Sources Recasens 1991

Language # 12 Catalan, Rossellenes
Phonemic vowels i,u,e,o,a
Neutralizations: /e,a/>[ə], /o/>[u] **Factorial Typology:** Output Pattern # 19
Comments
Sources Recasens 1991

Language # 13	Chamorro
Phonemic vowels	i,u,æ,ɑ
Neutralizations	/ɑ,æ/>[a] under secondary stress, /ɑ,æ/>[ə] in unstressed syllables
Factorial Typology:	n/a (not a 5- or 7- vowel language)
Comments	It is sometimes reported (i.e., Beckman 1997) that Chamorro has raising of unstressed /e,o/ to [i,u]. However, the vowels /e,o/ are not phonemic in Chamorro—they are allophonic variants of /i,u/ that appear in closed, stressed syllables (cf Chung 1983, Crosswhite 1999). In addition, preliminary instrumental works with a native speaker of Saipanese Chamorro suggests that the reduction /ɑ,æ/>[a] under secondary stress is a gradient process (i.e., it results only in a partial neutralization).
Sources	Topping 1969; Topping, Ogo, and Dungca 1975

Language # 14	Dutch
Phonemic vowels	
Neutralizations	reduction of unstressed vowels to [ə]
Factorial Typology:	n/a (see comments)
Comments	It has been argued by van Bergem (1994) that vowel reduction in Dutch is either phonetic (gradient, tempo-dependent), or lexicalized (i.e., non-phonological).
Sources	van Bergem 1994

Language # 15	English
Phonemic vowels	Varies. Commonly: i,u,ɪ,ʊ,e,o,ɛ,ɔ,æ,a,ʌ
Neutralizations	*Variant 1:* All unstressed vowels > [ə]. *Variant 2*: Unstressed vowels except /ɪ,ʊ/ reduce to [ə].
Factorial Typology:	Similar to Output Pattern # 235 and Output Pattern # 219
Comments	The phonetic realization of [ə] can vary: Common realization include [ə], [ɨ], [∅], and syllabic sonorants. Dipthongs and other “long” vowels reduce via laxing—this process is blocked in unstressed word-final open syllables. Several non-reduction phenomena can cause vowel quality changes in English (cf. trisyllabic shortening and managerial lengthening)

Language # 16	Gabrielino
Phonemic vowels	i,u,e,o,a
Neutralizations:	/i/>[e], /u/>[o]
Factorial Typology:	Output Pattern # 14
Comments	Gabrielino is a now-extinct Native American language.
Sources	Munro *in progress*

Language # 17	Greek, dialectal (Asia Minor)
Phonemic vowels	i,u,e,o,a
Neutralizations:	/e/>[i], /o/>[u]
Factorial Typology:	Output Pattern # 14
Comments	Unstressed [i] and [u] are commonly deleted. It is not clear from the source whether unstressed vowel reduction/deletion is obligatory or optional.
Sources	Dawkins 1916

Language # 18	Icelandic
Phonemic vowels	
Neutralizations	See comments
Comments	This vowel reduction process does not produce vowel quality alternations. The existence of this type of vowel reduction in Icelandic is based on indirect evidence, including distributional limitations of certain vowel qualities, and the behavior of umlaut in unstressed syllables.
Sources	Aranason, 1988

Language # 19	Italian, Standard
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations:	/ɛ/>[e], /ɔ/>[o]
Factorial Typology:	Output Pattern # 47
Comments	Reduction affects both unstressed vowels and vowels bearing 2ry stress.
Sources	Flemming 1995

Language # 20	Italian, dialectal (Northern Italian dialect)
Phonemic vowels	i,u,e,o,ε,ɔ,a
Neutralizations	moderate: /i,u,e,o,ε,ɔ/>[ə] extreme: /i,u,e,o,ε,ɔ,a/>[ə]
Factorial Typology:	Output Pattern # 234 (moderate), Output Pattern # 235 (extreme)
Comments	Moderate reduction affects unstressed syllables that precede the stress. Extreme reduction affects unstressed syllables that follow the stress.
Sources	Maiden 1995

Language # 21	Italian, dialectal (Neapolitan)
Phonemic vowels	i,u,e,o,ε,ɔ,a
Neutralizations	moderate /e,ε/>[i] /o,ɔ/>[u] extreme /i,e,ε,o,ɔ,u/ > [ə]
Factorial Typology:	Output Pattern # 122 (moderate), Output Pattern # 234 (extreme)
Comments	Extreme reduction affects unstressed phrase-final vowels. Moderate reduction affects other unstressed vowels.
Sources	Bafile 1997, Harris 1997

Language # 22	Luiseño
Phonemic vowels	i,u,e,o,a
Neutralizations:	/e/>[i], /o/>[u]
Factorial Typology:	n/a (see comments)
Comments	The constraint proposed for the Luiseno reduction pattern (Lic/Color) has rather sparse attestation cross-linguistically. For this reason, it was not included in the factorial typology.
Sources	Munro and Benson 1973

Language # 23	Polish, dialectal (found near Ukraine)
Phonemic vowels	i,u,e,o,a
Neutralizations	/e/>[i], /o/>[u]
Factorial Typology:	Output Pattern # 14
Comments	Standard Polish does not have vowel reduction. This dialectal variant is found in areas of Poland near Ukraine. Dialects with this pattern of reduction are characterized as having a stronger stress than Standard Polish.
Sources	Ubańczyk, 1953 (p. 11)

Language # 24	Portuguese, Brazilian
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations	moderate /ɛ/>[e], /ɔ/>[o] extreme /ɛ,e/>[i], /o,ɔ/>[u], /a/>[ə]
Factorial Typology:	Output Pattern # 47 (moderate); Output Pattern # 135
Comments	Extreme reduction occurs in word-final and (in some dialects) word-initial unstressed syllables. Moderate reduction occurs in other unstressed syllables. In the variant describe by Dukes (1993), the lax mid vowels do not undergo "superraising" to [i,u].
Sources	Dukes 1993, Redenbarger 1981

Language # 25	Portuguese, Brazilian, North-East dialects
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations	moderate /e/>[ɛ], /o/>[ɔ] extreme /ɛ,e/>[i], /o,ɔ/>[u], /a/>[ə]
Factorial Typology:	n/a (see comments)
Comments	Extreme reduction occurs in word-final unstressed syllables. Moderate reduction occurs in other unstressed syllables. A similar type of reduction has been described for Standard Slovene (cf.), but acoustic analysis reveals that the neutralization of /e,ɛ/ or /o,ɔ/ does not yield [ɛ] and [ɔ], but mid vowels that are unspecified for [ATR] (Lehiste 1961). No acoustic analysis for North-Eastern Brazilian Portuguese has been performed to my knowledge.
Sources	Perrone and Ledford-Miller 1985

Language # 26	Portuguese, European
Phonemic vowels	i,u,e,o,ɛ,ɔ,a and (marginally) ɐ
Neutralizations:	/e,ɛ,a/>[ə], /o,ɔ/>[u]
Factorial Typology:	Output Pattern # 148
Comments	Vowel reduction is blocked in unstressed syllables that possess a sonorant coda. Such syllables do not bear secondary stress.
Sources	de Carvalho 1988-92, Brakel 1985a

Language # 27	Portuguese, Sri-Lankan Creole
Phonemic vowels	i,u,e,o,æ,a,ɒ
Neutralizations: /æ/>[e], /a/>[ə], /ɒ/>[o] **Factorial Typology:** n/a (not a 5- or 7- vowel language)	
Comments	Reduction occurs in all unstressed syllables. In this language, vowels lengthen under stress, so this reduction pattern might be conditioned by lack of stress, lack of length, or both.
Sources	Smith 1978

Language # 28	Romansch, Bergün
Phonemic vowels	i,u,e,o,ɛ,ɔ,a
Neutralizations: /e/>[i], /o/>[u], /ɛ,ɔ/>[a] **Factorial Typology:** Output Pattern # 127	
Comments	
Sources	Lutta 1923, Kamprath 1991

Language # 29	Russian, Contemporary Standard
Phonemic vowels	i,u,e,o,a
Neutralizations moderate/e/>[i], /o,a/>[a] extreme /e/>[i], /o,a/>[ə] **Factorial Typology:** Output Pattern # 27 (moderate), Output Pattern # 33 (extreme)	
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic or immediately word-initial, and in certain unstressed hiatus positions. Extreme reduction occurs in other unstressed syllables. The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov 1984, Bondarko 1977, Bulanin 1977, Zubkova *et al.* 1985

Language # 30	Russian, dialectal (Muscovite *prostorechie*)
Phonemic vowels	i,u,e,o,a
Neutralizations: /i,u,e,o,a/>[ə] **Factorial Typology:** Output Pattern # 43	
Comments	It is not clear from the source whether this reduction process is affected by the presence of a preceding palatalized consonant.
Sources	Dedova 1988

Language # 31	Russian, dialectal with a-reduction
Phonemic vowels	i,u,e,o,a, and in some dialects ɛ,ɔ
Neutralizations	moderate /e,ɛ,o,ɔ/>[a] extreme /e,ɛ/>[i], /o,a/>[ə]
Factorial Typology:	Output Pattern # 25 (moderate), Output Pattern # 33 (extreme)
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic. Extreme reduction occurs in other unstressed syllables. (Behavior of immediately word-initial and hiatal unstressed vowels is not noted in the sources.) The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 32	Russian, dialectal with e-reduction
Phonemic vowels	i,u,e,o,a
Neutralizations	moderate /o,a/>[a] extreme /e/>[i], /a,o/>[ə]
Factorial Typology:	Output Pattern # 22
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic. Extreme reduction occurs in other unstressed syllables. (Behavior of immediately word-initial and hiatal unstressed vowels is not noted in the sources.) The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 33	Russian, dialectal with *incomplete okan'e*
Phonemic vowels	i,u,e,o,a and in some dialects ɛ,ɔ
Neutralizations	moderate no reduction extreme /e,ɛ/>[i], /o,a/>[ə]
Factorial Typology:	Output Pattern # 202
Comments	No reduction occurs in unstressed syllables that are immediately pretonic. Extreme reduction occurs in other unstressed syllables.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 34	Russian dialects with Don dissimilative pattern
Phonemic vowels	i,u,e,o,a and sometimes ɛ,ɔ
Neutralizations	moderate /e,ɛ,o,ɔ/>[a] extreme /e,ɛ/>[i], /o,a,ɔ/>[ə] **Factorial Typology:** Output Pattern # 25 (moderate), Output Pattern # 33 (extreme)
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic in words with a stressed high vowel. Extreme reduction occurs in other unstressed syllables. The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 35	Russian dialects with Obojan dissimilative pattern
Phonemic vowels	i,u,e,o,a and sometimes ɛ,ɔ
Neutralizations	moderate /e,ɛ,o,ɔ/>[a] extreme /e,ɛ/>[i], /o,a,ɔ/>[ə] **Factorial Typology:** Output Pattern # 25 (moderate), Output Pattern # 33 (extreme)
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic in words with a stressed high or mid-tense vowel. Extreme reduction occurs in other unstressed syllables. The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 36	Russian dialects with Zhizdra dissimilative pattern
Phonemic vowels	i,u,e,o,a and sometimes ɛ,ɔ
Neutralizations	moderate /e,ɛ,o,ɔ/>[a] extreme /e,ɛ/>[i], /o,a,ɔ/>[ə] **Factorial Typology:** Output Pattern # 25 (moderate), Output Pattern # 33 (extreme)
Comments	Moderate reduction occurs in unstressed syllables that are immediately pretonic in words with a stressed high or mid vowel. Extreme reduction occurs in other unstressed syllables. The non-front vowels /a,o/ show the same reduction reflexes as unstressed /e/ if the preceding consonant is palatalized.
Sources	Avanesov & Orlova 1965, Stroganova 1965, Meshcherskij 1972, Kuznetsov 1973, Kolesov 1990, Kasatkin 1989

Language # 37	Slovene, Contemporary Standard
Phonemic vowels	i,u,e,o,ɛ,ɔ,a,ʌ
Neutralizations /e/>[ɛ], /o/>[ɔ] **Factorial Typology:** n/a (see comments)	
Comments	The reduction of unstressed /e,o/ is conditioned not by stress~stresslessness, but by length. The tense and lax mid vowels are contrastive only when long. Short mid vowels (whether stressed or not) undergo neutralization. Colloquially, Contemporary Standard Slovene (CSS) also displays the reduction of /i,u,ʌ/ described for the Upper and Lower Carniolan dialects (cf.). The Carniolan dialects are the basis for CSS. Instrumental analysis by Lehiste (1961) suggests that the quality of the reduced vowels is not [ɛ,ɔ], but [ᴇ,ᴏ]—i.e., that the neutralized vowels are not marked for [ATR].
Sources	Bezlaj 1939, Toporishich 1976, Lencek 1982

Language # 38	Slovene, Horjulj
Phonemic vowels	not clear from source
Neutralizations /e/>[i], /o/>[a] **Factorial Typology:** Output Pattern # 14	
Comments	The Horjulj dialect belongs to the Rovte dialect group, which has replaced pitch-accent with stress.
Sources	Lencek 1982 (p. 145)

Language # 39	Slovene, Upper Carniolan
Phonemic vowels	i,u,e,o,ɛ,ɔ,a,ʌ
Neutralizations /i,u/>[ə], /ʌ/>[Ø] **Factorial Typology:** Output Pattern # 79	
Comments	
Sources	Lenchek 1982 (p. 147)

Language # 40	Slovene, Lower Carniolan
Phonemic vowels	i,u,e,o,ɛ,ɔ,a,ʌ
Neutralizations /i,u,ʌ/>[ə], /e,o/>[ɛ,ɔ] **Factorial Typology:** similar to Output Pattern # 81	
Comments	The reduction of high vowels (and ʌ) is weaker in the Lower Carniolan dialects than in the Upper Carniolan dialects.
Sources	Lencek 1982 (p. 147)

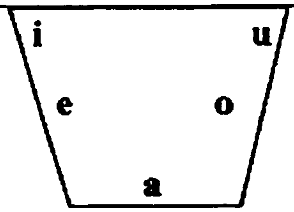
Language # 41	Spanish, Ecuadorian
Phonemic vowels	i,u,e,o,a
Neutralizations: /i/>[e], /u/>[o] **Factorial Typology:** Output Pattern # 14 or Output Pattern # 17	
Comments	Unstressed [i] and [u] also devoice and delete. Deletion and devoicing is more common in certain environments, such as adjacent to [s] or [h]. This seems to be an optional process. This type of reduction is also found in other South American dialects of Spanish. Standard Spanish does not have vowel reduction.
Sources	Lipski 1990

Language # 42	Tohono O'odham
Phonemic vowels	i,u,ɨ,o,a
Neutralizations: /ɨ,o,a/>[ə] **Factorial Typology:** n/a (not a typical 5-vowel inventory)	
Comments	The unstressed vowel inventory [i,u,ə] also undergoes devoicing. Hill and Zepeda transcribe the devoiced reduced vowels [i], [u], [ə]as [ʸ], [ʷ], and [ʰ], respectively.
Sources	Hill and Zepeda 1992

