From Simplest to Simple:
A Formal Look at Rimes and Contacts

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0. Introduction

While it has often been claimed that there exist "better" and "worse" syllables (___), few attempts have been made to theoretically motivate these preferences by positing a universal hierarchy of syllable structure complexity. For example, while a CV syllable is "preferred" over, say, a CCCVVCCC syllable, or a branching coda with homorganic segments is "preferred" to one with hetero-organic segments, there has been little attempt to systematically account for these preferences. Additionally, it is sometimes case that languages which allow coda consonants possess co-occurrence restrictions between these elements and following onsets. Thus there exist constraints both within the domain of the rime, and across the coda-onset barrier (I will refer to this second domain as the "contact" domain):

```
(1)            rime domain
                |__
                NCO          (where N=nucleus, C=coda, O=first
                 |            onset consonant)
               contact domain
```

In this paper I will attempt to preliminarily characterize consonant cluster complexity allowances in a formal manner by positing complexity hierarchies within both the rime domain, and the contact domain. I will consider languages that differ in the degree of cluster complexity they allow, formally characterizing them by assigning them to a particular branch in the follwoing posited complexity trees.

(2) The Rime/Contact Complexity Trees

```
---------------------------------------------------------------
     1. non-branching rime         branching rime
                                 /             \
               non-branching nucleus     branching nucleus
                                        /         \
R                                  2. no coda   coda
             /            \                   /      \
I    3. non-branching   branching  4. non-branching   branching
        coda            coda          coda            coda
M                      /        \                   /     \
                 5. single    multiple    6. single   multiple
E                   aperture  aperture       aperture aperture
                    position  positions      position positions
                             /       \              /       \
                   7. single  8. multiple 9. single  10.multiple
                       place      place        place      place
                      node      nodes        node      nodes
---------------------------------------------------------------
```

```
C    A. single aperture position    multiple aperture positions
O                                  /                     \
N                             B. single             C. multiple
T                                place                 place
A                                node                  nodes
C
T
```

```
     Constraints may apply:   -    in the lexical phonology
                                   -    in the post-lexical
                                   phonology
```

Any given language may allow or disallow branching rimes. One type of language which disallows branching rimes is the so-called CV variety, allowing solely non-branching onsets and light rimes. Languages allowing branching rimes differ in complex ways. Some will allow branching nuclei, while others will not. Some will allow codas, while others will not. Those which allow codas may permit either branching codas ((C)VCC or (CV)VCC) or non-branching codas ((C)VC or (CV)VC). Furthermore, particular constraints may hold on both the number (and type) of aperture positions (Steriade 1991), as well on the number of place nodes maximally allowable in the rime structure of a given language.

Further constraints may hold in the contact domain. Like codas, contacts may allow single or multiple aperture positions, as well as single or multiple place nodes. (Herein, unless specifically addressed, I will not be considering onset clusters, which appear to be constrained by different (though related) principles (Steriade 1991)).

Finally, a given language may be constrained in a particular fashion at a given stage in a derivation, while being constrained differently at another stage in a derivation. For example, certain constraints may hold within the lexical phonology, others holding at the post-lexical level.

The organization of this paper is quite straightforward, beginning with the simplest possible syllable structure (where "simplest" = "most constrained") , languages allowing increasingly complex consonant clusters will be presented in turn.

1. The Simplest Syllable: Fasu

Fasu allows syllables excusively of the form CV (Ian Maddieson, p.c.). Were the language to allow long vowels and/or geminate consonants, we could confine our syllable structure constraints solely to the aperture level: every non-A_v position must be followed by a vocalic element. However, as Fasu disallows long vowels or geminates, a stricter constraint must hold in the language: every rime position must be followed by a non-rime position. Thus the Fasu string template takes the following form:

```
(2)  skeletal tier  :    XXXXXXXX
                          | | | |
     rime tier :          r r r r
```

Fasu is thus a Class 1 language, falling at (#1) in the syllable complexity tree. As the language disallows branching rimes, all subsequent constraints hold redundantly. This is, of course, assuming that different principles are required which govern onset formation. So a language may possess maximally unipositional rimes, while simultaneously allowing onset clusters.

```
(3)  melody tier    :    CVCCV
                         |||||
     skeletal tier  :    XXXXX
                          |  |
                          n  n
                          |  |
                         or or
                          |  |
                          s  s
```

As Fasu does not permit such structures, it possesses the maximally constrained syllable type.

