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A Typology of Sonority Sequences in

Word-Final Consonant Clusters

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An abstract of
A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Abstract

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Syllable structure across languages appears to be governed by a Sonority Sequencing Principle that states that sonority must fall in syllable codas. However, this principle does not hold for all syllables in all languages. In this study, I examine the phonotactics of 178 languages in order to find the distribution of word-final biconsonantal clusters that violate this principle. I classify these languages according to the types of clusters they allow. I use this typology to demonstrate that violations of the Sonority Sequencing Principle do not occur randomly, but rather, according to an implicational relationship where the presence of violations in codas implies the presence of compliant codas. However, a language type emerges that does not follow from the Sonority Sequencing Principle. This type allows sonority plateaus of obstruents but disallows sonority plateaus of sonorants, even though these coda types violate the principle equally. Reviewing the proposals for constraint sets that model the effect of the Sonority Sequencing Principle in Optimality Theory, I conclude that the unequal treatment of these sonority plateaus is best accounted for by a universally fixed ranking between constraints on the sonority of single positions in the syllable.

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CONTENTS

TABLES

1. Introduction

In this study I examine word-final biconsonantal clusters cross-linguistically in a survey of 178 languages. I discuss the role of the feature [sonorant] in the restrictions imposed on such clusters, and present a typology of languages classified by clusters they permit. I argue that this typology demonstrates that violations of the Sonority Sequencing Principle (Selkirk, 1984) in syllable-final clusters do not occur randomly; rather, their distribution can be predicted from an implicational relationship. This implicational relationship can be modeled using universal, violable constraints in the framework of Optimality Theory.

I also show that the distribution of cluster types across languages depends on more than the Sonority Sequencing Principle, as there is a preference for sonority plateaus of obstruents over sonority plateaus of sonorants. I demonstrate that this phenomenon follows from independently motivated positional constraints when these constraints are placed in a fixed ranking. The current formulation of these positional constraints allows the generation of empirically unattested language types, and the proposed fixed ranking restricts the constraints to the existing language types while accounting for this unexpected relationship between clusters of sonorants and clusters of obstruents.

This paper is organized as follows: section 2 reviews the theoretical framework that guides the study, including the role of the Sonority Sequencing Principle and the domain over which it applies. Section 3 explains the challenges of determining which segmental sequences represent true coda clusters. Section 4 details the methodology of the survey. Section 5 presents the results of all languages studied, including those whose phonological representations are uncertain. In section 6, I interpret the results and offer explanations for them. Section 7 formalizes the descriptive interpretation given in section 6 using the framework of Optimality Theory. Section 8 concludes the thesis, offering a summary of the findings and raising questions for future research.

2. Theoretical Background

2.1 The Sonority Sequencing Principle

The role of sonority in the constraints placed on tautosyllabic sequences has been recognized for over a century, beginning with Sievers (1881) and Jespersen (1904). More recently, scholars such as Clements (1990), Selkirk (1984), Steriade (1982), and Zec (1995) have continued to explore how sonority influences the shape of syllables. As formulated in Selkirk (1984: 116), the Sonority Sequencing Principle (SSP) states the following:

(1) *Sonority Sequencing Principle*

In any syllable, there is a segment constituting a sonority peak that is preceded and/or followed by a sequence of segments with progressively declining sonority values.

In order to define the sonority values referred to in this definition, several sonority scales that rank natural classes of segments and sometimes individual segments have been proposed (Clements, 1990; Levin, 1985; Parker, 2002; Selkirk, 1984; Steriade, 1982). Three of the scales that have been proposed in the literature are presented in (2).

(2) *Sonority Scales*

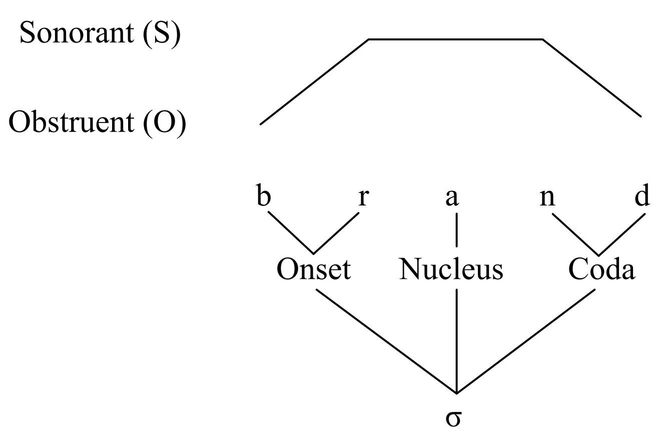
a. Sonorants > Obstruents (based on the major class features of Chomsky & Halle, 1968)

b. Vowels/Glides > Liquids > Nasals > Obstruents (Clements, 1990)

c. Low Vowels > Mid Vowels > High Vowels/Glides > Rhotics > Laterals > Nasals > /s/ > Voiced Fricatives > Voiceless Fricatives > Voiced Stops > Voiceless Stops (Selkirk 1984)

I use the scale in 2a for the present study. In this scale, [+sonorant] segments, called sonorants (S) are more sonorous than [-sonorant] segments, called obstruents (O). We can plot the sonority values of the segments in the word *brand* to show how it complies with the SSP as formulated in (1):

(3)



The segments [b] and [d] are obstruents, with the lower sonority level, while [r], [a], and [n] are sonorants, the higher sonority level. In compliance with the SSP, the sonority falls from the nucleus towards each syllable edge.

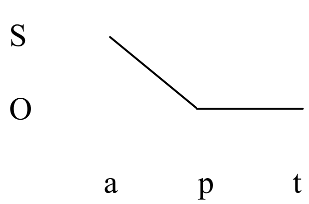
The relationship between the segments in the coda in terms of the feature [sonorant] is the focus of this study. Clusters in which a [+sonorant] consonant is followed by a [-sonorant] consonant constitute a fall in sonority, which is the optimal coda cluster type. Clusters in which both consonants have the same value for the feature [sonorant] are sonority plateaus. Clusters in which a [-sonorant] consonant is followed by a [+sonorant] consonant are rises in sonority, which are called sonority reversals when they occur in codas.

2.2 Exceptions to the Sonority Sequencing Principle

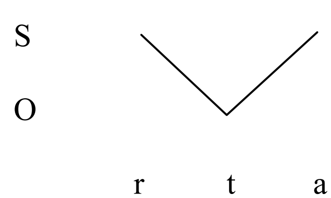
Although the SSP is a strong cross-linguistic tendency, it does not hold in all cases. Several languages allow syllables with sonority plateaus and sonority reversals, as in 4a and 4b, respectively. The examples, the English word *apt* and the Russian word *rta* 'mouth', are from Clements (1990: 288).

(4) *SSP Violations*

a. Plateau in Coda: *apt*

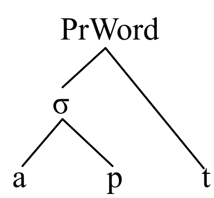


b. Reversal in Onset: *rta*

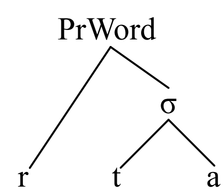


Working under the assumption that the SSP is an inviolable constraint, several researchers claim that apparent violations of the SSP are in fact situations where the SSP does not apply (Clements & Keyser, 1983; Davis, 1990; Levin, 1985; McCarthy, 2005; Steriade, 1982; Venneman, 1988, *and others*). Among the proposals is the notion of the appendix, or a segment which is not associated with the syllable but rather associates directly with the prosodic word. Because the SSP only applies to segments within the syllable, unsyllabified segments would not be constrained by the SSP. Under this theory, the examples in (4) are represented as in (5):

(5) a.



b.



As shown in (5), the appendices, [t] in *apt* and [r] in *rta,* are not associated with the syllable (σ), and therefore not in the domain of the SSP. The syllables *ap* and *ta* are compliant with the SSP. Thus, no violations of the SSP remain.