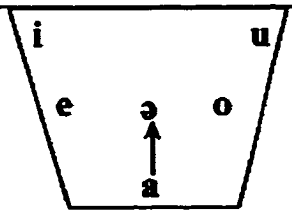
Language # 43	Ukrainian, Standard
Phonemic vowels	i,u,e,o,a
Neutralizations see comments **Factorial Typology:** n/a (see comments)	
Comments	According to Iushchuk (1984), the stressed syllable in standard Ukrainian is not sharply distinguished from unstressed syllables, and therefore all syllables are pronounced without reduction. However, Zilyns'kyj (1979) describes Ukrainian (including the "received pronunciation" of Ukrainian) as possessing phonetic vowel reduction—including the tendeny to reduce unstressed vowels in the immediately post-tonic syllable to [ə] or delete them entirely (depending on tempo and syllabic environment), and the tendency to slightly raise unstressed /e/ and /o/ (in the case of /o/, especially in a segmental environment favoring labialization).
Sources	Ioshchuk, 1984

Language # 44	Ukrainian, Sadzhava
Phonemic vowels	i,u,e,o,ɛ,a
Neutralizations /e,ɛ/ > [ə] **Factorial Typology:** Output Pattern # 98	
Comments	The original source uses the symbol *ä* instead of *ɛ*, and describe this vowel as "mid-low" in height, while *e* is described as "high-mid". It is therefore unclear whether this vowel corresponds to IPA [æ], [ɛ], or some intermediate quality. Sometimes [i] is also found in alternation with [ə]: *líd~lədú* 'ice, nom.~loc.' However, this [i] results from raising of underlying /ɛ,e/ in a closed final syllable: cf. *lɛ́du* (gen.).
Sources	Popova (1972)

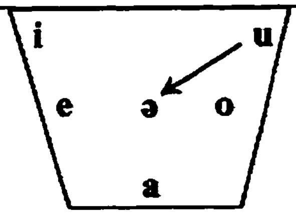
APPENDIX B: PREDICTED VOWEL REDUCTION PATTERNS FOR 5-VOWEL SYSTEMS



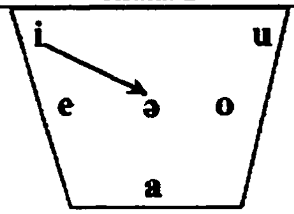
Output Pattern # 1
status: common
strata: 2



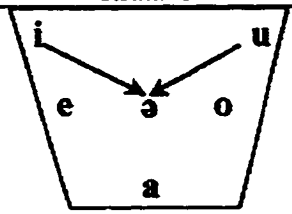
Output Pattern # 2
status: questionable[53]
strata: 3



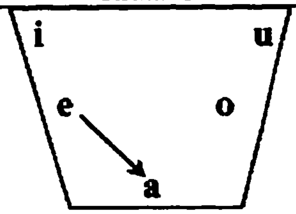
Output Pattern # 3
status: cf. #4
strata: 3



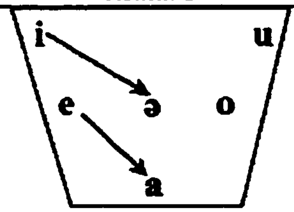
Output Pattern # 4
status: Pavilikianski Bulgarian
strata: 3



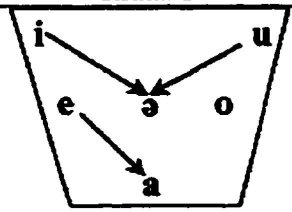
Output Pattern # 5
status cf Upper Carniolan Slovene #79
strata: 3



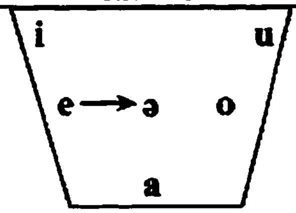
Output Pattern # 6
status: cf. Russ. [e]-reduction (#22)
strata: 3



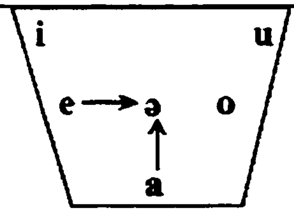
Output Pattern # 7
status: unattested
strata: 4



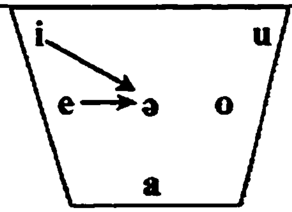
Output Pattern # 8
status: unattested
strata: 5



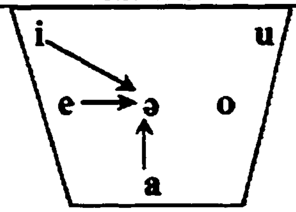
Output Pattern # 9
status cf Sadzhava Ukrainian #98
strata: 3



Output Pattern # 10
status: cf. Balear Catalan (#103)
strata: 3



Output Pattern # 11
status: Shirokolushki Bulgarian
strata: 3



Output Pattern # 12
status: cf. Balear Catalan (#103)
strata: 3

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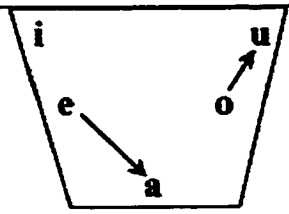
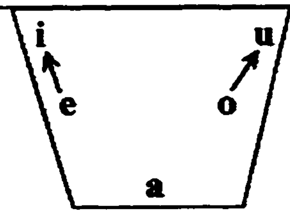
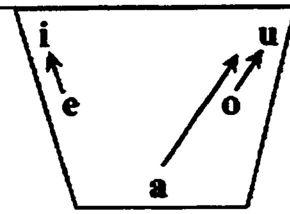
[53] Reduction of only /a/ to [ə] is probably quite common, but under-reported.



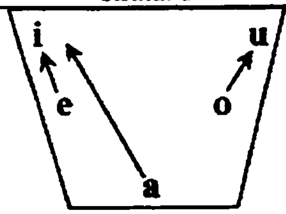
Output Pattern # 13
status: cf. Algueres Catalan (#117)
strata: 3



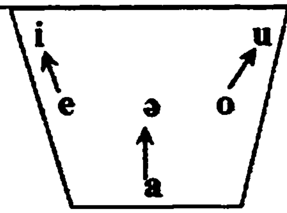
Output Pattern # 14
status: Gabrielino
strata: 2



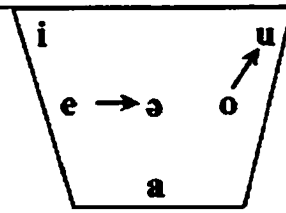
Output Pattern # 15
status: unattested
strata: 2



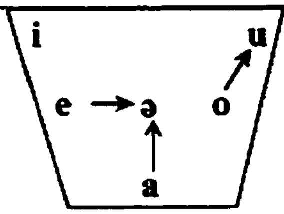
Output Pattern # 16
status: unattested
strata: 2



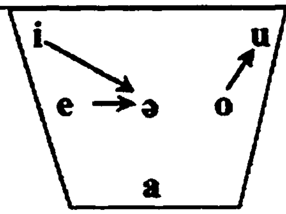
Output Pattern # 17
status: Bulgarian
strata: 2



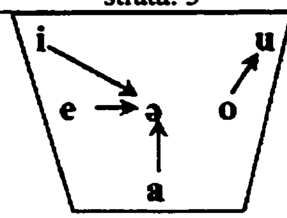
Output Pattern # 18
status: Sadzhava Ukrainian (#98)
strata: 3



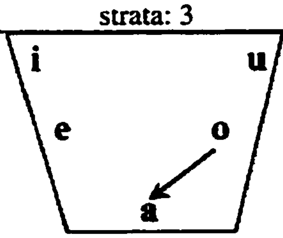
Output Pattern # 19
status: Rossellenes Catalan
strata: 3



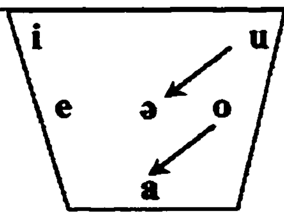
Output Pattern # 20
status: unattested
strata: 3



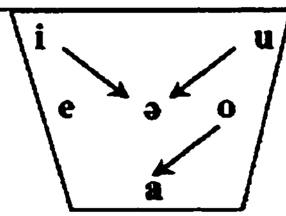
Output Pattern # 21
status: unattested
strata: 3



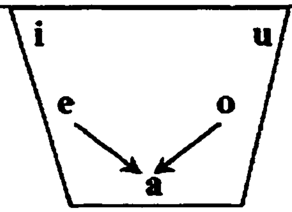
Output Pattern # 22
status: Russian [e]-reduction
strata: 3



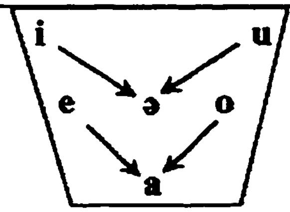
Output Pattern # 23
status: unattested
strata: 4



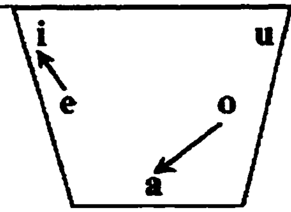
Output Pattern # 24
status: unattested
strata: 5



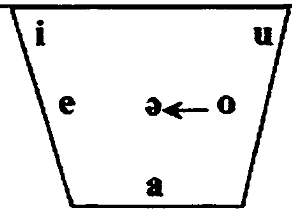
Output Pattern # 25
status: Russ. [a]-reduction, Rhodope Bulg.
strata: 2



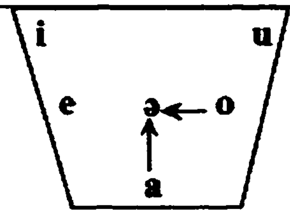
Output Pattern # 26
status: unattested
strata: 4



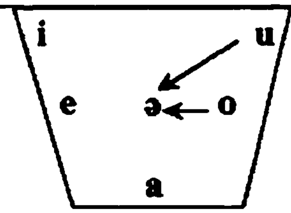
Output Pattern # 27
status: Standard Russian (pretonic)
strata: 3



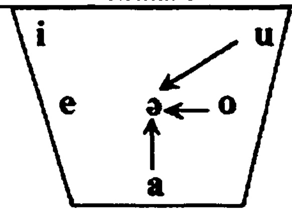
Output Pattern # 28
status: cf. Pavilikianski Bulgarian (#4)
strata: 3



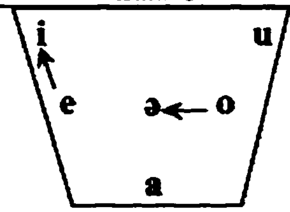
Output Pattern # 29
status: cf. Balear Catalan (#103)
strata: 3



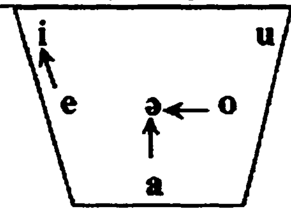
Output Pattern # 30
status: cf. Shirokolushki Bulgarian (#11)
strata: 3



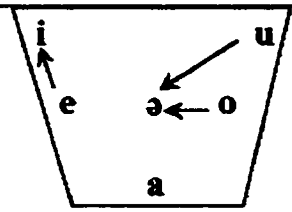
Output Pattern # 31
status: unattested
strata: 3



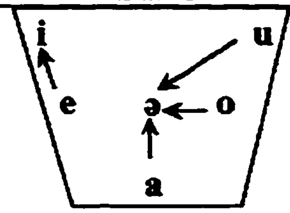
Output Pattern # 32
status: unattested
strata: 3



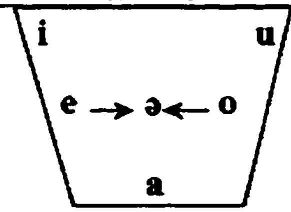
Output Pattern # 33
status: Standard Russian
strata: 3



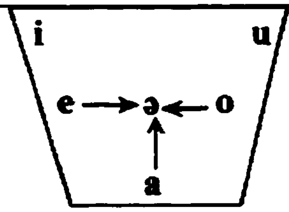
Output Pattern # 34
status: unattested
strata: 3



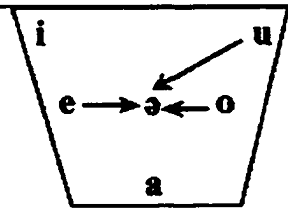
Output Pattern # 35
status: unattested
strata: 3



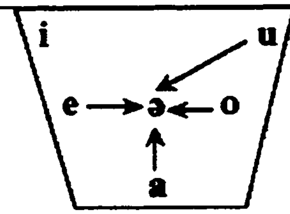
Output Pattern # 36
status: unattested
strata: 3



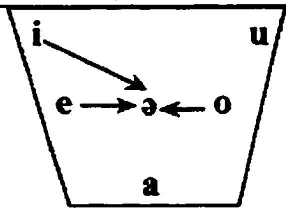
Output Pattern # 37
status: unattested
strata: 2



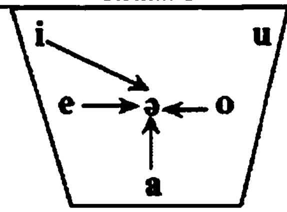
Output Pattern # 38
status: unattested
strata: 5



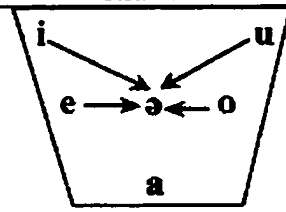
Output Pattern # 39
status: unattested
strata: 4



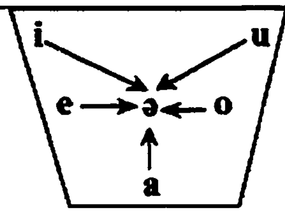
Output Pattern # 40
status: unattested
strata: 5



Output Pattern # 41
status: unattested
strata: 4



Output Pattern # 42
status: cf. Northern Italian (#47)
strata: 3



Output Pattern # 43
status: Muscovite *prostorechie*
strata: 2

Output Pattern # 1

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh

Output Pattern # 2

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(+lo)
	*Mid

Output Pattern # 3

/tota/	→[tota]
/teta/	→[teta]
/tita/	→[tita]
/tuta/	→[təta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-ft)
	Max(+rd)
	*Mid
	Max(+hi)
	Max(-lo)

Output Pattern # 4

/tota/	→[tota]
/teta/	→[teta]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
	Max(+hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 5

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(+ft)
	Max(-ft)
	*Mid
	Max(+rd)
	Max(-lo)

Output Pattern # 6

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
Stratum #3	Max(+ft)
	Dep(+lo)
	Max(-lo)

Output Pattern # 7

/tota/	→[tota]
/teta/	→[tata]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(+ft)
	Dep(+lo)
	Max(-lo)