2. Tahitian: Branching Nuclei

Tahitian syllable structure minimally contrasts with that of Fasu in the following way: Tahitian, unlike Fasu, allows long vowels. As the maximally simple syllable structure is the maximally constrained syllable structure, we may conclude that the Tahitian syllable, allowing a minimal amount of variation not permitted in Fasu, conforms to slightly less stringent constraints. I propose the following template for Tahitian, maximally specified (where "maximally specified" means the greatest degree of articulation *allowable* in the language, though not necessarily realized in any given instance):

```
(4)  skeletal tier  :    XXXXXXXXX
                          \/ \/ \/
     nuclear tier   :     n  n  n
```

In words, every consonantal element must be followed by a nuclear element. In Tahitian, nuclei may branch, but codas are not permissable. The string template, allowing solely a single non-nuclear position inter-nuclearly, even when maximally specified, disallows codas as a natural consequence: universal principles of syllabification will assign the inter-nuclear element to onset position (Ito 1986). Tahitian may consequently be classified as possessing a Class 2 rime structure, as shown in the complexity tree in (2). As the language disallows codas, no contact classification is required, as all constraints hold redundantly.

3. Japanese: Aperture Tier Constraints

We will next consider languages whose syllable structure indicates that they fall somewhat deeper in the complexity hierarchy shown in (2).

Japanese allows coda consonants, but only of the following forms: CVC_1C_1, CVNC. Following Steriade, I assume that nasal-

```
                 CVNC
                   \/
                   An
```

fricative sequences are simply geminate affricates, and thus their A_0 position is associated with two skeletal slots:

```
(5)      [nasal][place]
               \/\
               AoAf
                |\|
                X.X
```

We may thus classify Japanese as a Class 4A language, allowing branching rimes, non-branching codas, and a single aperture position in the contact domain.

4. Diola Fogny: Constraints on Coda [place]

Diola Fogny has the following constraint on syllable structure: non-branching codas, while allowable, must be a sonorant, and must be homorganic to the following segment. Some examples follow.

(6)	a.	salte	@rti
	b.	najun-to	takumbi
	c.	nammimin	ninennen
	d.	k@kump	panjimanj

In (a) we see homorganic liquid-consonant clusters. In (b) are examples of homorganic nasal-consonant clusters. In (c) geminate sonorants are exemplified. Finally, in (d), word-final homorganic clusters are shown, indicating that word-final codas are extrametrical.

The generalization to be made regarding the Diola Fogny data is that every consonantal place node must be followed by a vocalic element. That is to say, at the level of place-of-articulation, Diola Fogny behaves just like Fasu. The only further constraint required to characterize syllable structure constraints in this language is that codas are limited to sonorants. Alternatively, we may state that (sonorant) codas are allowable, provided they do not possess place nodes. We therefore may assume the following maximally specified string template:

```
(7)  place     :  [pl][pl] [pl][pl] [pl][pl] [pl]
                    |  |      |  |      |  |     |
     melody    :    C  V  S  C  V  S  C  V  S  C
                    |  |  |  |  |  |  |  |  |  |
     skeleton  :    X  X  X  X  X  X  X  X  X  X
```

Diola Fogny allows branching rimes of the form VS. However, rime Ss must share place features with the following segment, although there are no constraints on aperture positions. Therefore, each place node must alternate with a vocalic gesture, as the maximally specified template in (7) shows. Diola Fogny may therefore be characterized as a Class 4B language.