However, several studies suggest that appendices are not needed to explain syllables like those in (4). Kreitman (2008b) demonstrates that such an analysis does not account for the predictable distribution of sonority reversals in syllable onsets. Her study shows that violations of the SSP in word-initial consonant clusters are limited to languages which also contain word-initial consonant clusters that comply with the SSP. Similarly, Greenberg's statement 25 (1978) shows that in word-final consonant clusters, a sonority fall from a liquid to a nasal is implied by sonority plateaus or reversals involving liquids and nasals. If appendices were free from the influence of the SSP, we would not expect to see any regular pattern in the distribution of sonority reversals.

Thus, the empirical evidence shows that the SSP can be violated, but that it cannot be violated in a random way. This is in accordance with an interpretation of the SSP as a family of violable constraints, as in the framework of Optimality Theory (Prince and Smolensky, 1993/2004). Such constraints are always present and active in a language, but they can be overridden by more dominant constraints.

The present study seeks to build on the evidence in Kreitman (2008b) and Greenberg (1978) by examining the distribution of sonority plateaus and reversals in word-final consonant clusters with respect to the feature [sonorant]. This will allow further generalization of the hypothesis that the SSP effects universal implicational relationships, which are in accordance with a view of the SSP as a family of universal, violable constraints.

2.3 Defining Clusters

The domain of the SSP is restricted to the syllable; thus, in order to observe the effect of the SSP on syllable codas, we must only consider tautosyllabic consonant clusters, disregarding those clusters that occur across syllable boundaries. We must also exclude sound sequences that are composed of a single complex segment, because they usually have only one major class feature node, and thus only one value for [sonorant]. The following definitions will guide the distinction between data that should and should not be included in the study. I will use the term *sequence*, defined in (6), to refer to any contiguous segmental material. I will use the term *cluster*, defined in (7), to refer to the subset of sequences to which the SSP is believed to apply.

(6) *Definition of Sequence*

X_1X_2 is a sequence iff there is no segmental material intervening between X_1 and X_2. Segmental material includes consonants as well as vowels.

(7) *Definition of Cluster*

In the sequence VC_1C_2, C_1C_2 is a cluster iff all of the following conditions are met:

a. C_1C_2 is a sequence

b. $C_1 \neq C_2$

c. C_1 and C_2 each have exactly one place and exactly one manner of articulation

d. C_1 and C_2 are associated with the same syllable

As (7) shows, clusters are a subset of sequences, so that all clusters are sequences but not all sequences are clusters. We can also see that while sequences are defined phonetically, clusters are subject to both phonetic and phonological requirements. The definition in (7) excludes several types of sequences.

Condition 7a excludes from the set of clusters all non-sequences, including underlying sequences that are broken up on the surface by epenthetic material. However, in some cases of two adjacent voiced consonants, the release of the first consonant appears on a spectrogram as a region of vocalic material before the onset of the second consonant. This can occur even when speakers do not perceive a vowel between the two consonants. I accept sequences of two voiced consonants when they are recorded as such in my sources. I assume that any vowel-like releases that may be present but not perceived are a phonetic consequence of releasing a voiced consonant rather than an indication that the phonological system of the language does not permit the two consonants to form a cluster.

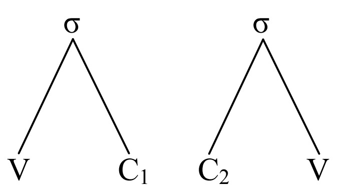
Condition 7b rules out geminates. The phonological representation of geminates is not transparent, and in some languages they pattern with single segments rather than with clusters (Chomsky and Halle, 1968; Ham, 1998 and references therein; Trubetzkoy, 1969 *among others*). Therefore, I excluded them from this study.

Condition 7c rules out secondarily and doubly articulated segments. These will be discussed further in section 3.1.

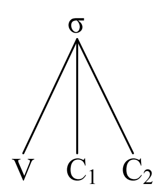
Condition 7d rules out sequences that include appendices and those that include syllabic segments. I discuss these in sections 3.4 and 3.5, respectively; as we will see, syllabification is theory-dependent, which raises challenges for this study.

Although condition 7d does not rule out word-medial coda clusters, it makes their inclusion impractical, because word-medial consonant clusters are often heterosyllabic. This situation is illustrated in 8a, where the sequence C_1C_2 fails to qualify as a cluster because the consonants are associated with different syllables. In contrast, the diagram in 8b shows how the same sequence does form a cluster when it occurs word-finally. The location of word-medial syllable boundaries is language-dependent, and the determination of these language-dependent boundaries is outside the scope of this study. Thus, I limit this study to word-final consonant clusters.

8) a. Word-medial non-cluster



b. Word-final cluster



Note, however, that condition 7d as well as the syllable diagrams in (8) disregard the moraic associations of the segments. For the purposes of this study, I do not distinguish between moraic and non-moraic consonants. Although moraic associations may play a role in weight assignment, syllable weight is beyond the scope of this study. Additionally, morpheme boundaries are irrelevant to the definition of a cluster as given in (7); this issue will be discussed further in section 3.5.

3. Challenges

The need to determine which sequences are also clusters poses a challenge for this survey because clusterhood is based on the phonological status of each segment. These phonological representations may be opaque in several ways, the most important of which I discuss below. In the results, I separate transparent clusters from non-transparent sequences. The latter may be clusters or non-clusters, depending on aspects of their phonological representation that are unavailable to me. I present languages with these non-transparent sequences separately from languages with transparent clusters in section 5.

3.1 Unary vs. Binary

In some cases, it is not possible to tell from the documented grammars whether a sequence is composed of two segments or of one segment with double or secondary articulation[1]. Ladefoged & Maddieson (1996) and Riehl (2008) show that sequences of a nasal and a homorganic obstruent form clusters in some languages, but are prenasalized obstruents in other languages. In other words, these sequences can be unary segments or binary clusters. Given this situation, I treat all sequences of a nasal and a homorganic obstruent as non-transparent.

The data collected here suggests that sequences including a laryngeal, [h] or [ʔ],

1 Sequences of a stop and a homorganic fricative can also be analyzed as unary (affricates) or binary, but the results of this study were not affected by any uncertainty regarding their status, so clusters including affricates were not considered separately from other straightforward clusters.

are also possibly unary sequences. For instance, the only word-final consonant sequences allowed in Tonkawa are [ʔs], [sʔ], [lʔ], and [jʔ] (Hoijer, 1946), which suggests that the glottal stop may not actually be a separate segment, but rather a secondary articulation. Distributions like that found in Tonkawa exist in several of the Native American languages studied. Due to this potential phonological ambiguity, I treat sequences that include laryngeals as non-transparent as well.

3.2 Glides: Vocalic vs. Consonantal

The underlying status of glides is not transparent. Segments pronounced as glides may be underlyingly vocalic (Levi, 2004) and associate with the nucleus rather than the coda of the syllable. Segments in the nucleus are outside the scope of this study, as they do not form part of consonant clusters. I have treated sequences that begin with glides as non-transparent for this reason.

3.3 Fricatives: Sonorant vs. Obstruent

In some languages, the fricative [v] patterns wholly or partially with sonorants. Scholars have proposed that this is the case in Hungarian (Siptár and Törcenczy, 2000), Russian (Andersen, 1969), Slovak (Rubach, 1993), Slovenian (Browne, W., p.c., March 21, 2009), and Swedish (Lombardi, 1995).

The typological classifications of Russian (Sawicka, 1974), Hungarian (Hall, 1944; Kenesei, 1998; Siptár, 2000), and Swedish (Bannert & Czigler, 1999) do not depend on the classification of [v]. In these languages, the same cluster types were found when [v] was considered an obstruent and when [v] was considered a sonorant, because [v] was never the only sonorant or the only obstruent to appear in a word-final sequence with either sonorants or obstruents.

However, the status of [v] is relevant for the classification of Slovak and Slovenian (Sawicka, 1974). These two languages have the set of cluster types shown in (9) when [v] is considered a sonorant, but they have the set of cluster types shown in (10) when [v] is considered an obstruent.