Output Pattern # 8

/tota/	→[tota]/teta/ →[tata]
/tita/	→[təta]
/tuta/	→[təta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+rd)
	Max(-ft)
	Max(+hi)
Stratum #4	*Mid
Stratum #5	Max(+ft)
	Dep(+lo)
	Max(-lo)

Output Pattern # 9

/tota/	→[tota]
/teta/	→[təta]
/tita/	→[tita]
/tuta/	→[tuta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
Stratum #3	Max(-hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 10

/tota/	→[tota]
/teta/	→[təta]
/tita/	→[tita]
/tuta/	→[tuta]
/tata/	→[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	*Mid
	Max(+ft)
	Max(+lo)
	Max(-lo)

Output Pattern # 11

/tota/	→[tota]
/teta/	→[təta]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(+ft)
	*Mid
	Max(+hi)
	Max(-lo)

Output Pattern # 12

/tota/	→[tota]
/teta/	→[təta]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(-hi)
	Max(+ft)
	*Mid
	Max(+lo)
	Max(-lo)

Output Pattern # 13

/tota/ →[tuta]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
Stratum #3	Dep(+lo)
	Max(+ft)
	*Nonhigh
	Max(-lo)

Output Pattern # 14

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
Stratum #2	Dep(+hi)
	*Nonhigh
	*Non-schwa
	Max(-hi)

Output Pattern # 15

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tuta]

Stratum	Abbr.
Stratum #1	*Mid
	*Nonhigh
	*LaxMid
	Max(+rd)
	Dep(+ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Max(-lo)
Stratum #2	Dep(-ft)
	*Non-schwa
	Max(-hi)
	Dep(+rd)
	Dep(-lo)
	Max(+lo)
	Dep(+hi)

Output Pattern # 16

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Max(-lo)
Stratum #2	*Non-schwa
	Max(-hi)
	Dep(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ft)

Output Pattern # 17

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
Stratum #2	Max(-hi)
	Dep(+hi)
	*Non-schwa
	Max(+lo)
	*Mid

Output Pattern # 18

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Dep(+hi)
	Max(+ft)
	*Mid
	Max(-lo)

Output Pattern # 19

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
	Max(+lo)
Stratum #3	*Mid
	Max(+ft)
	Max(-lo)

Output Pattern # 20

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(-hi)
	*Mid
	Dep(+hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 21

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(-hi)
	Dep(+hi)
	*Non-schwa
	Max(+lo)
Stratum #3	*Mid
	Max(+hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 22

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
	*Mid
Stratum #3	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 23

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 24

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	Max(+ft)
Stratum #4	*Mid
Stratum #5	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 25

/tota/ →[tata]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
	Max(+ft)
	Dep(+lo)
	Max(-ft)
	Max(+rd)
	Max(-lo)

Output Pattern # 26

/tota/ →[tata]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(+rd)
	Dep(+lo)
	Max(+ft)
	Max(-ft)
	Max(-lo)

Output Pattern # 27

/tota/ →[tata]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	**Abbr.**
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
Stratum #3	Max(+rd)
	Dep(+lo)
	*Nonhigh
	Max(-ft)
	Max(-lo)

Output Pattern # 28

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	**Abbr.**
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
	*Mid
Stratum #3	Max(-ft)
	Max(+rd)
	Max(-hi)
	Max(-lo)

Output Pattern # 29

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Max(-hi)
	Max(+rd)
	*Mid
	Max(+lo)
	Max(-lo)

Output Pattern # 30

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(-hi)
	Max(-ft)
	Max(+rd)
	*Mid
	Max(-lo)

Output Pattern # 31

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	*Mid
	Max(+hi)
	Max(-hi)
	Max(-ft)
	Max(+rd)
	Max(+lo)
	Max(-lo)

Output Pattern # 32

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
	Max(-hi)
	Max(-ft)
	Dep(+hi)
	Max(+rd)
	Max(-lo)

Output Pattern # 33

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
	Max(+lo)
Stratum #3	*Mid
	Max(-ft)
	Max(+rd)
	Max(-lo)

Output Pattern # 34

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+rd)
	Max(+hi)
	Max(-hi)
	*Mid
	Max(-ft)
	Dep(+hi)
	Max(-lo)

Output Pattern # 35

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(-hi)
	Dep(+hi)
	*Non-schwa
	Max(+lo)
Stratum #3	Max(-ft)
	Max(+rd)
	*Mid
	Max(+hi)
	Max(-lo)

Output Pattern # 36

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Mid
	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(+rd)
	Max(+ft)
	Max(-ft)
	Max(-lo)

Output Pattern # 37

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	**Abbr.**
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(+rd)
	*Mid
	*Non-schwa
	Max(-hi)
	Max(+ft)
	Max(-ft)
	Max(+lo)
	Max(-lo)

Output Pattern # 38

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]

Stratum	**Abbr.**
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
Stratum #3	Max(-hi)
	Max(+ft)
Stratum #4	*Non-schwa
Stratum #5	Max(-ft)
	Max(+rd)
	*Mid
	Max(+hi)
	Max(-lo)

Output Pattern # 39

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(+ft)
	Max(-hi)
	Max(+lo)
Stratum #3	*Non-schwa
Stratum #4	Max(-ft)
	Max(+rd)
	*Mid
	Max(+hi)
	Max(-lo)

Output Pattern # 40

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
Stratum #3	Max(+rd)
	Max(-ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	*Mid
	Max(+hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 41

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	Max(-hi)
	Max(+rd)
	Max(-ft)
	Max(+lo)
Stratum #3	*Non-schwa
Stratum #4	*Mid
	Max(+hi)
	Max(+ft)
	Max(-lo)

Output Pattern # 42

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]

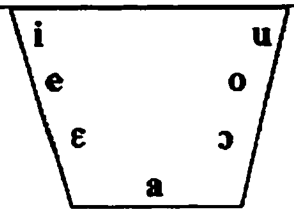
Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+rd)
	Max(+hi)
	Max(-hi)
	Max(+ft)
	Max(-ft)
	*Mid
	Max(-lo)

Output Pattern # 43

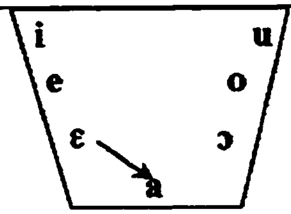
/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[təta]

Stratum	Abbr.
Stratum #1	*Non-schwa
	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
Stratum #2	*Mid
	Max(+rd)
	Max(+hi)
	Max(-hi)
	Max(+ft)
	Max(-ft)
	Max(+lo)
	Max(-lo)

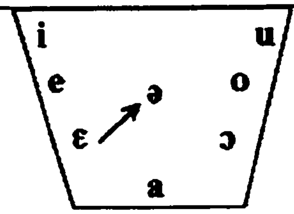
APPENDIX C: PREDICTED VOWEL REDUCTION PATTERNS FOR 7-VOWEL SYSTEMS



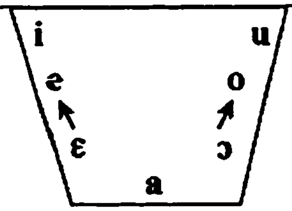
Output Pattern # 44
Status: common
Strata: 2



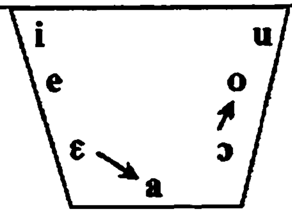
Output Pattern # 45
Status: not attested
Strata: 3



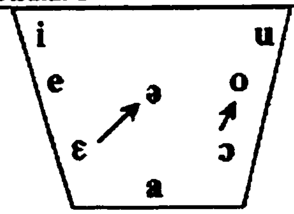
Output Pattern # 46
Status: cf. Pavlikianski Bulg. (#4)
Strata: 3



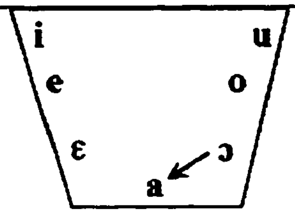
Output Pattern # 47
Status: Standard Italian
Strata: 2



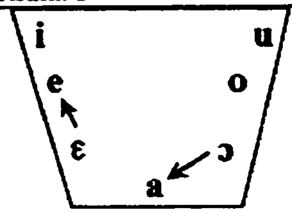
Output Pattern # 48
Status: cf. Trigrad Bulgarian (#161)
Strata: 3



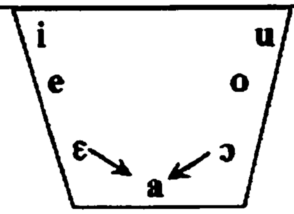
Output Pattern # 49
Status: not attested
Strata: 3



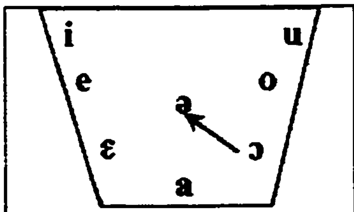
Output Pattern # 50
Status: not attested
Strata: 3



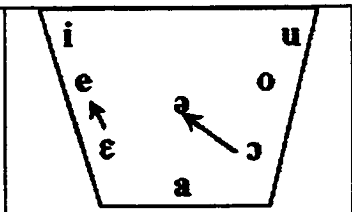
Output Pattern # 51
Status cf. Trigrad Bulg. #161
Strata: 3



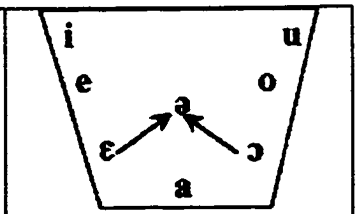
Output Pattern # 52
Status: cf. Russ. [a]-reduction (#25)
Strata: 2



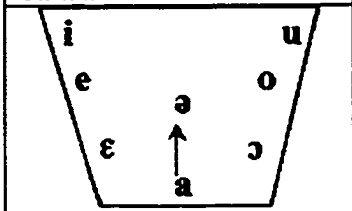
Output Pattern # 53
Status: cf. Pavlikiansk Bulgarian (#4)
Strata: 3



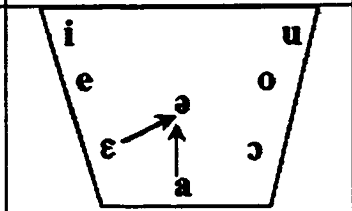
Output Pattern # 54
Status: not attested
Strata: 3



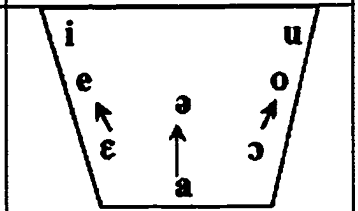
Output Pattern # 55
Status: not attested
Strata: 2



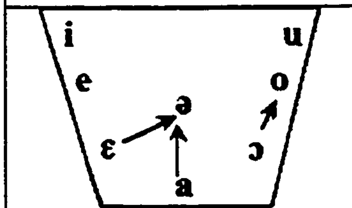
Output Pattern # 56
Status: questionable[54]
Strata: 3



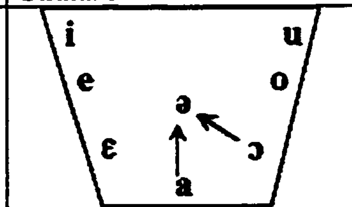
Output Pattern # 57
Status: cf. Russian [e]-reduction (#22)
Strata: 3



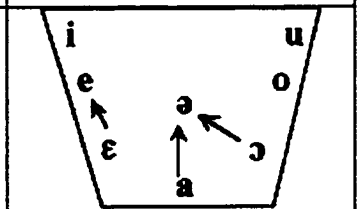
Output Pattern # 58
Status: cf. Italian (#47)
Strata: 3



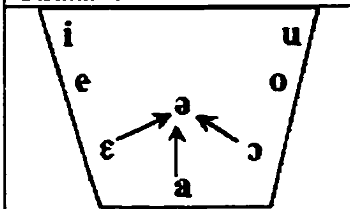
Output Pattern # 59
Status: cf. Majorcan Catalan (#104)
Strata: 3



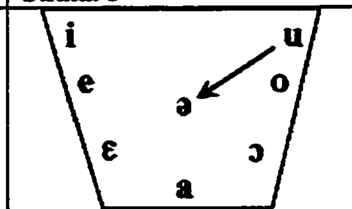
Output Pattern # 60
Status: cf. Russian [e]-reduction (#22)
Strata: 3



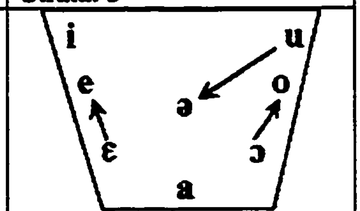
Output Pattern # 61
Status: cf. Trigrad Bulgarian (#161)
Strata: 3



Output Pattern # 62
Status: not attested
Strata: 3

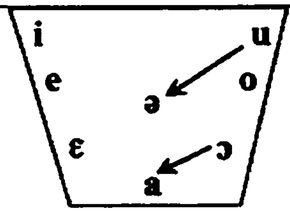


Output Pattern # 63
Status: cf. Pavlikianski Bulgarian (#4)
Strata: 3

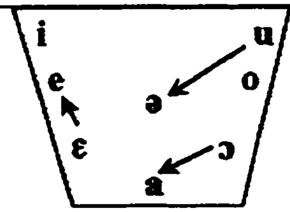


Output Pattern # 64
Status: not attested
Strata: 3

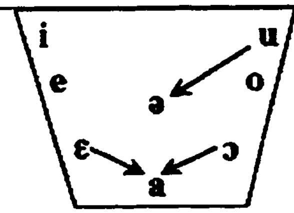
[54] Reduction of only /a/ to [ə] is probably quite common, but under-reported.