5. Italian: Marginal Acceptability of Coda Aperture Positions

Italian allows the following medial clusters (not including onset satellite features, which, as stated in the introduction, appear to be governed by independent principles),

(8)	liquid + C	:	altro, sorprendere
	nasal + C	:	emblema, cancro
	s + plosive	:	aspro, lastra
	$C_1 + C_1$	:	labbro, pubblico

I propose a constraint on Italian rimes of the following form: codas are maximally unipositional. Only liquids may fill the coda position. Other consonants are also acceptable, but only if no aperture positions are added to the representation. This will limit non-liquid clusters to homorganic nasals, geminated onsets, as well as s, which I presume does not project an independent aperture position in coda position, since it surfaces only when preceding a plosive. As plosives possess an optional "approach" feature, I assume that s attaches directly to the A_0 projected by the following segment.

Therefore, the maximally specified segmental string (again, not including onset satellite features) takes the following form:

```
(9)  aperture tier  :    A  A  A    A  A  A    A  A  A
                         |  |  |    |  |  |    |  |  |
     melody tier    :    C  V  L/X  C  V  L/X  C  V  C
                         |  |   |   |  |   |   |  |  |
     skeletal tier  :    X  X   X   X  X   X   X  X  X
```

(9) shows that only liquids may project aperture positions in coda position. Other coda consonants are limited to those segments which will not add aperture positions to the representation.

Italian may be maximally classified as a Class 4C language, however, this level of complexity is allowed only under very particular circumstances. Excluding the acceptability of liquid-projected aperture positions pre-consonantally, Italian patterns as a Class 4A language, as codas normally do not project aperture positions. The fact that a given language relaxes its constraints for its more sonorous segments would seem a natural tendency, and thus the exceptional behavior of Italian liquids should not be unexpected.

6. Finnish: The Co-Occurrence of Projecting and Non-Projecting Coda Elements

As Finnish allows for a more complex syllable structure than any of the languages considered up to now, it may be characterized as possessing fewer constraints on its maximally specified segmental string. The consonant inventory is shown in (10), and crucial segmental strings are exemplified in (11) (from Ito 1986).

(10) Finnish consonant inventory

```
     p b  t d  k g
     f v  s        h
     m    n
          r l
             y
```

(11) consonant cluster exemplification

```
     a.   lap.si    b.   hat.tu    c.   pyrs.to   d.   help.po
           uk.si         pap.pi         kons.ti        polt.ta
          lat.va         myk.ka         sals.kea       kynt.tila
          jat.ka

     e.   *pyrk.so
```

*tolp.ko
*kont.po

(11a) shows that Finnish allows consonant-consonant clusters (specific disallowed sequences will be discussed below). In (11b) are examples of heterosyllabic geminates. In (11c), the most complex allowable segmental string is shown: a sonorant may be followed by a tautosyllabic s, which in turn is followed by a plosive. In (11d) we see sonorants followed by heterosyllabic geminate plosives. Finally, in (11e), are examples of some disallowed sequences.

The following are the crucial generalizations about Finnish syllable structure

- onsets are maximally non-branching
- codas maximally branch once (11c,d)
- branching codas must be of the form SC (cf. Diola Fogny, where this constraint holds intervocalically)
- The maximal syllable is CVSO, where O = P or s, and if O = P, then geminate P: CVSP.P

(where O = obstruent, P = plosive)

How can these generalizations be accounted for within a theory of segmental string complexity? Prince (1984) assumes that Finnish possesses a filter on clusters of the following form:

(12) *[-cons][-cont][+cons]

Prince notes that this filter makes reference only to melodic elements, not skeletal elements (which he refers to as "syllabic terminals"). Therefore, geminates, and sonorant-geminate sequences are still allowed, as such sequences possess only two elements at the melodic level.

However, it is still not clear how this filter disallows certain unattested sequences in Finnish. For example, only s is allowed inter-consonantally, yet the filter would allow for f and v as well (assuming a separate constraint disallows sonorants in this position). Further, only plosives are allowed as the third element in a consonantal string, whereas the filter in (12) would seemingly allow any consonantal element (assuming a violation arises elsewhere in the string). Also, as the filter makes reference to three distinct elements, it is unclear exactly what type of structure is disallowed, and for exactly what reason. In other words, the filter is merely a descriptive and stipulative (and not entirely correct) characterization of the facts, without an anchor in a principled theory of segmental string complexity.