(9) {SO, OO, SS}

(10) {SO, OO, SS, OS}

The sets in (9) and (10) differ only in their last cluster type, OS. This is because both languages contain clusters of [v] followed by a sonorant, but they do not contain any clusters of an obstruent besides [v] followed by a sonorant. Thus, if [v] is a sonorant, these languages have no OS clusters.

Based on the available evidence, I consider [v] to be a sonorant in these languages. Therefore, I have treated these languages as lacking OS clusters, in accordance with (9). Nevertheless, it should be noted that both the cluster set in (9) and the cluster set in (10) are empirically attested by other languages in the survey. Therefore, the cross-linguistic typology is not affected by the classification of [v] in these languages.

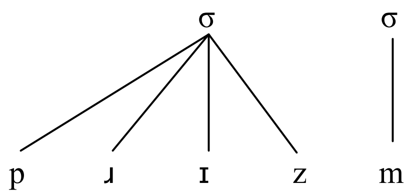
3.4 Appendices vs. Syllabified Segments

As discussed in section 2.2, many researchers (Clements & Keyser, 1983; Davis, 1990; Levin, 1985; McCarthy, 2005; Steriade, 1982; Venneman, 1988, *and others*) claim that some segments at the edges of prosodic words associate directly with the prosodic word. These segments have been described in several ways, but I will refer to them as *appendices*. The distribution of appendices is language specific, which makes it difficult to ascertain which segments behave as appendices in the range of languages included in this typological study. Furthermore, the theory remains controversial; Ohala (1990) and Ohala and Kawasaki (1984) argue that the reasoning behind the theory of appendices is circular, and Broselow (1995) and Kreitman (2008b) point out that the theory of appendices predicts that languages will have sets of sequence types that are empirically unattested. For these reasons, I do not subscribe to appendices as an explanation for violations of the SSP, and I assume that word-final consonant sequences are tautosyllabic. As we will see in section 5, this decision does not appear to interfere with the results. Rather, the results of this study echo those of Kreitman's study in showing that the theory of appendices overgenerates and is not necessary to account for violations of the SSP.

3.5 Syllabic Consonants vs. Coda Consonants

Although some languages only allow vowels to occupy syllable nuclei, others allow certain types of consonants to occupy syllable nuclei as well. In languages that allow syllabic consonants, a word-final consonant sequence may be heterosyllabic, as exemplified in (11) in the English word *prism*. Although [zm] forms a sequence, it is not a cluster because the two segments are associated with different syllables.

(11)



Although languages with such syllabic consonants could interfere with the findings, evidence from Polish shows that each of the four types of biconsonantal clusters can occur without intervening syllabic consonants. Polish does not allow syllabic consonants, but it allows all four cluster types in both word-initial and word-final position (Bethin, 1992). This rules out the possibility that all apparent sonority reversals can be attributed to syllabic consonants.

3.6 Heteromorphemic vs. Tautomorphemic

One other issue that may affect the results is the presence or absence of morpheme boundaries. Although in the definition of clusters, only phonological representation was deemed relevant, the presence or absence of morpheme boundaries seems to influence the types of clusters that are allowed, at least in some languages. Namely, heteromorphemic sequences are less constrained than tautomorphemic sequences in some languages (see for example Kenesei, 1998 on Hungarian). This effect may suggest that heteromorphemic sequences should not be considered clusters. However, we will see in section 5 that known morpheme boundaries do not change the overall typology even when they change the categorization of a particular language. Therefore, I maintain that clusters need not be tautomorphemic in order to be subject to the SSP.

4. Methods

4.1 Data Collection and Analysis

In this study, I reviewed 178 languages from approximately 40 language families. I collected data on these languages from reference grammars and phonological studies, comparing multiple sources on one language when possible. I selected the languages on the basis of availability of information.

I gathered information from these sources on word-final consonant clusters. The relevant aspect of the word-final clusters was the value of the feature [sonorant] for each segment. The set of [+sonorant] consonants consists of nasals, liquids, and glides, and the set of [-sonorant] consonants consists of stops, fricatives, and affricates. As discussed in section 3.5, the fricative [v] behaves as a sonorant in certain languages, but this issue did not affect the overall typology.

Because I used only the feature [sonorant], I did not distinguish among types of sonorants or among types of obstruents. For instance, I treat clusters of a liquid (S) followed by a fricative (O) as identical to clusters of a nasal (S) followed by a fricative (O). The possible cluster types for this study are thus limited to those in (12):

(12) SO, OO, SS, OS

I recorded all cluster types that were present in each language studied, and then compared the languages in terms of the cluster types that they allowed. Languages that allowed the same set of cluster types were considered to be of the same type.

4.2 Treatment of Problematic Sequences

Based on the discussion in section 3, I excluded all sequences that contain epenthetic segments in surface representations, all geminates, and all sequences that contain syllabic consonants, to the extent that the sources provide this information. I also excluded sequences that exist only in recent loan words, onomatopoetic words, and proper nouns. For instance, the only word-final consonant clusters present in Finnish (Sulkala, 1992) are found in recent loans and onomatopoetic words, so Finnish was treated as lacking clusters for the purposes of this study.

I excluded all sequences of a nasal and a homorganic obstruent, all sequences that contain laryngeals, and all sequences that begin with a glide. I consider these sequences to be non-transparent, as discussed in sections 3.1 and 3.2. In many languages, excluding these sequences from the study had no effect on the classification of the language. In cases where the classification of a language changed due to the exclusion of non-transparent sequences, I presented the language with all of its possible classifications in section 5.2.

Following the discussions in sections 3.5 and 3.6, I did not exclude any clusters on the basis of appendices or morpheme boundaries. However, when the sources explicitly labeled morpheme boundaries, I determined the ways in which the classification of the language would shift if heteromorphemic clusters were excluded; these type shifts are discussed in section 5.3.

5. Results

5.1 Attested Language Types

In this study, I sought to determine which language types are empirically attested as classified by their word-final consonant clusters. I will contrast this set of existing language types with the set of logically possible language types. These possible types are shown in Table 1. Boxes marked with a check show cluster types that are present in each language type.

Table 1. Logically possible language types

# Cluster Types	Language Type	SO	OO	SS	OS
Zero	Type I				
One	Type II	✓			
	Type III		✓		
	Type IV			✓	
	Type V				✓
Two	Type VI	✓	✓		
	Type VII	✓		✓	
	Type VIII	✓			✓
	Type IX		✓	✓	
	Type X		✓		✓
	Type XI			✓	✓
Three	Type XII	✓	✓	✓	
	Type XIII	✓	✓		✓
	Type XIV	✓		✓	✓
	Type XV		✓	✓	✓
Four	Type XVI	✓	✓	✓	✓

The languages studied here present evidence for the existence of five of these language types, but not for any of the other possible language types. The attested language types and the number of languages that I found to belong to each type are presented in Table 2. Languages with non-transparent clusters are not included in Table 2; they will be discussed in section 5.2.

Table 2. Empirically attested language types

Language Type	SO	OO	SS	OS	# Languages
Type 0					107
Type 1	✓				4
Type 2	✓	✓			11
Type 3	✓	✓	✓		23
Type 4	✓	✓	✓	✓	19

From this table, we can see that languages that allow OO clusters also allow SO clusters, that languages with SS clusters also allow OO and SO clusters, and that languages with OS clusters allow all other cluster types. From this data, an implicational relationship of the type shown in (13) emerges.

(13) OS $\Rightarrow$ SS $\Rightarrow$ OO $\Rightarrow$ SO

That is, the presence of OS clusters in a language implies the presence of SS clusters in that language, the presence of SS clusters implies the presence of OO clusters, and the presence of OO clusters implies the presence of SO clusters. We can compare this relationship to the one Kreitman (2008a, 2008b) found for word-initial biconsonantal clusters (14).

(14) SO $\Rightarrow$ SS $\Rightarrow$ OO $\Rightarrow$ OS (Kreitman, 2008a, 2008b)

Because the SSP states that sonority should rise in the onset and fall in the coda, we expect the relationships found for the coda to be the reverse of those found for the onset. The implicational relationships in Table 2 and (13) show that this expectation is confirmed when the two types of sonority plateaus are not differentiated. For codas, rising sonority implies flat sonority which implies falling sonority, and for onsets, falling sonority implies flat sonority which implies rising sonority. The relationships for both margins can be captured in the generalization that sonority reversals imply sonority plateaus, which imply SSP-compliant sonority profiles.