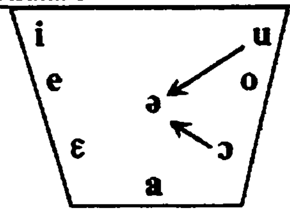
Output Pattern # 65
Status: not attested
Strata: 3



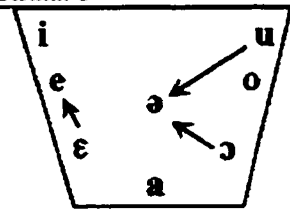
Output Pattern # 66
Status: not attested
Strata: 3



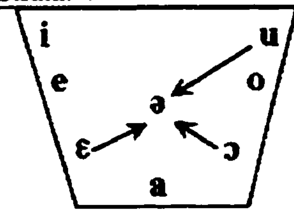
Output Pattern # 67
Status: not attested
Strata: 4



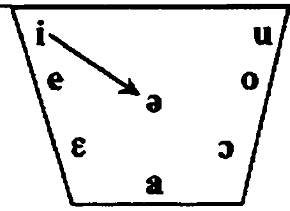
Output Pattern # 68
Status: not attested
Strata: 5



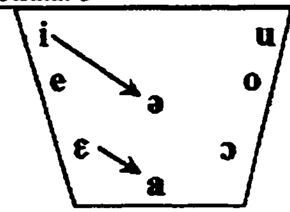
Output Pattern # 69
Status: not attested
Strata: 5



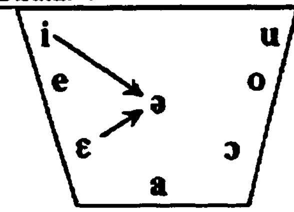
Output Pattern # 70
Status: not attested
Strata: 4



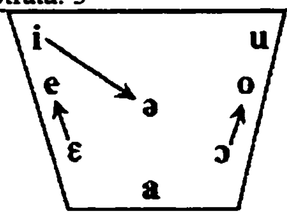
Output Pattern # 71
Status: cf. Pavlikianski Bulgarian (#4)
Strata: 3



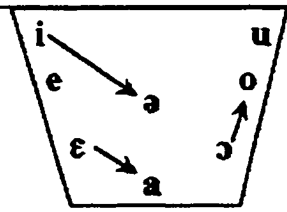
Output Pattern # 72
Status: not attested
Strata: 3



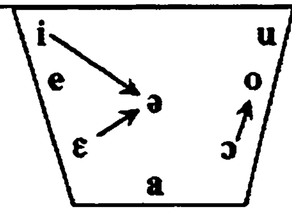
Output Pattern # 73
Status: not attested
Strata: 5



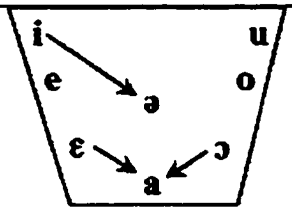
Output Pattern # 74
Status: cf. Lower Carn. Slovene (p. 293)
Strata: 3



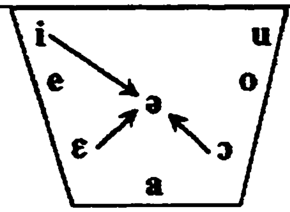
Output Pattern # 75
Status: not attested
Strata: 3



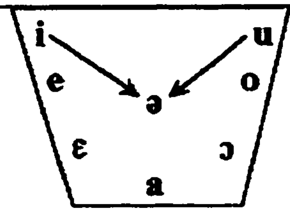
Output Pattern # 76
Status: not attested
Strata: 5



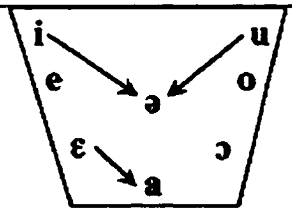
Output Pattern # 77
Status: not attested
Strata: 4



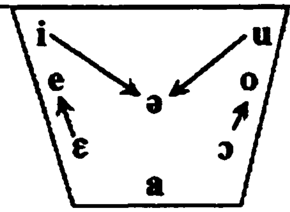
Output Pattern # 78
Status: not attested
Strata: 4



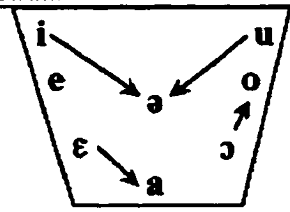
Output Pattern # 79
Status: Upper Carn. Slovene (p. 292)
Strata: 3



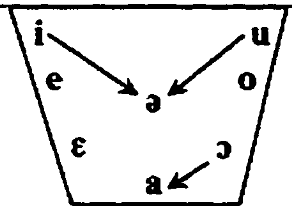
Output Pattern # 80
Status: not attested
Strata: 5



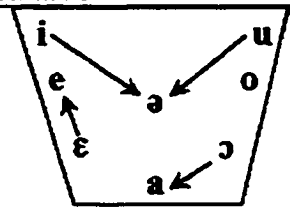
Output Pattern # 81
Status: cf. Lower Carn. Slovene (p. 293)
Strata: 3



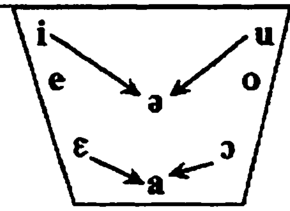
Output Pattern # 82
Status: not attested
Strata: 5



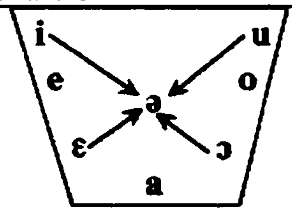
Output Pattern # 83
Status: not attested
Strata: 5



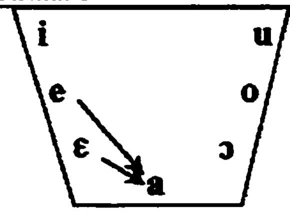
Output Pattern # 84
Status: not attested
Strata: 5



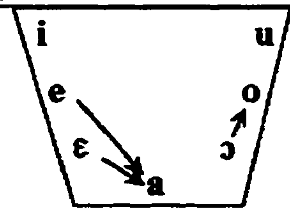
Output Pattern # 85
Status: not attested
Strata: 3



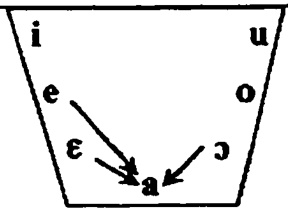
Output Pattern # 86
Status: not attested
Strata: 4



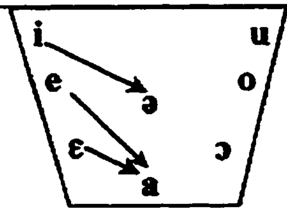
Output Pattern # 87
Status: cf. Russian [e]-reduction (#22), Balear Catalan (#103)
Strata: 3



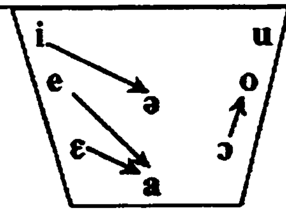
Output Pattern # 88
Status: cf. Majorcan Catalan (#104)
Strata: 3



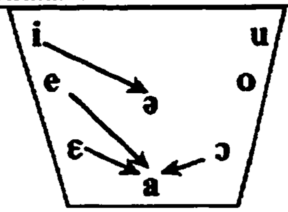
Output Pattern # 89
Status: not attested
Strata: 4



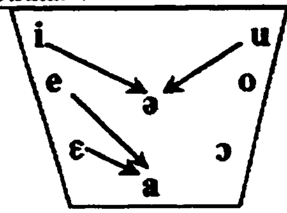
Output Pattern # 90
Status: not attested
Strata: 4



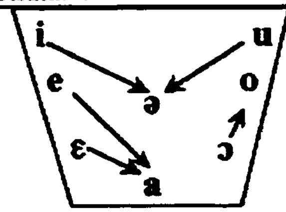
Output Pattern # 91
Status: not attested
Strata: 4



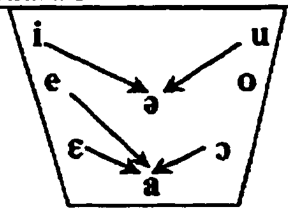
Output Pattern # 92
Status: not attested
Strata: 5



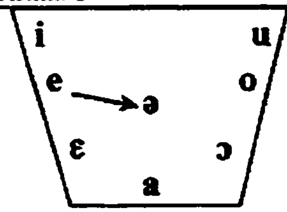
Output Pattern # 93
Status: not attested
Strata: 5



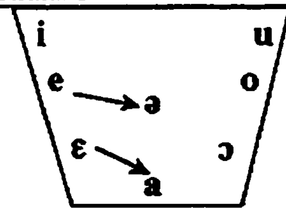
Output Pattern # 94
Status: not attested
Strata: 5



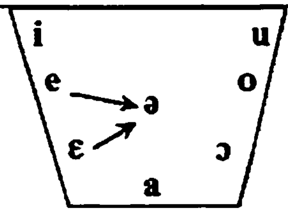
Output Pattern # 95
Status: not attested
Strata: 5



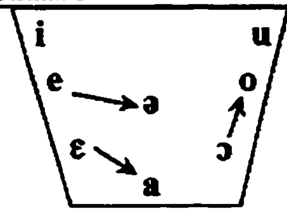
Output Pattern # 96
Status: cf. Pavlikianski Bulgarian (#4)
Strata: 3



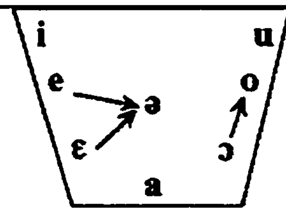
Output Pattern # 97
Status: not attested
Strata: 3



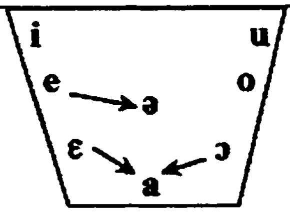
Output Pattern # 98
Status: Sadzhava Ukrainian
Strata: 3



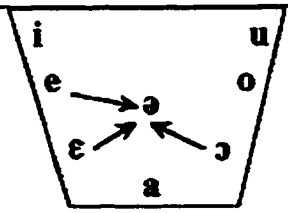
Output Pattern # 99
Status: not attested
Strata: 4



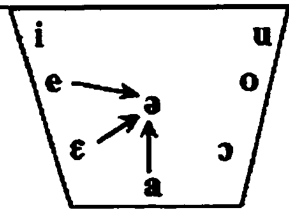
Output Pattern # 100
Status: cf. Sadzhava Ukrainian (#98)
Strata: 3



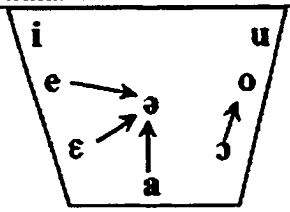
Output Pattern # 101
Status: not attested
Strata: 4



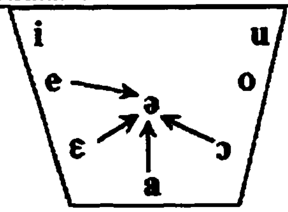
Output Pattern # 102
Status: not attested
Strata: 4



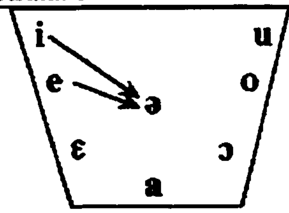
Output Pattern # 103
Status: Balear Catalan
Strata: 3



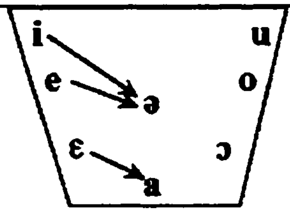
Output Pattern # 104
Status: Majorcan Catalan
Strata: 3



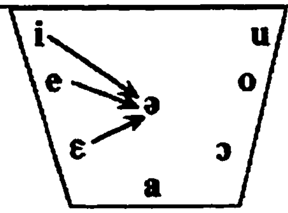
Output Pattern # 105
Status: not attested
Strata: 4



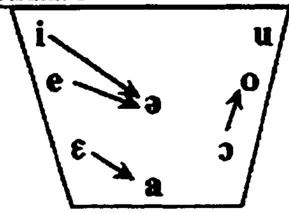
Output Pattern # 106
Status: cf. Shirokolushki Bulg. (#11)
Strata: 3



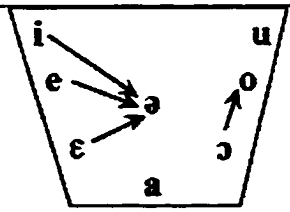
Output Pattern # 107
Status: not attested
Strata: 3



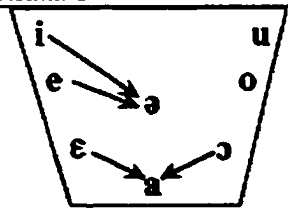
Output Pattern # 108
Status: cf. Shirokolushki Bulgarian (#108)
Strata: 3



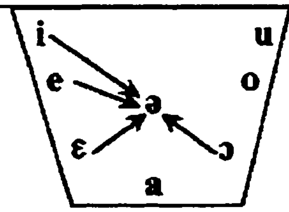
Output Pattern # 109
Status: not attested
Strata: 4



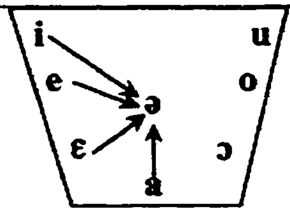
Output Pattern # 110
Status: not attested
Strata: 3



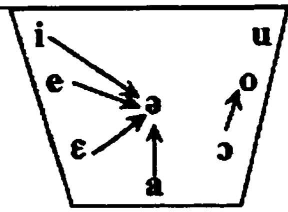
Output Pattern # 111
Status: not attested
Strata: 4



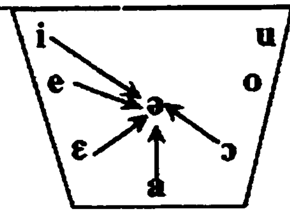
Output Pattern # 112
Status: not attested
Strata: 4



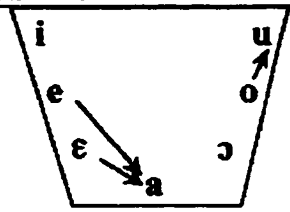
Output Pattern # 113
Status: not attested
Strata: 3



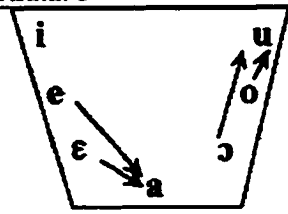
Output Pattern # 114
Status: not attested
Strata: 3



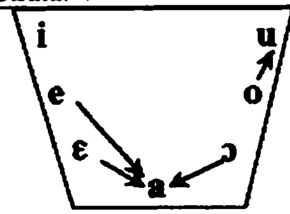
Output Pattern # 115
Status: not attested
Strata: 4



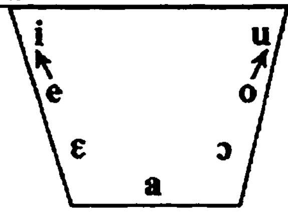
Output Pattern # 116
Status: not attested
Strata: 4



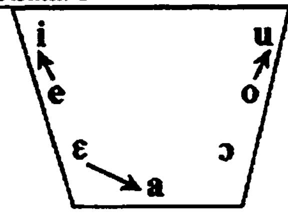
Output Pattern # 117
Status: Algueres Catalan
Strata: 3



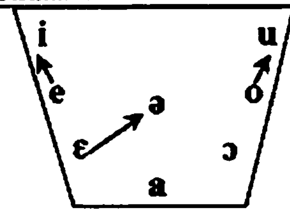
Output Pattern # 118
Status: not attested
Strata: 4



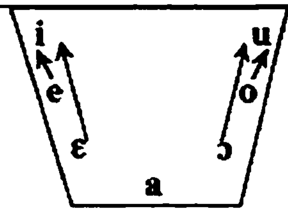
Output Pattern # 119
Status: not attested
Strata: 3



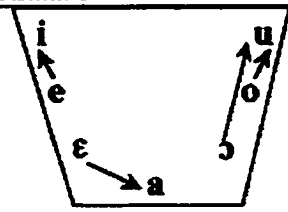
Output Pattern # 120
Status: cf. Bergün Romansch (#127)
Strata: 3



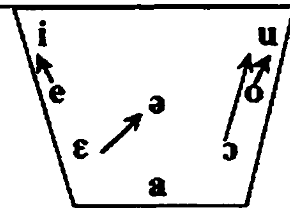
Output Pattern # 121
Status: Not attested
Strata: 3



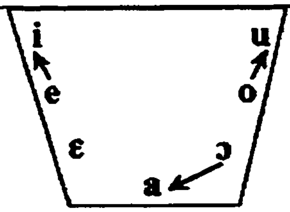
Output Pattern # 122
Status: Neapolitan Italian
Strata: 2



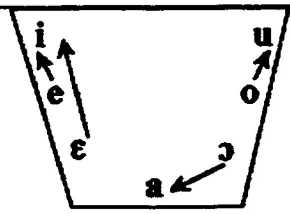
Output Pattern # 123
Status: not attested
Strata: 3



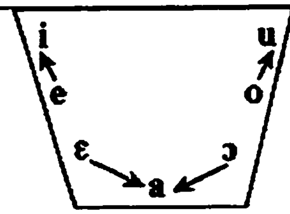
Output Pattern # 124
Status: not attested
Strata: 3



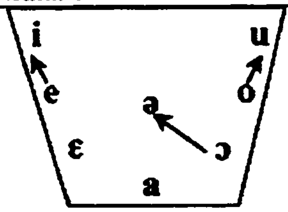
Output Pattern # 125
Status: cf. Bergün Romansch (#127)
Strata: 3



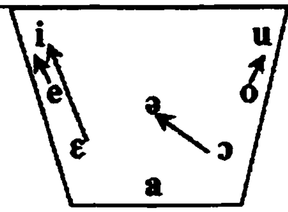
Output Pattern # 126
Status: not attested
Strata: 3



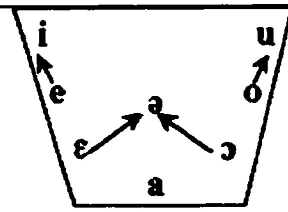
Output Pattern # 127
Status: Bergün Romansch
Strata: 2



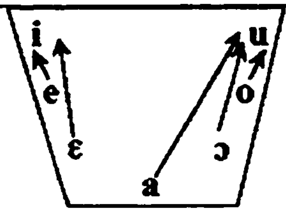
Output Pattern # 128
Status: not attested
Strata: 3



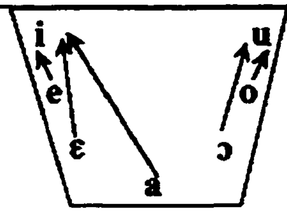
Output Pattern # 129
Status: not attested
Strata: 3



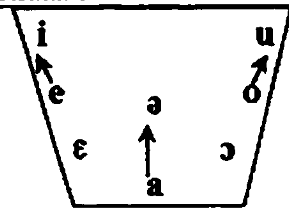
Output Pattern # 130
Status: cf. Bergün Romansch (#127)
Strata: 3



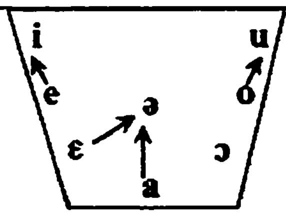
Output Pattern # 131
Status: not attested
Strata: 2



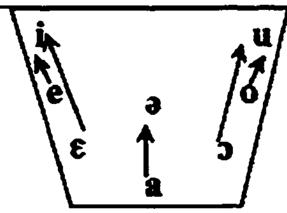
Output Pattern # 132
Status: not attested
Strata: 2



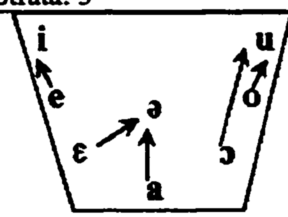
Output Pattern # 133
Status: cf. Brazilian Portuguese as in Dukes 1993 (p. 288)
Strata: 3



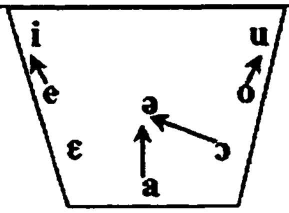
Output Pattern # 134
Status: not attested
Strata: 3



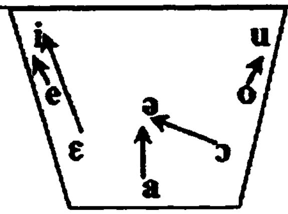
Output Pattern # 135
Status: Brazilian Portuguese (extreme)
Strata: 2



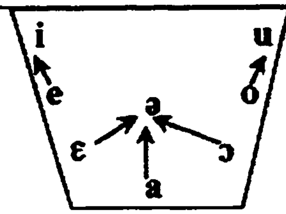
Output Pattern # 136
Status: not attested
Strata: 3



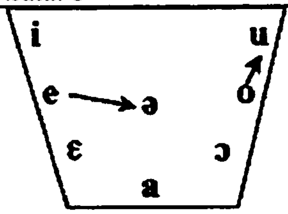
Output Pattern # 137
Status: not attested
Strata: 3



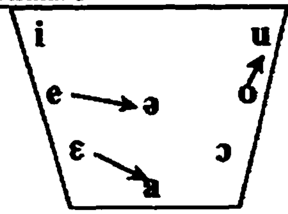
Output Pattern # 138
Status: not attested
Strata: 3



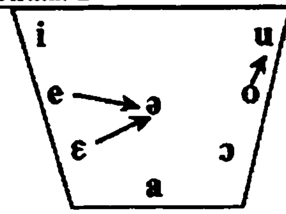
Output Pattern # 139
Status: not attested
Strata: 2



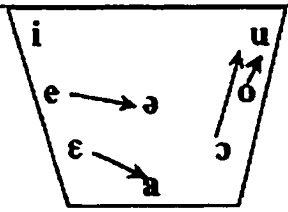
Output Pattern # 140
Status: not attested
Strata: 3



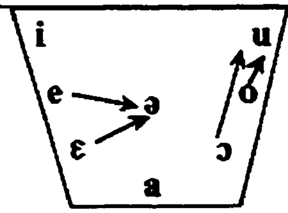
Output Pattern # 141
Status: not attested
Strata: 3



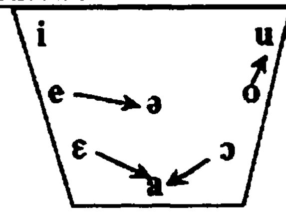
Output Pattern # 142
Status: cf. Sadzhava Ukrainian (#98)
Strata: 3



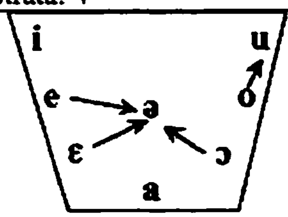
Output Pattern # 143
Status: not attested
Strata: 4



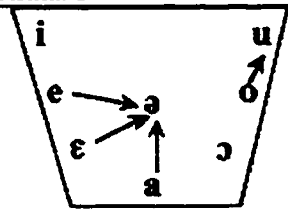
Output Pattern # 144
Status: not attested
Strata: 3



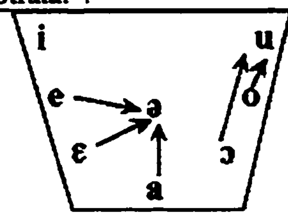
Output Pattern # 145
Status: not attested
Strata: 4



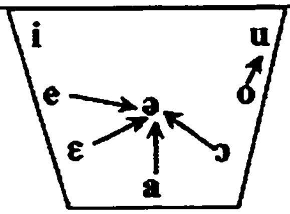
Output Pattern # 146
Status: not attested
Strata: 4



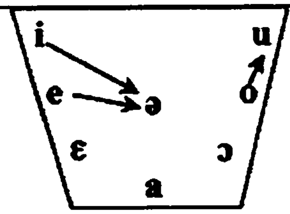
Output Pattern # 147
Status: cf. Majorcan Catalan (#104)
Strata: 3



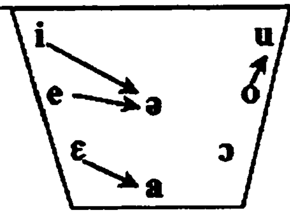
Output Pattern # 148
Status: Central Catalan
Strata: 3



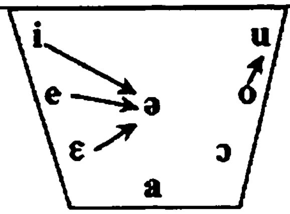
Output Pattern # 149
Status: not attested
Strata: 4



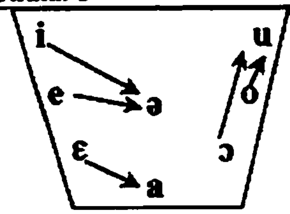
Output Pattern # 150
Status: cf. Shirokolushki Bulg. (#11)
Strata: 3



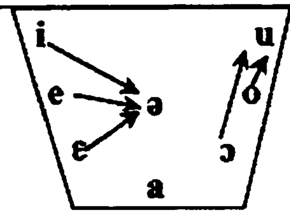
Output Pattern # 151
Status: not attested
Strata: 3



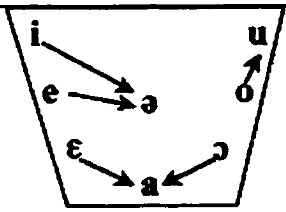
Output Pattern # 152
Status: not attested
Strata: 3



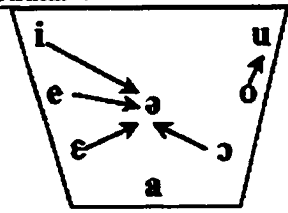
Output Pattern # 153
Status: not attested
Strata: 4



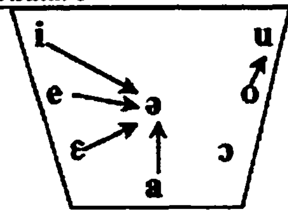
Output Pattern # 154
Status: not attested
Strata: 3



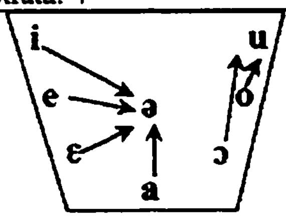
Output Pattern # 155
Status: not attested
Strata: 4



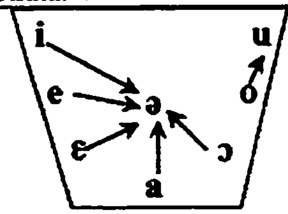
Output Pattern # 156
Status: not attested
Strata: 4



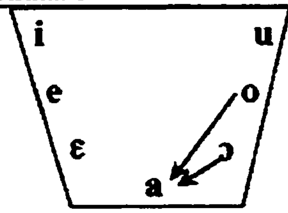
Output Pattern # 157
Status: not attested
Strata: 3



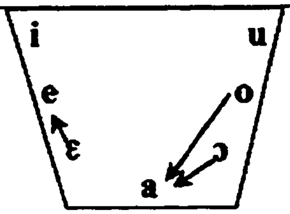
Output Pattern # 158
Status: not attested
Strata: 3



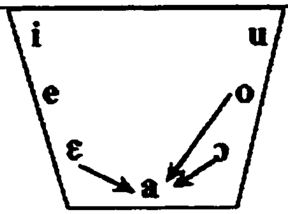
Output Pattern # 159
Status: not attested
Strata: 4



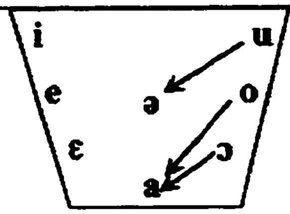
Output Pattern # 160
Status: cf. Russian [e]-reduction (#22), Trigrad Bulg. (#161)
Strata: 3



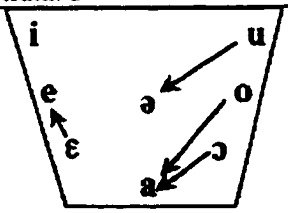
Output Pattern # 161
Status: Trigrad Bulgarian
Strata: 3



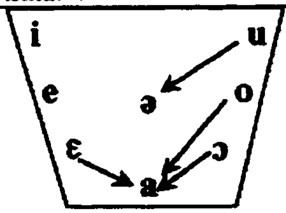
Output Pattern # 162
Status: not attested
Strata: 4



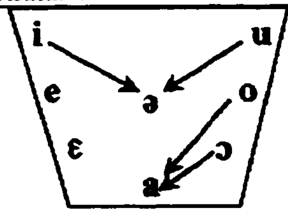
Output Pattern # 163
Status: not attested
Strata: 4



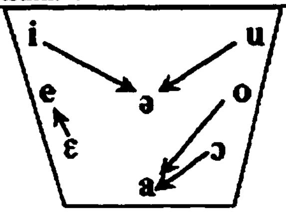
Output Pattern # 164
Status: not attested
Strata: 4



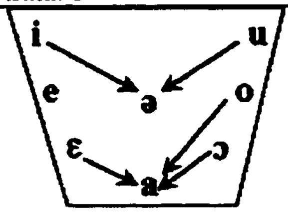
Output Pattern # 165
Status: not attested
Strata: 5



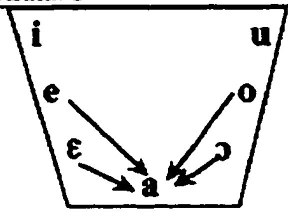
Output Pattern # 166
Status: not attested
Strata: 5



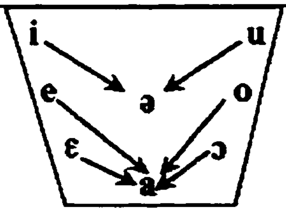
Output Pattern # 167
Status: not attested
Strata: 5



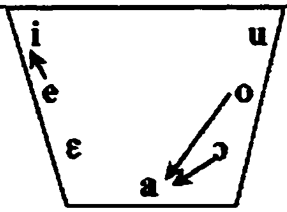
Output Pattern # 168
Status: not attested
Strata: 5



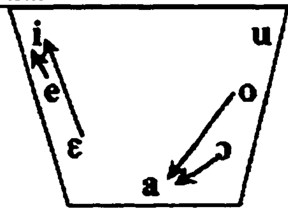
Output Pattern # 169
Status: cf. Russian [a]-reduction (#25)
Strata: 2



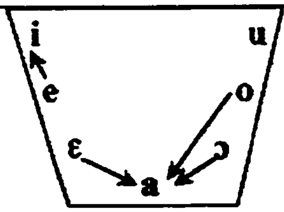
Output Pattern # 170
Status: not attested
Strata: 4



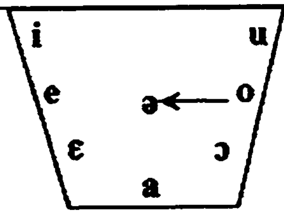
Output Pattern # 171
Status: not attested
Strata: 4