However, both Table 2 and (13) show that SS clusters imply OO clusters. This is not predicted by the SSP, as both clusters are sonority plateaus and the relationship between them does not change direction from the onset to the coda. It is especially surprising that this relationship was not reversed from onsets to codas because codas are known to be preferentially high in sonority. This phenomenon will be discussed further in section 6.2.

5.2 Distribution of Languages

The 178 languages studied fall into the five types in the following ways. The majority of the languages, 107 of them, lack all word-final consonant clusters, which places them in Type 0. This type includes languages like Arapaho (Kroeber, 1916), which has epenthetic vowels following its consonant sequences; Spokane (Bates & Carlson, 1997), whose consonant sequences contain syllabic consonants; and Fijian (Scheutz, 1985), which does not allow word-final consonants at all. The full list of these languages is presented in Appendix A.

Of the remaining 71 languages, 57 languages had transparent clusters while 14 languages had non-transparent clusters. Table 2 reflects the findings on the 57 languages with transparent clusters; the other 14 languages will be discussed below.

The distribution of the 57 languages whose clusters were transparent is presented in Appendix B. As shown in Table 2, four of these languages fall into Type 1, containing only one type of consonant cluster, which is always SO. Eleven of them fall into Type 2, containing SO and OO clusters. Twenty-three languages were found to belong to Type 3, containing SO, OO, and SS clusters. Nineteen languages fall into Type 4, and permit all four biconsonantal cluster types: SO, OO, SS, and OS. No other sets of cluster types were found among these languages.

The types of the remaining 14 languages cannot be determined with certainty, because these languages have sequences of nasals and homorganic obstruents, sequences that contain laryngeals, and/or sequences beginning with glides. As discussed in sections 3.1 and 3.5, such sequences only form clusters in certain languages. The distribution of clusters and non-clusters across the languages in this study is unpredictable from the data gathered here, so we expect these sequences to be clusters in some of the languages studied but not in others. Thus, it is likely that an across-the-board policy of either excluding or including these sequences would lead to inaccurate results. Therefore, I consider all possible classifications of these languages in (14).

These languages cannot be used to argue definitively for the pattern found in the more transparent languages discussed above. However, it is conceivable that these languages could present counterexamples to the typology in Table 2. For instance, if a language was found that permitted only the cluster type OO and the non-transparent sequence type OS, then regardless of whether or not the sequence was a cluster, the language would not fall into one of the five types attested so far. Significantly, the data show no such cases. When we consider all possible classifications of these 14 languages, we find that there is at least one possibility for each language that would place that language into one of Types 0 through 4.

Table 3 shows all of the possible classifications of the languages with non-transparent (NT) sequences. The middle column shows the set of transparent cluster types that each language is known to have. The right column lists the logically possible combinations of transparent cluster types and non-transparent sequence types. For instance, Amuesha (Fast, 1953) has transparent OO clusters, but it also has sequences of nasals and homorganic obstruents. These latter sequences are non-transparent SO sequences. Therefore, if these SO sequences are not clusters, Amuesha has only OO clusters, as shown in the middle column; if on the other hand, the SO sequences are clusters, Amuesha has the cluster types OO and SO, as shown in the right column. Some languages, such as Chitimacha, have two non-transparent sequence types, which increases the number of possible combinations. Appendix C lists the types of non-transparent sequences found for each language.

Sets of cluster types that coincide with the empirically attested language types in Table 2 are marked with a check. As noted above, there is at least one attested set of cluster types for each language in Table 3.

Table 3. The distribution of languages with non-transparent (NT) sequences

Language	**Excluding NT Sequences**	**Including NT Sequences**
Amuesha, Arawak (Fast, 1953)	OO	✓SO, OO
Chitimacha (Swadesh, 1946a)	✓SO	SO, OS SO, SS SO, SS, OS
Chontal (Waterhouse & Morrison, 1950)	✓none	✓SO
Delaware (Voegelin, 1946)	OO	✓SO, OO
Huambisa (Beasley & Pike, 1957)	✓none	✓SO
Kashmiri (Koul, 2005)	OO	✓SO, OO
Keresan (Spencer, 1946)	OO	✓SO, OO OO, OS SO, OO, OS
Klamath (Barker, 1964)	✓SO, OO	✓SO, OO, SS
Kutenai (Garvin, 1948)	✓SO, OO	SO, OO, OS
Sre (Manley, 1972)	✓none	✓SO
Tonkawa (Hoijer, 1946)	✓none	✓SO OO ✓SO, OO
Totonac, Misantla (MacKay, 1994)	OO	✓SO, OO
Tunica (Haas, 1946)	✓none	OO
Zoque (Wonderly, 1951)	OO	✓SO, OO OO, OS SO, OO, OS

5.3 Effects of Morpheme Boundaries and Appendices

Heteromorphemic clusters were included when determining the types of the languages in Tables 2 and 3. The exclusion of these sequences would have no effect on the classification of Aguacatec (H. McArthur & L. McArthur, 1956), Albanian (Newmark, 1957), Breton (Ternes, 1970), Danish (Martinet, 1937), or Swedish (Bannert & Czigler, 1999). However, when known heteromorphemic sequences are excluded, Komi (Hausenberg, 1998) changes from Type 2 to Type 1 and Hungarian (Kenesei, 1998; Siptár, 2000) changes from Type 4 to Type 3. Since both of these languages would move from one existing type to another existing type, known morpheme boundaries do not affect the overall typology.

Note also that although appendices, if present, would not be subject to the SSP and therefore would not be expected to follow any pattern related to sonority sequences, no exceptions to the pattern were found. This is true despite the fact that several languages believed to contain appendices, including but not limited to Armenian (Vaux, 1998), Dutch (Booij, 1995), English (Hayes, 1982), and German (Kohler, 1995), were among the languages studied.

6. Discussion

6.1 Effect of the SSP

Results from the survey of biconsonantal clusters confirmed that the distribution of coda clusters can be modeled with the implicational relationship in (15): OS ⇒ SS ⇒ OO ⇒ SO. In this relationship, the presence of sonority reversals (OS) in a language implies the presence of sonority plateaus (SS and OO), which in turn implies the presence of clusters that comply with the SSP (SO). The data further show a distinction between OO and SS clusters that is not predicted by the SSP; I will discuss this distinction in section 6.2.

A comparison of the present study with that of Kreitman (2008a) offers additional insights. In the onset, sonority reversals imply sonority plateaus, which imply SSP-compliant sonority sequences, just as in the coda. This result suggests that the relationship found for the coda, excluding the distinction between OO and SS clusters, is due to the SSP. However, it also suggests that the SSP applies to the onset and coda independently, because languages in a given onset-based type do not always fall into the analogous coda-based type. For instance, Belarusian is a Type 3 language as classified by its onset clusters, allowing OS, OO, and SS clusters (Kreitman, 2008a), but it is a Type 4 language as classified by its coda clusters, allowing all four cluster types (Sawicka, 1974).

6.2 Preference for Obstruent Clusters

The results show that a cluster of two sonorants (SS) implies a cluster of two obstruents (OO), while the opposite is not true. In terms of the binary values of the feature [sonorant], both of these cluster types represent sonority plateaus, so the SSP does not predict that one should be preferable to the other. Furthermore, the direction of the implicational relationship between SS and OO clusters for onset clusters is the same as that found for coda clusters. This effect is unlikely to derive from the SSP, because the SSP requires opposite behavior from the onset than from the coda.

I propose that the preference for OO clusters over SS clusters in both margins is due to the relationship between the preference for consonants adjacent to the nucleus to be high in sonority and the preference for consonants at the syllable edge to be low in sonority. I suggest that the latter preference is stronger than the former.