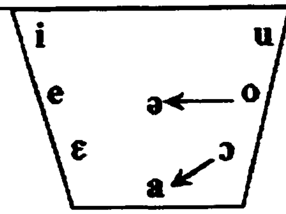
Output Pattern # 172
Status: cf. Algueres Catalan (# 117), Standard Russ. (#27)
Strata: 3



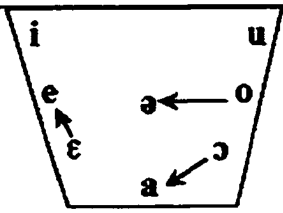
Output Pattern # 173
Status: not attested
Strata: 4



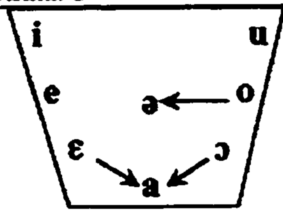
Output Pattern # 174
Status: cf. Pavlikianski Bulgarian (#4)
Strata: 3



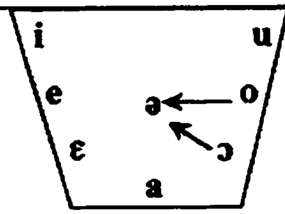
Output Pattern # 175
Status: not attested
Strata: 3



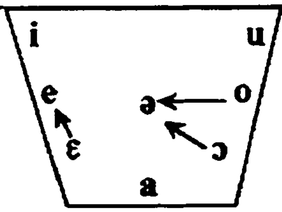
Output Pattern # 176
Status: not attested
Strata: 4



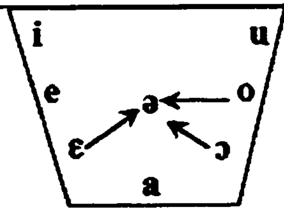
Output Pattern # 177
Status: not attested
Strata: 4



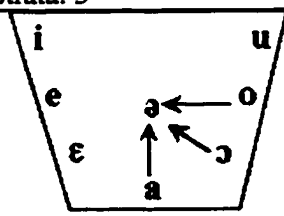
Output Pattern # 178
Status: cf. Sadzhava Ukrainian (#98)
Strata: 3



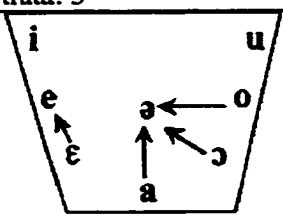
Output Pattern # 179
Status: cf. Sadzhava Ukrainian (#98)
Strata: 3



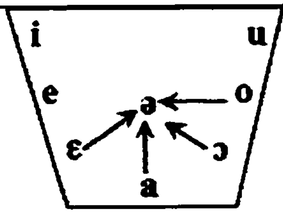
Output Pattern # 180
Status: not attested
Strata: 4



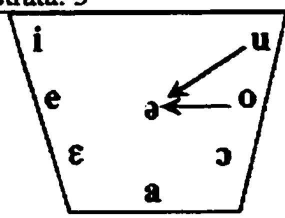
Output Pattern # 181
Status: cf. Balear Catalan (#103)
Strata: 3



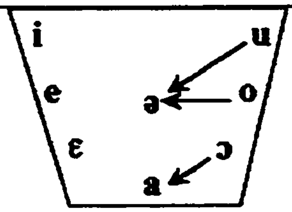
Output Pattern # 182
Status: not attested
Strata: 3



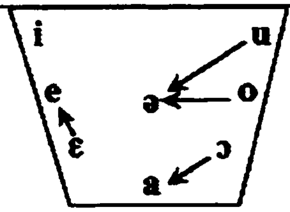
Output Pattern # 183
Status: not attested
Strata: 4



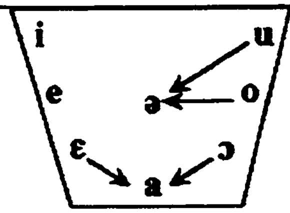
Output Pattern # 184
Status: cf. Shirokolushki Bulg. (#11)
Strata: 3



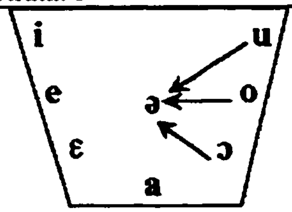
Output Pattern # 185
Status: not attested
Strata: 3



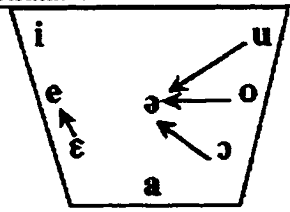
Output Pattern # 186
Status: not attested
Strata: 4



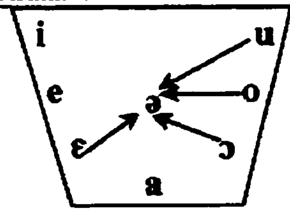
Output Pattern # 187
Status: not attested
Strata: 4



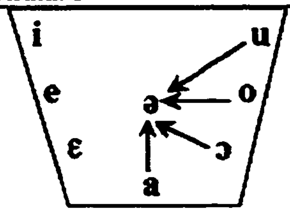
Output Pattern # 188
Status: not attested
Strata: 3



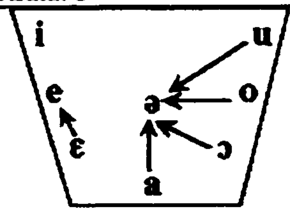
Output Pattern # 189
Status: not attested
Strata: 3



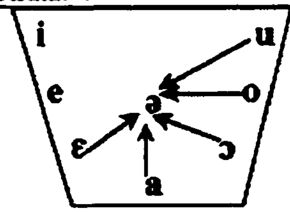
Output Pattern # 190
Status: not attested
Strata: 4



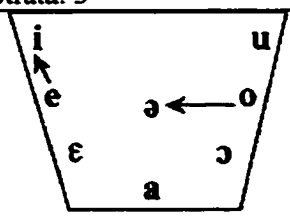
Output Pattern # 191
Status: not attested
Strata: 3



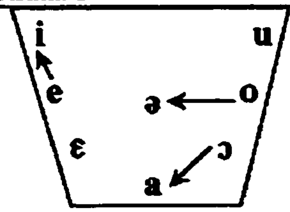
Output Pattern # 192
Status: not attested
Strata: 3



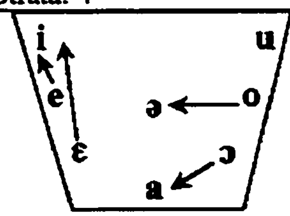
Output Pattern # 193
Status: not attested
Strata: 4



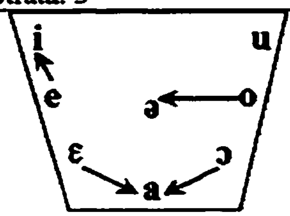
Output Pattern # 194
Status: not attested
Strata: 3



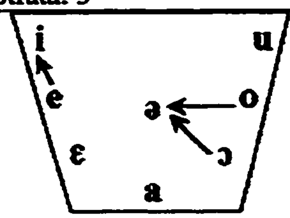
Output Pattern # 195
Status: not attested
Strata: 3



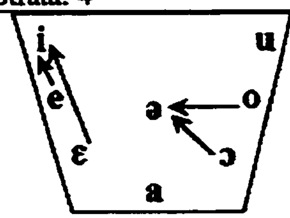
Output Pattern # 196
Status: not attested
Strata: 4



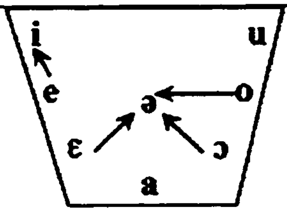
Output Pattern # 197
Status: not attested
Strata: 4



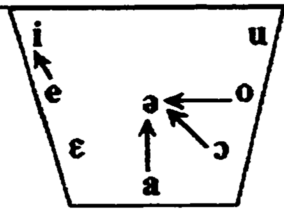
Output Pattern # 198
Status: not attested
Strata: 3



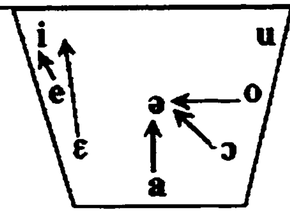
Output Pattern # 199
Status: not attested
Strata: 3



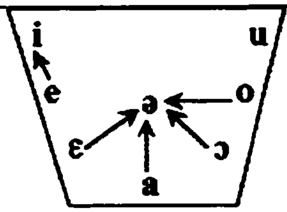
Output Pattern # 200
Status: not attested
Strata: 4



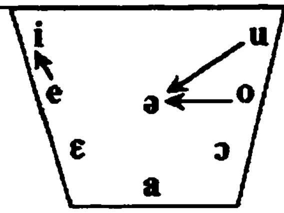
Output Pattern # 201
Status: not attested
Strata: 3



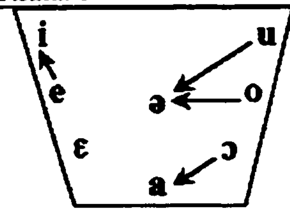
Output Pattern # 202
Status: Russian w/ incomplete *oka'ne*
Strata: 3



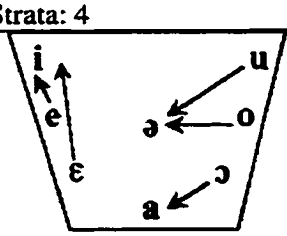
Output Pattern # 203
Status: not attested
Strata: 4



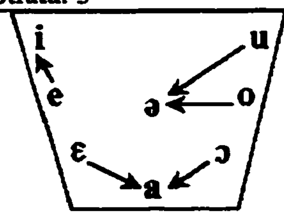
Output Pattern # 204
Status: not attested
Strata: 3



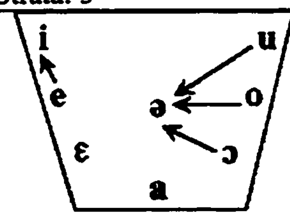
Output Pattern # 205
Status: not attested
Strata: 3



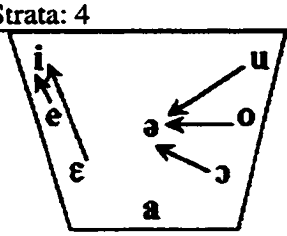
Output Pattern # 206
Status: not attested
Strata: 4



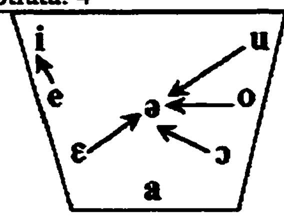
Output Pattern # 207
Status: not attested
Strata: 4



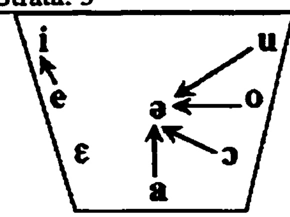
Output Pattern # 208
Status: not attested
Strata: 3



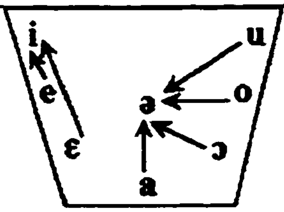
Output Pattern # 209
Status: not attested
Strata: 3



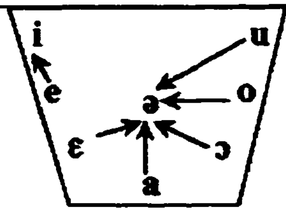
Output Pattern # 210
Status: not attested
Strata: 4



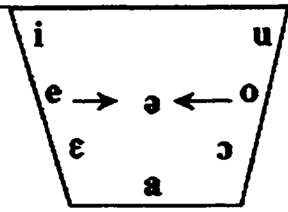
Output Pattern # 211
Status: not attested
Strata: 3



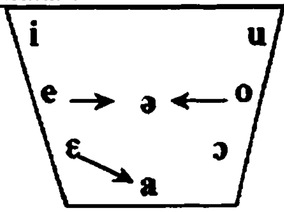
Output Pattern # 212
Status: not attested
Strata: 3



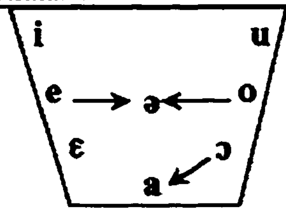
Output Pattern # 213
Status: not attested
Strata: 4



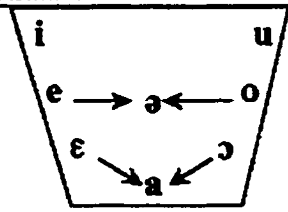
Output Pattern # 214
Status: not attested
Strata: 3



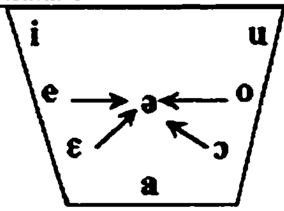
Output Pattern # 215
Status: not attested
Strata: 5



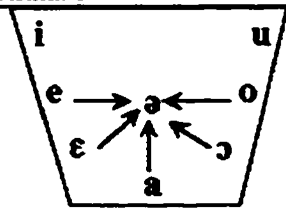
Output Pattern # 216
Status: not attested
Strata: 5



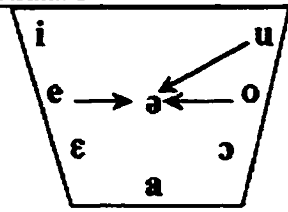
Output Pattern # 217
Status: not attested
Strata: 3



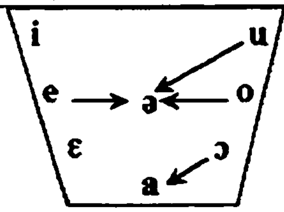
Output Pattern # 218
Status: not attested but cf. No. Ital. (#234)
Strata: 3



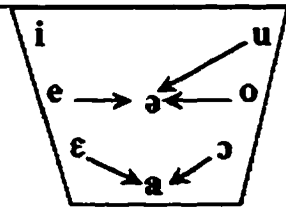
Output Pattern # 219
Status: cf. English (p. 285)
Strata: 2



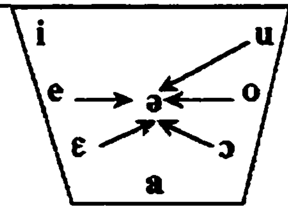
Output Pattern # 220
Status: not attested
Strata: 5



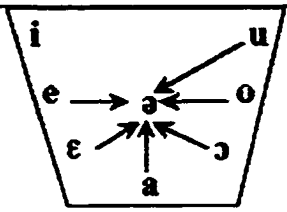
Output Pattern # 221
Status: not attested
Strata: 5



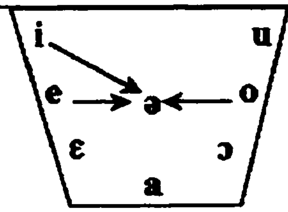
Output Pattern # 222
Status: not attested
Strata: 5



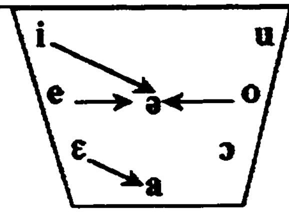
Output Pattern # 223
Status: not attested, but see Northern Italian
Strata: 5



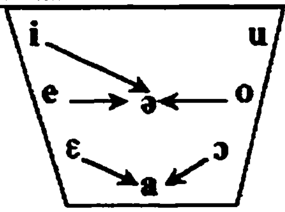
Output Pattern # 224
Status: not attested
Strata: 4



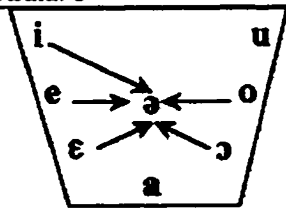
Output Pattern # 225
Status: not attested
Strata: 5



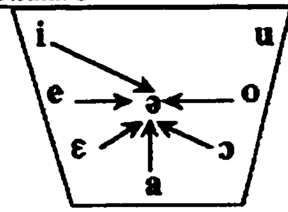
Output Pattern # 226
Status: not attested
Strata: 5



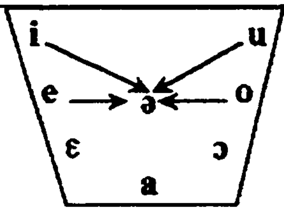
Output Pattern # 227
Status: not attested
Strata: 5



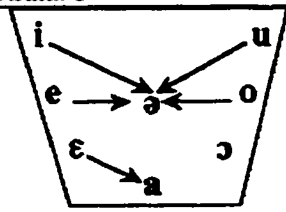
Output Pattern # 228
Status: not attested, but see No. Ital. (#234)
Strata: 5



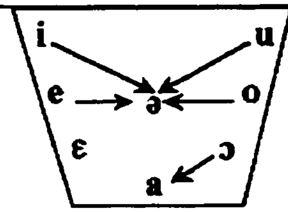
Output Pattern # 229
Status: not attested
Strata: 4



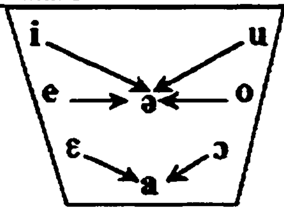
Output Pattern # 230
Status: not attested
Strata: 3



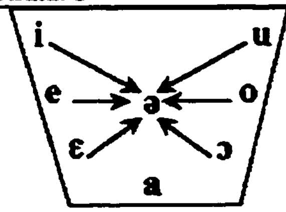
Output Pattern # 231
Status: not attested
Strata: 5



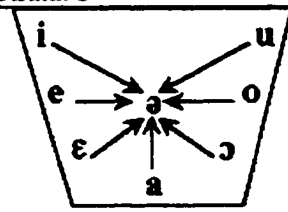
Output Pattern # 232
Status: not attested
Strata: 5



Output Pattern # 233
Status: not attested
Strata: 3



Output Pattern # 234
Status: Northern Italian
Strata: 3



Output Pattern # 235
Status: cf. Russian *prostorechie* (#43)
Strata: 2

Output Pattern # 44

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
	*Mid

Output Pattern # 45

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Mid
	*Nonhigh
Stratum #3	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 46

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
	*Mid
Stratum #3	Max(-hi)
	Max(+ft)
	Max(-lo)
	Max(-ATR)

Output Pattern # 47

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	*Mid
	Max(-ATR)

Output Pattern # 48

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	*Mid
	Max(-ATR)
Stratum #3	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 49

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	*Mid
	Max(-ATR)
Stratum #3	Max(+ft)
	Max(-lo)
	Max(-hi)

Output Pattern # 50

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
	*Mid
Stratum #3	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 51

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Mid
	Dep(+ATR)
	*Nonhigh
	*Non-schwa
	Max(-ATR)
Stratum #3	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 52

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+ft)
	Max(-ft)
	Max(-lo)
	*Mid
	Max(+rd)
	*Nonhigh
	*Non-schwa

Output Pattern # 53

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(-hi)
	Max(-ATR)

Output Pattern # 54

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Mid
	Dep(+ATR)
	*Nonhigh
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(-ft)
	Max(+rd)
	Max(-hi)
	Max(-lo)

Output Pattern # 55

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Max(-hi)
	*Non-schwa
	Max(+ft)
	Max(-ft)
	Max(-lo)
	*Mid
	Max(+rd)
	*Nonhigh
	Max(-ATR)

Output Pattern # 56

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(-hi)
	Max(+lo)
	*Mid
	Max(-ATR)

Output Pattern # 57

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(+lo)
	Max(-lo)
	Max(-hi)
	*Mid
	Max(+ft)
	Max(-ATR)

Output Pattern # 58

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tota]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+ATR)
	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(+lo)
	*Mid
	Max(-ATR)

Output Pattern # 59

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+ATR)
	*Nonhigh
	*Non-schwa
Stratum #3	Max(+lo)
	Max(-lo)
	Max(-hi)
	*Mid
	Max(+ft)
	Max(-ATR)

Output Pattern # 60

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tεta/ →[tεta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	*Mid
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Max(+rd)
	Max(-ATR)

Output Pattern # 61

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tεta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+ATR)
	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Max(+rd)
	Max(-ATR)

Output Pattern # 62

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Max(+ft)
	Max(-ft)
	Max(-lo)
	Max(+rd)
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-hi)
	Max(+lo)
	*Mid
	Max(-ATR)

Output Pattern # 63

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 64

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 65

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-ft)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 66

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tɜta]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-ft)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 67

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+ft)
	*Nonhigh
Stratum #3	*Non-schwa
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 68

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
Stratum #3	Max(-hi)
	Max(-ATR)
Stratum #4	*Non-schwa
	*Nonhigh
Stratum #5	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 69

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(-hi)
Stratum #4	*Non-schwa
	*Nonhigh
Stratum #5	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 70

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-hi)
	Max(+ft)
	Max(-ATR)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 71

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 72

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(+hi)
	Max(-lo)
	Max(+ft)
	Dep(+lo)
	Max(+ATR)
	*Mid

Output Pattern # 73

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
Stratum #3	Max(-hi)
	Max(-ATR)
Stratum #4	*Nonhigh
	*Non-schwa
Stratum #5	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 74

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 75

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+hi)
	Max(-lo)
	Max(+ft)
	Dep(+lo)
	Max(+ATR)
	*Mid

Output Pattern # 76

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(-hi)
Stratum #4	*Nonhigh
	*Non-schwa
Stratum #5	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 77

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Max(+rd)
	Max(-ft)
	Dep(+lo)
	*Nonhigh
Stratum #3	*Non-schwa
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 78

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-hi)
	Max(+rd)
	Max(-ft)
	Max(-ATR)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 79

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	*Mid
	Max(+rd)
	Max(-lo)
	Max(+hi)
	Max(+ft)
	Max(+ATR)
	Max(-ft)

Output Pattern # 80

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+rd)
	Max(-ft)
	Max(+ATR)
	Max(+hi)
Stratum #4	*LaxMid
	*Mid
Stratum #5	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 81

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	*Mid
	Max(+rd)
	Max(-lo)
	Max(+hi)
	Max(+ft)
	Max(+ATR)
	Max(-ft)

Output Pattern # 82

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Max(+hi)
	Max(+rd)
	Max(+ATR)
Stratum #4	*Mid
	Dep(+ATR)
	Max(-ATR)
Stratum #5	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 83

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+ft)
	Max(+ATR)
	Max(+hi)
Stratum #4	*Mid
	*LaxMid
Stratum #5	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 84

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+ft)
	Max(+hi)
	Max(+ATR)
Stratum #4	*Mid
	Dep(+ATR)
	Max(-ATR)
Stratum #5	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 85

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	*Nonhigh
	*Non-schwa
Stratum #3	*Mid
	Max(+rd)
	Max(-lo)
	Max(+hi)
	Max(+ft)
	Max(+ATR)
	Max(-ft)

Output Pattern # 86

/tota/ →[tota]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-hi)
	Max(-ATR)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	*Mid
	Max(+rd)
	Max(-lo)
	Max(+hi)
	Max(+ft)
	Max(+ATR)
	Max(-ft)

Output Pattern # 87

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 88

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 89

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	Max(+rd)
	*Non-schwa
	*Nonhigh
	Max(-ft)
Stratum #3	*Mid
Stratum #4	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 90

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 91

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 92

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	Max(+rd)
	Max(-ft)
	*Nonhigh
Stratum #3	*Non-schwa
Stratum #4	Max(+hi)
	*Mid
Stratum #5	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 93

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(+rd)
	Max(-ft)
Stratum #4	*LaxMid
	*Mid
Stratum #5	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 94

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+rd)
	Max(-ft)
	Max(+hi)
Stratum #4	*Mid
	Dep(+ATR)
	Max(-ATR)
Stratum #5	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 95

/tota/ →[tota]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	Max(+rd)
	Max(-ft)
Stratum #4	*Mid
Stratum #5	Max(-lo)
	Max(+ft)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 96

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
	*Mid
Stratum #3	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 97

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Dep(+lo)
	Max(+ft)
	Max(+ATR)
	Max(-hi)

Output Pattern # 98

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 99

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	*Mid
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Nonhigh
	*Non-schwa
Stratum #4	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 100

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Mid
	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 101

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Max(+rd)
	Max(-ft)
	Dep(+lo)
	*Mid
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 102

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-ft)
	*Mid
	Max(+rd)
	Max(-ATR)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 103

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+ft)
	Max(+lo)
	Max(-lo)
	Max(-hi)
	*Mid
	Max(+ATR)
	Max(-ATR)

Output Pattern # 104

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tota]
/tεta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
Stratum #3	Max(+ft)
	Max(+lo)
	Max(-lo)
	Max(-hi)
	*Mid
	Max(+ATR)
	Max(-ATR)

Output Pattern # 105

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tεta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-ft)
	Max(+rd)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(+ft)
	Max(+lo)
	Max(-lo)
	Max(-hi)
	*Mid
	Max(+ATR)
	Max(-ATR)

Output Pattern # 106

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	*Mid

Output Pattern # 107

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+ft)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 108

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	*Mid
	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 109

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Non-schwa
	*Nonhigh
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	*Mid

Output Pattern # 110

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	*Mid

Output Pattern # 111

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+rd)
	Max(-ft)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	*Mid

Output Pattern # 112

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-ft)
	Max(+rd)
	Max(-ATR)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-hi)
	Max(+ft)
	Max(+ATR)
	*Mid

Output Pattern # 113

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(+ft)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 114

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tota]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
Stratum #3	Max(+ft)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 115

/tota/ →[tota]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+rd)
	Max(-ft)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(+ft)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 116

/tota/ →[tuta]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Mid
Stratum #3	Dep(+hi)
	Max(-hi)
	*Non-schwa
Stratum #4	*Nonhigh
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+ft)

Output Pattern # 117

/tota/ →[tuta]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
	Dep(+ATR)
	Max(-ATR)
Stratum #3	*Nonhigh
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+ft)

Output Pattern # 118

/tota/ →[tuta]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	Max(+rd)
	Max(-ft)
Stratum #3	Dep(+hi)
	Max(-hi)
Stratum #4	*Nonhigh
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+ft)

Output Pattern # 119

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Dep(+hi)
	Max(-hi)

Output Pattern # 120

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(-hi)
	Dep(+lo)
	Max(+ft)
	Dep(+hi)

Output Pattern # 121

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(+ft)
	Dep(+hi)
	Max(-hi)
	Max(-ATR)

Output Pattern # 122

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	Max(-hi)
	Dep(+ATR)
	Dep(+hi)
	*Nonhigh
	Max(-ATR)

Output Pattern # 123

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+hi)
	Dep(+ATR)
	Max(-hi)
	*Non-schwa
	Max(-ATR)
Stratum #3	Dep(+lo)
	Max(+ft)
	*Nonhigh
	Max(-lo)

Output Pattern # 124

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+ATR)
	*Nonhigh
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+ft)
	*Mid

Output Pattern # 125

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(+rd)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Dep(+lo)
	Dep(+hi)

Output Pattern # 126

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+hi)
	Dep(+ATR)
	Max(-hi)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(-lo)
	Max(+rd)
	Dep(+lo)
	*Nonhigh
	Max(-ft)

Output Pattern # 127

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
	Max(-ATR)
Stratum #2	Max(-hi)
	Dep(+lo)
	*Nonhigh
	Max(+ft)
	Max(-lo)
	Max(-ft)
	Dep(+hi)
	Max(+rd)
	*Non-schwa

Output Pattern # 128

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(-ft)
	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+rd)
	Max(-ATR)

Output Pattern # 129

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+ATR)
	*Non-schwa
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+rd)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(-ft)
	Dep(+hi)

Output Pattern # 130

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Nonhigh
	*Non-schwa
	Max(+ft)
	Max(-lo)
	Max(-ft)
	*Mid
	Max(+rd)
	Max(-ATR)
Stratum #3	Dep(+hi)
	Max(-hi)

Output Pattern # 131

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tuta]
/tɔta/ →[tuta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*Nonhigh
	*LaxMid
	Max(+rd)
	Dep(+ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Max(-hi)
	Dep(+rd)
	Dep(-lo)
	Max(+lo)
	Dep(+hi)
	Dep(+ATR)
	Dep(-ft)
	*Non-schwa
	Max(-ATR)

Output Pattern # 132

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tita]
/tɔta/ →[tuta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ft)
	Dep(+ATR)
	*Non-schwa
	Max(-hi)
	Max(-ATR)

Output Pattern # 133

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-hi)
	*Mid
	Dep(+hi)
	Max(+lo)
	Max(-ATR)

Output Pattern # 134

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+ft)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(-hi)
	Dep(+hi)
	Max(-ATR)

Output Pattern # 135

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tuta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Non-schwa
	Max(+lo)
	*Mid
	Dep(+ATR)
	Max(-hi)
	Dep(+hi)
	Max(-ATR)

Output Pattern # 136

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tuta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+hi)
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(+ft)
	Max(-lo)
	*Mid

Output Pattern # 137

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Dep(+hi)
	Max(+lo)
	Max(-lo)
	Max(+rd)
	*Mid
	Max(-hi)
	Max(-ATR)

Output Pattern # 138

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	Dep(+hi)
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	*Non-schwa
	Max(-ATR)
Stratum #3	*Mid
	Max(-ft)
	Max(+rd)
	Max(-lo)

Output Pattern # 139

/tota/ →[tuta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(+ATR)
Stratum #2	*Mid
	Max(-hi)
	*Non-schwa
	Max(+ft)
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Dep(+hi)
	Max(+rd)
	Max(-ATR)

Output Pattern # 140

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	*Mid
	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 141

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Dep(+hi)
	Max(+ft)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 142

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+ft)
	*Mid
	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 143

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Non-schwa
	*Nonhigh
Stratum #4	*Mid
	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 144

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	*Mid
	Max(-lo)
	Max(-hi)
	Dep(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 145

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	Max(+rd)
	Dep(+lo)
	Max(-ft)
Stratum #3	*Non-schwa
	Dep(+hi)
	Max(-hi)
Stratum #4	*Mid
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 146

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+rd)
	Max(-ft)
	*Nonhigh
	Max(-ATR)
Stratum #3	*Non-schwa
	Dep(+hi)
	Max(-hi)
Stratum #4	*Mid
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 147