Any explanation of this phenomenon must be reconciled with the preference for single-consonant codas to be high in sonority and for sonority to drop from the end of a coda to the beginning of the onset of the following syllable. This latter preference is known as the Syllable Contact Law (SCL) (Hooper, 1976; Murray and Venneman, 1983). Although further research is necessary to ascertain how the SS $\Rightarrow$ OO relationship interacts with these other tendencies, I claim that both of these apparent conflicts are not actually problematic for the cases examined here.

First, I assume that the preference for high sonority in codas derives from the constraint on the sonority of the innermost segment in the coda. The coda positions can be defined (see (16)) so that singleton codas will fall under the jurisdiction of this constraint rather than under the jurisdiction of the constraint that prefers low sonority in outer segments.

Second, the SCL may not apply to word-final consonant clusters. These clusters do not necessarily precede other syllables, and when they do, they are likely to be separated from the following syllable by a phonologically relevant boundary. The SCL may act only within a certain domain, such as the foot or the prosodic word. Thus, the clusters included in this study, which are all word-final, probably represent the behavior of clusters when they are free from constraint by the SCL.

As with the SSP, the constraint against sonorous outer segments acts similarly but independently on onsets and codas. Frisian, for instance, is a Type 2 language in terms of onsets (Kreitman, 2008a), with SO and OO clusters only, but it is a Type 3 language in terms of codas (Cohen, 1971), allowing SO, OO, and SS clusters.

7. Analysis in Optimality Theory

7.1 Overview

In the framework of Optimality Theory (OT) (Prince and Smolensky, 1993/2004), the tendencies I have been discussing are formalized as universal, violable constraints. Optimality Theory assumes a structure in which GEN, the generator, generates an unlimited number of candidates based on an input form, and EVAL evaluates these candidates by referring to CON, the set of constraints. These constraints include markedness constraints and faithfulness constraints. Markedness constraints assign violations for marked forms, such as forms that violate the SSP, while faithfulness constraints assign violations for candidates that do not match the input in a particular way. The ranking of these constraints varies from language to language, except in fixed constraint hierarchies that derive from primitive scales, such as the sonority scale. Each constraint strictly dominates all constraints ranked below it. These constraints filter out all ungrammatical forms of a particular input, leaving only the form that surfaces in the language.

Some controversy remains on the subject of how best to formalize the SSP in OT constraints. Prince and Smolensky (1993/2004) propose hierarchies of constraints based on sonority, the Peak hierarchy and the Margin hierarchy, but they do not propose constraints that refer to the sonority sequence within a cluster. Hammond (1997), Kenstowicz (1994), and others use a single SSP constraint that militates against sonority reversals and plateaus in clusters; Bat-El (1996) uses a similar constraint for the SCL.

However, as Baertsch (2002), Gouskova (2004), and Morelli (1999) argue, a single constraint cannot make all of the necessary distinctions between levels of violations of the SSP and SCL. The results of this study support the claim that a distinction between plateaus and reversals is necessary and therefore that the SSP must be represented by multiple constraints. However, the issue of defining these constraints remains. Many formulations of the SSP and SCL (Bat-El, 1996; Hammond, 1997; *and others*) require constraints to refer to an external sonority scale in order to determine whether to assign a violation to a candidate. Baertsch (1998, 2002) argues that SSP constraints should not need to refer to external elements, but rather, that they should be constructed in a manner analogous to the construction of Prince and Smolensky's Peak and Margin constraints, using harmonic alignment. She uses local conjunction to achieve this, while Gouskova (2004) proposes relational alignment in place of local conjunction, but otherwise uses a similar method. I discuss both of these approaches in section 7.2.

In section 7.3, I show that both Baertsch's and Gouskova's approaches generate language types that are not empirically attested. This is due to the fact that both harmonic alignment and local conjunction produce hierarchies of constraints[2] which are freely rankable with respect to each other; some rankings produce attested language types, while other rankings produce unattested language types. I point out that this apparent weakness can be used to generate Type 2 languages, which otherwise do not appear to derive from the SSP. Therefore, I suggest that a fixed ranking be applied between the two hierarchies created by harmonic alignment, to preserve the ability to generate Type 2

2 These hierarchies use universally fixed rankings between constraints. De Lacy (2002) argues that constraints should be in stringency relationships rather than in fixed rankings, but I use fixed rankings here for simplicity and agreement with Baertsch and Gouskova's proposals.

languages while eliminating the ability to generate unattested language types.

7.2 Review of Previous Proposals

7.2.1 Harmonic Alignment using the Split Margin Approach

Prince and Smolensky (1993/2004) use harmonic alignment to construct two constraint hierarchies, the Peak Hierarchy and the Margin Hierarchy. These constraint sets have the effect of preferring sonorous peaks and obstruent syllable margins. Baertsch (1998, 2002) applies this method to subsets of the margin in her Split Margin approach. The definition of harmonic alignment is presented in (15).

(15) *Harmonic Alignment* (Prince and Smolensky, 1993/2004: 149)

Suppose given a binary dimension D_1 with a scale $X > Y$ on its elements $\{X, Y\}$ and another dimension D_2 with a scale $a > b > ... > z$ on its elements. The *harmonic alignment* of D_1 and D_2 is the pair of Harmony scales:

H_x: $X/a \succ X/b \succ ... \succ X/z$

H_y: $Y/z \succ ... \succ Y/b \succ Y/a$

The *constraint alignment* is the pair of constraint hierarchies:

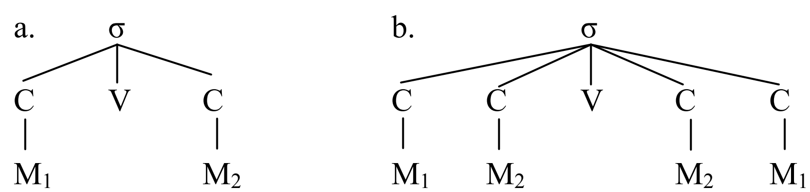
C_x: $*X/z \gg ... \gg *X/b \gg *X/a$

C_y: $*Y/a \gg *Y/b \gg ... \gg *Y/z$

The prominence scales *X* > *Y* and *a* > *b* > ... > *z* show that *X* is more prominent than *Y* and that *a* is more prominent than *b*, and so on. The Harmony scales show that *X* is most harmonic when it is associated with *a*, because *X* and *a* are both highly prominent, while *Y* is most harmonic when it is associated with *z*, because they are both low in prominence. The constraint alignment encodes this information in optimality theoretic constraints, which rank bans against unharmonic associations more highly than bans against harmonic associations. This ensures an implicational relationship whereby unharmonic associations will only occur in languages that also allow harmonic associations.

Under Baertsch's Split Margin approach, the binary dimension D_1 refers to the two margin positions M_1 and M_2. M_1 refers to the single position in a singleton onset and to the outer position in biconsonantal onsets and biconsonantal codas. M_2 refers to the single position in a singleton coda and to the inner position in biconsonantal onsets and biconsonantal codas. These positions are illustrated in (16).

(16)



Baertsch argues that M_2 is more prominent, and so should be more sonorous, than M_1 (M_2 > M_1). When this scale is aligned with the sonority scale S > O, the constraint hierarchies in (17) result. These hierarchies are independently motivated, as they account for the preference for obstruent singleton onsets (M_1) and sonorant singleton codas (M_2). However, they can also be manipulated to produce constraints that account for the SSP, as we will see in sections 7.2.2 and 7.2.3.

(17) C_{M1}: $*M_1/S \gg *M_1/O$

C_{M2}: $*M_2/O \gg *M_2/S$

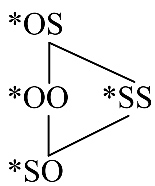
The ranking between the two constraints on M_1 is universally fixed, and the ranking between the two constraints on M_2 is fixed as well; however, there are no restrictions on the possible rankings of the hierarchy C_{M1} with respect to the hierarchy C_{M2}. I will return to this point in section 7.3, where I show that this property of the constraint hierarchies generated by harmonic alignment leads to the generation of an unattested language type.

7.2.2 Local Conjunction

Local conjunction is a process that Smolensky (1993) proposed to create a new constraint from two other constraints. The new constraint is only violated when both of the original constraints are violated in a particular domain; it is not violated when neither or only one of the component constraints are violated. Baertsch (2002) uses local conjunction to create constraints that account for the SSP out of the constraints produced by harmonic alignment.