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Dep(+hi)
	Max(+ft)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 148

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tuta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+hi)
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	Max(-ATR)
Stratum #3	*Mid
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 149

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-ft)
	Max(+lo)
	Max(-hi)
	Max(+rd)
	Max(-ATR)
Stratum #3	Dep(+hi)
	*Non-schwa
Stratum #4	*Mid
	Max(+ft)
	Max(+ATR)
	Max(-lo)

Output Pattern # 150

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Dep(+hi)
	Max(+ft)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	*Mid

Output Pattern # 151

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Dep(+lo)
	*Mid
	Dep(+hi)
	Max(-lo)
	Max(+ft)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 152

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
	Dep(+hi)
	Max(+ft)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 153

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Nonhigh
	*Non-schwa
Stratum #4	Dep(+hi)
	Max(+ft)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	*Mid

Output Pattern # 154

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tuta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Dep(+hi)
	Max(+ft)
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	*Mid

Output Pattern # 155

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Max(-ft)
	*Nonhigh
	Dep(+lo)
	Max(+rd)
Stratum #3	Dep(+hi)
	*Non-schwa
	Max(-hi)
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 156

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Max(+rd)
	Max(-ft)
	Max(-ATR)
Stratum #3	Dep(+hi)
	*Non-schwa
	Max(-hi)
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 157

/tota/ →[tuta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[tɔta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-hi)
	*Mid
	Dep(+hi)
	Max(+lo)
	Max(-lo)
	Max(+ft)
	Max(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 158

/tota/	→[tuta]
/teta/	→[təta]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[təta]
/tɔta/	→[tuta]
/tɛta/	→[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Max(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	Dep(+hi)
	*Non-schwa
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	Max(-ATR)
Stratum #3	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 159

/tota/	→[tuta]
/teta/	→[təta]
/tita/	→[təta]
/tuta/	→[tuta]
/tata/	→[təta]
/tɔta/	→[təta]
/tɛta/	→[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+rd)
	Max(+lo)
	Max(-hi)
	Max(-ft)
	Max(-ATR)
Stratum #3	*Non-schwa
	Dep(+hi)
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 160

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 161

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
	*Mid
	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 162

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	Max(+ft)
	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
Stratum #4	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 163

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 164

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Non-schwa
	*Nonhigh
	Dep(+ATR)
	Max(-ATR)
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 165

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	Max(+ft)
	*Nonhigh
Stratum #3	*Non-schwa
Stratum #4	Max(+hi)
	*Mid
Stratum #5	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 166

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(+hi)
	Max(+ft)
Stratum #4	*Mid
	*LaxMid
Stratum #5	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 167

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	Max(+ft)
Stratum #4	*Mid
	Dep(+ATR)
	Max(-ATR)
Stratum #5	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 168

/tota/ →[tata]
/teta/ →[teta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	Max(+ft)
Stratum #4	*Mid
Stratum #5	Max(-ft)
	Max(-lo)
	Dep(+lo)
	Dep(-ATR)
	Max(+ATR)
	Max(+rd)

Output Pattern # 169

/tota/ →[tata]
/teta/ →[tata]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	Max(+ft)
	Dep(+lo)
	Max(-ft)
	Max(+rd)
	Max(-lo)
	*Non-schwa
	Dep(-ATR)
	Max(+ATR)
	*Nonhigh

Output Pattern # 170

/tota/ →[tata]
/teta/ →[tata]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(+hi)
	*Mid
Stratum #4	Max(+ft)
	Max(-ft)
	Max(-lo)
	Max(+rd)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 171

/tota/ →[tata]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Mid
	*LaxMid
Stratum #3	Dep(+hi)
	Max(-hi)
	*Non-schwa
Stratum #4	*Nonhigh
	Max(-ft)
	Max(-lo)
	Max(+rd)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 172

/tota/ →[tata]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
Stratum #2	Max(-hi)
	*Non-schwa
	Dep(+hi)
	Dep(+ATR)
	Max(-ATR)
Stratum #3	*Nonhigh
	Max(-ft)
	Max(-lo)
	Max(+rd)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 173

/tota/ →[tata]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*Mid
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	Max(+ft)
Stratum #3	Dep(+hi)
	Max(-hi)
Stratum #4	*Nonhigh
	Max(-ft)
	Max(-lo)
	Max(+rd)
	Dep(-ATR)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 174

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Mid
	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-hi)

Output Pattern # 175

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(+rd)
	Max(-lo)
	Max(-hi)
	Dep(+lo)
	Max(+ATR)
	Max(-ft)

Output Pattern # 176

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	*Mid
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Non-schwa
	*Nonhigh
Stratum #4	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-hi)

Output Pattern # 177

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+ft)
	*Mid
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-hi)

Output Pattern # 178

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(-hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 179

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Mid
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-hi)

Output Pattern # 180

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Mid
	Max(+ft)
	Max(-ATR)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	Max(-hi)

Output Pattern # 181

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(+rd)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 182

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
Stratum #3	Max(+rd)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 183

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+ft)
Stratum #3	*Non-schwa
	*Nonhigh
Stratum #4	Max(+rd)
	*Mid
	Max(+lo)
	Max(-lo)
	Max(-ft)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 184

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 185

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Dep(+lo)
	Max(-ft)
	Max(+rd)
	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 186

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Nonhigh
	*Non-schwa
Stratum #4	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 187

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+ft)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 188

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 189

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 190

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+ft)
	Max(-ATR)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 191

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-hi)
	Max(-ft)
	Max(+rd)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 192

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[teta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
Stratum #3	Max(-hi)
	Max(-ft)
	Max(+rd)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 193

/tota/ →[təta]
/teta/ →[teta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+ft)
Stratum #3	*Nonhigh
	*Non-schwa
Stratum #4	Max(-hi)
	Max(-ft)
	Max(+rd)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 194

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Dep(+hi)
	Max(+rd)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 195

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Dep(+lo)
	Max(-ft)
	Dep(+hi)
	Max(-lo)
	Max(+rd)
	*Mid
	Max(+ATR)
	Max(-hi)

Output Pattern # 196

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Nonhigh
	*Non-schwa
Stratum #4	Dep(+hi)
	Max(+rd)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 197

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	*Nonhigh
	Max(+ft)
Stratum #3	*Non-schwa
	Dep(+hi)
	Max(-hi)
Stratum #4	Max(-lo)
	*Mid
	Max(-ft)
	Max(+ATR)
	Max(+rd)

Output Pattern # 198

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Dep(+hi)
	Max(+rd)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 199

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Dep(+ATR)
	*Non-schwa
	Max(-ATR)
Stratum #3	Dep(+hi)
	Max(+rd)
	Max(-lo)
	*Mid
	Max(-hi)
	Max(+ATR)
	Max(-ft)

Output Pattern # 200

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+ft)
	*Nonhigh
	Max(-ATR)
Stratum #3	*Non-schwa
	Dep(+hi)
	Max(-hi)
Stratum #4	Max(-lo)
	*Mid
	Max(-ft)
	Max(+ATR)
	Max(+rd)

Output Pattern # 201

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-hi)
	Max(-ft)
	Dep(+hi)
	Max(+lo)
	Max(-lo)
	Max(+rd)
	*Mid
	Max(+ATR)
	Max(-ATR)

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+hi)
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	Max(-ATR)
Stratum #3	Max(-lo)
	*Mid
	Max(-ft)
	Max(+ATR)
	Max(+rd)

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+lo)
	Max(+ft)
	Max(-hi)
	Max(-ATR)
Stratum #3	Dep(+hi)
	*Non-schwa
Stratum #4	Max(-lo)
	*Mid
	Max(-ft)
	Max(+ATR)
	Max(+rd)

Output Pattern # 204

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	*Mid
	Max(-ft)
	Dep(+hi)
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 205

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-hi)
	Dep(+lo)
	*Mid
	Max(-ft)
	Max(-lo)
	Dep(+hi)
	Max(+rd)
	Max(+ATR)
	Max(+hi)

Output Pattern # 206

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	Dep(+ATR)
	Max(-ATR)
Stratum #3	Dep(+lo)
	*Non-schwa
	*Nonhigh
Stratum #4	*Mid
	Max(-ft)
	Dep(+hi)
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 207

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	Max(+ft)
	*Nonhigh
Stratum #3	Dep(+hi)
	*Non-schwa
	Max(-hi)
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 208

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	*LaxMid
	*Non-schwa
Stratum #3	Max(-hi)
	*Mid
	Max(-ft)
	Dep(+hi)
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 209

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Dep(+ATR)
	*Nonhigh
	Max(-ATR)
Stratum #3	*Mid
	Max(-ft)
	Dep(+hi)
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 210

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Max(+ft)
	Max(-ATR)
Stratum #3	Dep(+hi)
	*Non-schwa
	Max(-hi)
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 211

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
	*LaxMid
Stratum #3	Max(+hi)
	Max(-hi)
	*Mid
	Max(-ft)
	Max(+lo)
	Max(-lo)
	Dep(+hi)
	Max(+rd)
	Max(+ATR)
	Max(-ATR)

Output Pattern # 212

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[tita]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Max(+ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(-ATR)
Stratum #2	Dep(+hi)
	*Non-schwa
	Max(+lo)
	Dep(+ATR)
	Max(-hi)
	Max(-ATR)
Stratum #3	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 213

/tota/ →[təta]
/teta/ →[tita]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+lo)
	Max(+ft)
	Max(-hi)
	Max(-ATR)
Stratum #3	*Non-schwa
	Dep(+hi)
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 214

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	*LaxMid
Stratum #3	Max(-ft)
	Max(-lo)
	Max(-hi)
	Max(+rd)
	Max(+ATR)
	Max(+ft)

Output Pattern # 215

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(-ft)
	Max(+ATR)
	Max(+rd)
Stratum #4	*LaxMid
	*Mid
Stratum #5	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 216

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
Stratum #3	Max(-hi)
	Max(+ATR)
	Max(+ft)
Stratum #4	*Mid
	*LaxMid
Stratum #5	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 217

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
	Dep(+lo)
	*Mid
Stratum #3	Max(-ft)
	Max(-lo)
	Max(-hi)
	Max(+rd)
	Max(+ATR)
	Max(+ft)

Output Pattern # 218

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	*Mid
	*Nonhigh
	Max(-ATR)
Stratum #3	Max(-ft)
	Max(-lo)
	Max(-hi)
	Max(+rd)
	Max(+ATR)
	Max(+ft)

Output Pattern # 219

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Max(+hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Non-schwa
	Max(-hi)
	Max(+ft)
	Max(-ft)
	Max(+lo)
	Max(-lo)
	Max(+rd)
	*Mid
	Max(+ATR)
	Max(-ATR)

Output Pattern # 220

/tota/	→[təta]
/teta/	→[təta]
/tita/	→[tita]
/tuta/	→[təta]
/tata/	→[tata]
/tɔta/	→[tɔta]
/tɛta/	→[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Nonhigh
Stratum #3	Max(+ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 221

/tota/	→[təta]
/teta/	→[təta]
/tita/	→[tita]
/tuta/	→[təta]
/tata/	→[tata]
/tɔta/	→[tata]
/tɛta/	→[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
Stratum #3	Max(-hi)
	Max(+ft)
Stratum #4	*Non-schwa
	*LaxMid
Stratum #5	Max(+rd)
	*Mid
	Max(-lo)
	Max(+hi)
	Max(-ft)
	Max(+ATR)
	Dep(+lo)

Output Pattern # 222

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	*Nonhigh
Stratum #3	Max(+ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 223

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 224

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[tita]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+lo)
	Max(+ft)
	Max(-hi)
	Max(-ATR)
Stratum #3	*Non-schwa
Stratum #4	Max(+hi)
	Max(-lo)
	Max(-ft)
	Max(+rd)
	Max(+ATR)
	*Mid

Output Pattern # 225

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Nonhigh
Stratum #3	Max(+rd)
	Max(-ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 226

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Nonhigh
Stratum #3	Max(-hi)
	Max(+rd)
	Max(-ft)
Stratum #4	*LaxMid
	*Non-schwa
Stratum #5	Max(+hi)
	Max(-lo)
	Max(+ft)
	Dep(+lo)
	Max(+ATR)
	*Mid

Output Pattern # 227

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	*Nonhigh
Stratum #3	Max(+rd)
	Max(-ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 228

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	Max(-ATR)
Stratum #3	Max(+rd)
	Max(-ft)
	Max(-hi)
Stratum #4	*Non-schwa
Stratum #5	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 229

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[tuta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(-ft)
	Max(+lo)
	Max(-hi)
	Max(+rd)
	Max(-ATR)
Stratum #3	*Non-schwa
Stratum #4	Max(-lo)
	*Mid
	Max(+hi)
	Max(+ATR)
	Max(+ft)

Output Pattern # 230

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*LaxMid
	*Non-schwa
	*Nonhigh
Stratum #3	Max(+ft)
	Max(-ft)
	*Mid
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 231

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tɔta]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(-ft)
	Max(+hi)
	Max(-hi)
	Max(+ATR)
	Max(+rd)
Stratum #4	*LaxMid
	*Mid
Stratum #5	Dep(+lo)
	Max(-lo)
	Max(+ft)

Output Pattern # 232

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tɛta]

Stratum	Abbr.
Stratum #1	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	*Non-schwa
	*Nonhigh
Stratum #3	Max(-hi)
	Max(+ft)
	Max(+ATR)
	Max(+hi)
Stratum #4	*Mid
	*LaxMid
Stratum #5	Dep(+lo)
	Max(+rd)
	Max(-ft)
	Max(-lo)

Output Pattern # 233

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[tata]
/tɛta/ →[tata]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
	Max(-ATR)
Stratum #2	Dep(+lo)
	*Non-schwa
	*Nonhigh
Stratum #3	Max(+ft)
	Max(-ft)
	*Mid
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 234

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[tata]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Max(+lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	*Nonhigh
	*Non-schwa
	Max(-ATR)
Stratum #3	Max(+ft)
	Max(-ft)
	*Mid
	Max(-lo)
	Max(+rd)
	Max(+hi)
	Max(+ATR)
	Max(-hi)

Output Pattern # 235

/tota/ →[təta]
/teta/ →[təta]
/tita/ →[təta]
/tuta/ →[təta]
/tata/ →[təta]
/tɔta/ →[təta]
/tɛta/ →[təta]

Stratum	Abbr.
Stratum #1	*Non-schwa
	*Nonhigh
	*LaxMid
	Dep(+rd)
	Dep(+ft)
	Dep(-ft)
	Dep(+hi)
	Dep(-hi)
	Dep(+lo)
	Dep(-lo)
	Dep(+ATR)
	Dep(-ATR)
Stratum #2	Max(+hi)
	Max(-hi)
	Max(+ft)
	Max(-ft)
	Max(+lo)
	Max(-lo)
	*Mid
	Max(+rd)
	Max(+ATR)
	Max(-ATR)

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