Each constraint from the hierarchy C_{M1} is conjoined with each constraint from the hierarchy C_{M2} (see (20) for these hierarchies). Because conjoined constraints are only violated when both of their component constraints are violated, each conjoined constraint militates against sequences of a particular M1 *and* a particular M2; in other words, each conjoined constraint bans one of the four cluster types. To make these constraints easier to read, I will write them as constraints against each cluster type (eg, *SO) rather than using the usual notation for local conjunction (eg, $*M_2/S\&*M_1/O$). The conjoined constraints preserve the rankings of their component constraints. For instance, the constraint *OS is the highest ranked because the constraint against an initial O ($*M_2/O$) and the constraint against a final S ($*M_1/S$) are both the highest ranked constraints in their respective hierarchies. The constraints are shown in their rankings in (18).

(18)



The constraint *OS dominates the constraints *OO and *SS. These latter two both dominate *SO. As Gouskova (2004) points out with reference to the SCL constraints, this ranking leaves *OO and *SS unranked with respect to each other. Therefore, this approach predicts that some languages rank them in the order *OO ≫ *SS, while other languages rank them in the order *SS ≫ *OO. When the relevant faithfulness constraint ranks in between these two constraints, languages that rank *OO above *SS allow the set of clusters in 19a. On the other hand, languages that rank *SS above *OO allow the set of clusters in 19b.

(19) a. {SO, SS}

b. {SO, OO}

Gouskova (2004) argues that sets like these are unlikely to occur in human language, and therefore that the approach using local conjunction is overly powerful. I will return to this claim in section 7.3, where I argue that Gouskova is only partially correct, as 19a is an unattested type, but 19b is an existing type (Type 2) according to my findings. First, though, I will review her proposal.

7.2.3 Relational Alignment (Gouskova, 2004)

As we have seen in the previous section, local conjunction is capable of differentiating between clusters that have the same type of sonority sequence. Gouskova argues that this is likely to result in the generation of non-existing language types. Thus, she proposes a way of generating SCL constraints, which I will consider in the similar context of the SSP, that makes it impossible to treat clusters that have the same sonority sequence in different ways.

Gouskova's approach uses the notion of a stratum, which is the collection of all clusters with the same type of sonority sequence. Using the binary feature [sonorant], these types of sonority sequences are falls, plateaus, and rises. Her constraints ban entire strata of cluster types instead of separately banning each cluster type.

(20) *Relational Alignment* (Gouskova, 2004: 210)

The Relational alignment of two harmonic scales H_X ($X_1 \succ \ldots X_n$) and

H_Y ($Y_1 \succ \ldots Y_m$) is the relational scale $Stratum_1 \succ \ldots Stratum_{n+m-1}$, where

$Stratum_s = \{X_iY_j \mid i + j = s+1\}$.

H_X and H_Y are the product of harmonically aligning the prominence scales

$X > Y$ and $a > b > ... z$.

The harmonic scales H_{M1} and H_{M2} are presented in (21). As shown in the definition of relational alignment, Gouskova assigns each member of each harmonic scale an index, starting with the most harmonic member as 1. I have put the indices assigned to each member next to it in parentheses.

(21) H_{M1}: M_1/O (1) $\succ$ M_1/S (2)

H_{M2}: M_2/S (1) $\succ$ M_2/O (2)

Based on the indices assigned to the members of these harmonic scales, we can determine how the clusters fall into strata. To do so, we add the numbers assigned to each segment in the cluster and subtract one from the sum. This process is shown in (22), where the subscripts denote the position filled by each segment type.

(22) $S_{M2}O_{M1}$ = 1+1-1 = Stratum 1

$O_{M2}O_{M1}$= 2+1-1 = Stratum 2

$S_{M2}S_{M1}$= 1+2-1 = Stratum 2

$O_{M2}S_{M1}$= 2+2-1 = Stratum 3

For convenience, I will refer to Stratum 1 as Fall, Stratum 2 as Plateau, and Stratum 3 as Rise. The definition states that the strata are ordered on a harmonic scale based on their indices. This scale is shown in (23). The constraints that align with this harmonic scale are presented in (24).

(23) Fall ≻ Plateau ≻ Rise

(24) *RISE ≫ *PLATEAU ≫ *FALL

As (24) shows, the two plateaus OO and SS are inseparable under this approach, because they are banned by a single constraint rather than by two separate ones as in local conjunction. However, in the next section I will show that harmonic alignment has the same property that leads her to argue against local conjunction: it allows for the arbitrary division of strata.

7.3 Harmonic Alignment and Local Conjunction: Generating Type 2

Both harmonic alignment and local conjunction allow OO clusters and SS clusters to be treated differently, so that one type is allowed while the other is banned. I show this in the tableaux below.[3]

3 The repair strategies used to break up disallowed clusters and the faithfulness constraints that these repair strategies violate vary from language to language. This issue is outside the scope of this study, so I use a single faithfulness constraint and a single repair stategy (deletion of the entire cluster) to allow us to focus on the effects of the markedness constraints.

(25) a. Harmonic Alignment

i. SS without OO

input: OO	$*M_2/O$	FAITH	$*M_1/S$
VOO	*!		
☞ V		**	
input: SS			
☞VSS			*
V		**!	

ii. OO without SS

input: OO	$*M_1/S$	FAITH	$*M_2/O$
☞ VOO			*
V		**!	
input: SS			
VSS	*!		
☞ V		**	

b. Local Conjunction

i. SS without OO

input: OO	*OO	FAITH	*SS
VOO	*!		
☞ V		**	
input: SS			
☞VSS			*
V		**!	

ii. OO without SS

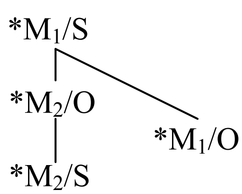
input: OO	*SS	FAITH	*OO
☞ VOO			*
V		**!	
input: SS			
VSS	*!		
☞ V		**	

The tableaux in (25) show that both harmonic alignment (25a) and local conjunction (25b) are capable of separating OO clusters from SS clusters, allowing one cluster type while eliminating the other. The constraints that are ranked the highest in each of the hierarchies produced by harmonic alignment, $*M_2/O$ and $*M_1/S$, are not fixed in a ranking with respect to each other, so they can be ranked in either order. Local conjunction, likewise, produces two constraints against plateaus that can be ranked in either order. When FAITH intervenes between these freely rankable constraints, cluster types that are equally harmonic in terms of the SSP are treated differently.

I did not find any languages that allowed SS clusters but disallowed OO clusters. Therefore, both of these types of constraints overgenerate because they allow the incorrect outputs in 25a-i and 25b-i. However, it is not always a weakness to be able to divide OO clusters from SS clusters. Languages that allow OO clusters but disallow SS clusters, as in 25a-ii and 25b-ii, are empirically attested: they are Type 2 languages. As discussed in section 6.2, this type is impossible to generate using SSP constraints that do not differentiate between clusters of the same stratum.

Both the problem of overgeneration and the problem of the difficulty of deriving Type 2 languages can be solved at once if we fix the rankings of either the harmonic alignment constraints or the local conjunction constraints such that the constraint against SS clusters dominates the constraint against OO clusters. The ranking of the harmonic alignment constraints would be as follows:

(26)



In this ranking, the original rankings between constraints on the same position are preserved, so that $*M_1/S$ dominates $*M_1/O$ and $*M_2/O$ dominates $*M_2/S$, but the additional ranking $*M_1/S \gg *M_2/O$ is added. The results of this study do not suggest that any other fixed rankings are needed, so I have left the relationship of $*M_1/O$ to the constraints on M_2 undecided. These rankings can be freely changed from one language to another without generating any unattested language types. However, if a fixed ranking is deemed necessary, $*M_2/O$ must rank above $*M_1/O$ to allow the generation of Type 1 languages. Under the opposite ranking, plateaus cannot be eliminated by the $*M_2/O$ constraint without also eliminating all coda clusters due to the higher-ranking $*M_1/O$ constraint.

If we use local conjunction, it is not necessary to introduce a new fixed ranking into the harmonic alignment constraints, because conjoined constraints always dominate their component constraints. Thus, the ranking below is sufficient.

(27) *OS ≫ *SS ≫ *OO ≫ *SO

There are two reasons to prefer the approach using relational alignment. First, Gouskova (2004) and others argue that the process of local conjunction is problematic because it appears to be overly powerful; that is, there are few restrictions on what constraints can be conjoined, and this may result in overgeneration. Secondly, Baertsch (2002: 40) notes that there is a tendency for all of the Margin hierarchy to dominate at least part of the Peak hierarchy, in reference to the constraints on sonority that Prince and Smolensky (1993/2004) developed. This suggests that restrictions on rankings exist between other hierarchies of the same nature as the C_{M1} and C_{M2} hierarchies. Because a local conjunction approach would make fixed rankings between the C_{M1} and C_{M2} hierarchies irrelevant, the relational alignment approach may allow a more unified explanation of the data, one in which all constraint hierarchies deriving from harmonic alignment have certain fixed rankings with respect to each other.

This ranking may derive from the alignment process. Based on the typology found in this study and the tendency for the Margin hierarchy to dominate some part of the Peak hierarchy, it appears that at least the highest-ranked constraint on a less prominent position outranks the highest-ranked constraint on a more prominent position. Thus, the highest constraints in each constraint hierarchy formed by harmonic alignment may be aligned with the reverse of the positional prominence scale, as in (28).

(28) *Possible Alignment Process*

Given the positional prominence scale A > B and the constraint hierarchies C_A ($A_1 \gg ... \gg A_n$) and C_B ($B_1 \gg ... \gg B_n$), the inter-hierarchy constraint alignment is the constraint hierarchy:

$B_1 \gg A_1$

Further research is necessary to test the predictions of this proposed alignment process and uncover the exact relationships among the various constraint hierarchies.

7.4 Generating Type 3

The constraint hierarchies C_{M1} and C_{M2} are not capable of generating Type 3 languages (SO, OO, SS) because they cannot allow an obstruent in M_2, as in OO, and allow a sonorant in M_1, as in SS, without allowing both to occur together, as in OS. Local conjunction and relational alignment, however, are capable of generating Type 3 languages. In the diagrams below, I show the language types generated by each approach. Each arrow points to a place where the relevant faithfulness constraint could be ranked in a specific language, and shows which language type would result from ranking the faithfulness constraint in that place.

(29) Local Conjunction

*OS ≫ *SS ≫ *OO ≫ *SO

↑ ↑ ↑ ↑ ↑

Type 4 Type 3 Type 2 Type 1 Type 0

In (29), we see that all cluster types are allowed when faithfulness is more important than any other constraints, and so Type 4 languages are generated when Faith outranks the other constraints. As we consider ranking Faith lower and lower, more and more cluster types are eliminated. The first cluster type to be eliminated is the OS type; the resulting languages are of Type 3. The second cluster type to be eliminated is the SS type, according to my proposal to fix the ranking of the constraint against SS clusters above the constraint against OO clusters. Type 2 languages are thus produced. Type 1 languages are generated when OO clusters are also ruled out, and Type 0 languages result when even the least marked cluster type, SO, is eliminated.

(30) Relational Alignment

*RISE ≫ *PLATEAU ≫ *FALL

↑ ↑ ↑ ↑

Type 4 Type 3 Type 1 Type 0

In (30), we see that Type 4 languages are again produced when FAITH outranks the markedness constraints, and that Type 3 languages are produced when OS clusters are eliminated. Relational alignment is incapable of producing Type 2 languages, because it bans both OO clusters and SS clusters in a single constraint, the constraint against sonority distance 0. Thus, if this constraint is ranked above faithfulness, neither type of sonority plateau is allowed; Type 1 languages, with only SO clusters, are produced. When even these clusters are eliminated by ranking *Distance -1 above Faith, Type 0 languages result.

Note that, although relational alignment cannot produce Type 2, relational alignment assumes harmonic alignment, and harmonic alignment can produce Type 2, as shown in 25a. Thus either approach can generate the full variety of language types.

8. Conclusions

This study allows us to draw several conclusions about syllable structure across languages. First, we have seen that the empirical data agrees with a view of the SSP as a collection of universal, violable constraints. This view renders appendices unnecessary to account for violations of the SSP. However, many researchers (see Vaux, 2004) have shown that appendices can explain other phonological phenomena. An important goal of future research will be to reconcile these findings.

I used relational alignment (Gouskova, 2004) of the sonority scale with the constraint hierarchies on the two positions of the Split Margin approach (Baertsch, 2002) to produce constraints that account for two of the three implicational relationships found in this study. The third implicational relationship, that between SS and OO clusters, can be explained through an additional fixed ranking between the constraint on the outer position in a coda cluster (M_1) and the constraint on the inner position (M_2). Future research may investigate the generality of the proposed ranking and the process from which this ranking may derive.

Based on the account given here, I predict that all languages will fall into one of Types 0 through 4. This includes situations in which loan words are adopted and situations in which constraints are reordered. Further cross-linguistic surveys which include loan words may show whether this prediction is borne out.

Appendix A: Languages Without Word-final Consonant Clusters: Type 0

1. Akha (Hansson, 2003)
2. Akuapem (Schachter, 1968)
3. Alabama (Lupardus, 1982)
4. Arapaho (Kroeber, 1916)
5. Asante (Schachter, 1968)
6. Aztec, Milpa Alta (Whorf, 1946)
7. Bai (Wiersma, 2003)
8. Belhare (Bickel, 2003)
9. Bengali (Dakshi, 2002)
10. Boko (Jones, 1998)
11. Bokobaru (Jones, 1998)
12. Boro (Basumatåaråi, 2005)
13. Burmese (Wheatley, 2003)
14. Busa (Jones, 1998)
15. Camling (Ebert, 2003)
16. Campa, Arawak (Dirks, 1953)
17. Cantonese (C. N. Li & Thompson, 1990)
18. Chama (Firestone, 1955)
19. Chinantec, Usila (Skinner, 1962)
20. Choctaw (Broadwell, 2006)
21. Ciyao (Ngunga, 2000)
22. Comanche (Riggs, 1949)
23. Cuicateco (Needham & Davis, 1946)
24. Cuitlateco (Hernández, 1962)
25. Dakota (Matthews, 1955)
26. Diyari (Austin, 1981)
27. Dulong (LaPolla, 2003)
28. Dyirbal (Dixon, 1972)
29. Fante (Schachter, 1968)
30. Fijian (Schèutz, 1985)
31. Finnish (Sulkala, 1992)
32. Fuuta Jaloo (Diallo, 2000)
33. Ganda (Cole, 1967)
34. Greenlandic, South (Swadesh, 1946b)
35. Hakha Lai (Peterson, 2003)
36. Hausa (Hodge, 1947; P. Newman, 1990)
37. Hayu (Michailovsky, 2003)
38. Huichol (McIntosh, 1945)
39. Ikalanga (Mathangwane, 1999)

40. Ioway-Oto (Whitman, 1947)

41. Ixcateco (de Miranda, 1959)

42. Izi (Meier, 1975)

43. Italian (Vincent, 1990)

44. Japanese (Shibatani, 1990)

45. Jinghpo (Qingxia & Diehl, 2003)

46. Kana (Ikoro, 1996)

47. Kayah Li, Eastern (Solnit, 2003)

48. Kham (Waters, 2003)

49. Khezha (Kapfo, 2005)

50. Khmer (Pinnow, 1978)

51. Kiowa (Watkins, 1984)

52. Korean (Martin, 1951)

53. Koromfe (Rennison, 1997)

54. Lahu (Matisoff, 1973)

55. Lepcha (Plaisier, 2007)

56. Lisu (Bradley, 2003)

57. Maidu, Northeastern (Shipley, 1956)

58. Malayalam (Asher, 1997)

59. Mantjiltjara (Marsh, 1969)

60. Maori (Bauer, 1993)

61. Mandarin (C. N. Li & Thompson, 1990)

62. Manipuri (Singh, 2000)

63. Marathi (Pandharipande, 1997)

64. Mazateco (K. L. Pike & E. V. Pike, 1947)

65. Meithei (Chelliah, 2003)

66. Mlabri (Rischel, 1995)

67. Ndyuka (Huttar, 1994)

68. Nenets (Salminen, 1998)

69. Newar, Kathmandu (Hargreaves, 2003)

70. Osage (Wolff, 1952)

71. Paiute, Southern (Sapir, 1992)

72. Palaung (Shorto, 1960)

73. Po-ai (F. K. Li, 1977)

74. Pwo Karen (Kato, 2003)

75. Quechua, Huallaga/Huanuco (Weber, 1989)

76. Rabha (Joseph, 2007)

77. Setswana (Lesedi, 2001)

78. Sinhalese (Coates & de Silva, 1960)

79. Shanghai (Zee, 2003)

80. Shona (Brauner, 1995)

81. Spanish (Saporta & Olson, 1958)

82. Spokane (Czaykowski-Higgins & Kinkade, 1997)
83. Swahili (Mohamed, 2001)
84. Tagalog (Schachter, 1990)
85. Tamang (Mazaudon, 2003)
86. Tangut (Hwang-Cherng , 2003)
87. Tani (Sun, 2003)
88. Tarao (Singh, 2002)
89. Terena (Harden, 1946)
90. Tibetan, Lhasa (DeLancey, 2003)
91. Thai (Hudak, 1990; F. K. Li, 1977)
92. Tshlangla (Andvik, 2003)
93. Tok Pisin (Verhaar, 1995)
94. Tuvaluan (Besnier, 2000)
95. Udihe (Nikolaeva & Tolskaya, 2001)
96. Vai (Welmers, 1976)
97. Vietnamese (Nguyen, 1997)
98. Wari (Everett, 1997)
99. Wikchamni (Gamble, 1978)
100. Wintu (Pitkin, 1984)
101. Wolof (Ngom, 2003)
102. Yaqui (Johnson, 1962)
103. Yidin (Dixon, 1977)
104. Yokuts, Yawelmani (S. S. Newman, 1946)
105. Yoruba (Bamgboòse, 1966; Pulleyblank, 1990)
106. Yuchi (Crawford, 1973)
107. Zapotec, Isthmus (Marlett & Pickett, 1987)

Appendix B: Typology of Languages with Biconsonantal Clusters

Language	SO	OO	SS	OS	References
Type 1					
Cornish	✓				(George, 2002)
Efate, South	✓				(Thieberger, 2004)
Pomo, Eastern	✓				(McLendon, 1975)
Saamic	✓				(Sammallahti, 1998)
Type 2					
Basque	✓	✓			(Hualde, 1991; Hualde & Ortiz de Urbina, 2003; Trask, 1997)
Cogtse Gyarong	✓	✓			(Nagano, 2003)
Hopi	✓	✓			(Whorf, 1956)
Komi	✓	✓			(Hausenberg, 1998)
Ladakh	✓	✓			(Sarmåa, 1998)
Lezgian	✓	✓			(Haspelmath, 1993)
Scottish Gaelic	✓	✓			(Gillies, 2002)
Takelma	✓	✓			(Sapir, 1990)
Totonaco	✓	✓			(Aschmann, 1946)
Turkish	✓	✓			(Kornfilt, 1997)
Yuma	✓	✓			(Halpern, 1946)
Type 3					
Albanian	✓	✓	✓		(Newmark, 1957)
Armenian	✓	✓	✓		(Vaux, 1998)
Berber, Shilha	✓	✓	✓		(Applegate, 1958)
Breton	✓	✓	✓		(Ternes, 1970)
Bulgarian	✓	✓	✓		(Sawicka, 1974)
Catalan	✓	✓	✓		(Wheeler, 1979)
Dutch	✓	✓	✓		(Booij, 1995; Schutter, 1994)
English	✓	✓	✓		(Hultzén, 1965)
Frisian	✓	✓	✓		(Cohen, 1971)
German	✓	✓	✓		(Kohler, 1995)
Irish	✓	✓	✓		(Carnie, 1994)
Macedonian	✓	✓	✓		(Sawicka, 1974)
Manx	✓	✓	✓		(Broderick, 2002)

Language	SO	OO	SS	OS	References
Nez Perce	✓	✓	✓		(Aoki, 1973)
Norwegian	✓	✓	✓		(Askedal, 1994)
Ossetic, Digoron	✓	✓	✓		(Henderson, 1949)
Serbo-Croatian	✓	✓	✓		(Sawicka, 1974)
Seri	✓	✓	✓		(Marlett, 1988)
Slovak	✓	✓	✓		(Sawicka, 1974)
Slovenian	✓	✓	✓		(Sawicka, 1974)
Sunwar	✓	✓	✓		(Borchers, 2008)
Swedish	✓	✓	✓		(Bannert & Czigler, 1999)
Welsh, Southern	✓	✓	✓		(Ball & Jones, 1984)
Type 4					
Aguacatec	✓	✓	✓	✓	(H. McArthur & L. McArthur, 1956)
Belarusian	✓	✓	✓	✓	(Sawicka, 1974)
Czech	✓	✓	✓	✓	(Sawicka, 1974)
Danish	✓	✓	✓	✓	(Martinet, 1937)
Dogri	✓	✓	✓	✓	(Bhari, 2001)
Georgian	✓	✓	✓	✓	(Vogt, 1958)
Hungarian	✓	✓	✓	✓	(Hall, 1944; Kenesei, 1998; Siptár, 2000)
Icelandic	✓	✓	✓	✓	(Haugen, 1958)
Otomi, Pame	✓	✓	✓	✓	(Gibson, 1956)
Persian	✓	✓	✓	✓	(Mahootian, 1997; Samei, H., p.c., September 6, 2008)
Polish	✓	✓	✓	✓	(Bethin, 1992; Gussmann, 2007)
Punjabi	✓	✓	✓	✓	(Bhatia, 1993)
Romani, Finnish	✓	✓	✓	✓	(Granqvist, 1999)
Sorbian, Lower	✓	✓	✓	✓	(Sawicka, 1974)
Sorbian, Upper	✓	✓	✓	✓	(Sawicka, 1974)
Ukrainian	✓	✓	✓	✓	(Sawicka, 1974)
Urdu	✓	✓	✓	✓	(Khan, 2000)
Welsh, Northern	✓	✓	✓	✓	(Ball & Jones, 1984)
Zapotec, Mitla	✓	✓	✓	✓	(Briggs, 1961)

Appendix C: Types of Non-Transparent Sequences

Language	Transparent Cluster Types	Non-Transparent Sequence Types
Amuesha, Arawak (Fast, 1953)	OO	nasal + hom. O (SO)
Chitimacha (Swadesh, 1946a)	SO	laryngeal + S (OS) glide + S (SS)
Chontal (Waterhouse & Morrison, 1950)	none	nasal + hom. O (SO) S + laryngeal (SO)
Delaware (Voegelin, 1946)	OO	nasal + hom. O (SO)
Huambisa (Beasley & Pike, 1957)	none	nasal + hom. O (SO)
Kashmiri (Koul, 2005)	OO	nasal + hom. O (SO)
Keresan (Spencer, 1946)	OO	S + laryngeal (SO) laryngeal + S (OS)
Klamath (Barker, 1964)	SO, OO	glide + S (SS)
Kutenai (Garvin, 1948)	SO, OO	laryngeal + S (OS)
Sre (Manley, 1972)	none	glide + laryngeal (SO)
Tonkawa (Hoijer, 1946)	none	S + laryngeal (SO) O + laryngeal (OO) laryngeal + O (OO)
Totonac, Misantla (MacKay, 1994)	OO	nasal + hom. O (SO)
Tunica (Haas, 1946)	none	laryngeal + O (OO)
Zoque (Wonderly, 1951)	OO	glide + laryngeal (SO) laryngeal + S (OS)

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