Ito (1986) criticizes Prince's filter in its violation of locality (i.e. as the filter possesses three elements, the first and third being non-adjacent, strict adjacency is violated. Ito offers an alternative filter for Finnish, invoking the Linking Constraint (Hayes 1986) to account for the acceptability of multiply-linked syllable-final elements:

```
(13)      * C C]σ
              |
           [-cont]
```

Ito claims that as the filter includes only a single association line, multiply-linked syllable-final stops are acceptable (cf. (11b,d)). Furthermore, as Ito's filter makes reference only to syllable-internal structure, she claims that no locality violations arise.

However, Steriade (1991) argues convincingly that, while the Linking Constraint may indeed be exploited to account for rule application/non-application within a given structural description, it cross-linguistically fails to act as a filter on representations. Therefore, Steriade concludes that no filter in any language may crucially invoke Hayes' Linking Constraint (I refer the reader to Steriade for discussion).

Note additionally that Ito's filter, as Prince's, will allow for certain unattested sequences (for example, interconsonantal f,v, as well as any following consonant). It is thus apparent that constraints hold both within a syllable, and, contrary to Ito's assumptions, across a syllable boundary.

Finally, note that Ito's filter, as Prince's, is ultimately descriptive, as it fails to be anchored in a hierarchically structured theory of cluster complexity.

I will now offer an alternative account of the Finnish data, which will be motivated by the theory of syllable structure complexity as outlined herein. As the present theory argues for the phonological relevance of both the rime domain and the contact domain, the more complicated facts form Finnish may be accounted for without violating locality.

First, note the following observation, which will be shown to play an important role in the subsequent analysis: allowable word-final codas in Finnish are t,s,n,r,l. In other words, all and only coronal consonants are allowed word-finally. We may conclude that coronal is the default place in Finnish, as it is the only place of articulation allowed form-finally.

With this observation in mind, I propose the following aperture level constraints in Finnish syllable structure:

```
(14) onsets    :    1 aperture position
     codas     :    1 aperture position, with an extra timing
               slot allowable
```

And I thus assume the following template for Finnish, maximally specified:

```
(15) aperture tier  :    AAA AAA AA
                         ||| ||| ||
     melody tier    :    CVS PVS PV
                         ||| ||| ||
     skeletal tier  :    XXXXXXXXXXX
```

Note that these constraints hold throughout the syllabification process of a string of segments. Therefore, the extra timing slot, while theoretically fillable by any melodic element, is limited to s or geminate P by the constraint which disallows the addition of any aperture positions to the representation. First, I assume that no place features be allowed added, which follows redundantly from a constraint prohibiting the addition of aperture positions. Therefore, only coronals, which lack place features, or geminates (of the following plosive) may fill the extra timing slot. This limits the potential segments to t,s,n,r,l, or geminate P. Additionally, t,n,l,r, if they were to be acceptable inter-consonantal segments, would require the projection of distinct aperture positions in order to be realized (A_0 for t,n, A_{max} for l,r). s, on the other hand, despite being an A_f, may under particular circumstances attach directly to a pre-projected A_0 position, acting as an "approach" feature to this position. I assume s behaves in this fashion in Finnish, which explains why only A_0s are allowed as the third element of a consonant cluster, and not, for example, an A_f or an A_{max}, which disallow approach features (recall that an identical constraint holds in Italian).

We may now formally characterize Finnish syllable structure in the following way: Finnish allows branching rimes, including branching nuclei, and (conditionally) allows branching codas, but only a single coda aperture position. It allows up to two aperture positions intervocalically, as well as multiple place nodes. It may therefore be classified as a Class 6C language in the complexity tree in (2).

There are certain co-occurrence restrictions on bipositional contacts in Finnish:

(16) some cluster restrictions:

	p	t	s	k
p	pp	*pt	ps	*pk
t	*tp	tt	ts	tk
s	sp	st	ss	sk
k	*kp	*kt	ks	kk

p may only occur in geminate structures, or with s. Furthermore, the sequence kt is disallowed, while tk is allowed. I have no compelling account for these facts, although it is interesting that s, the only segment with which p may co-occur, has the freest distribution of any consonant, as it is the only consonantal element allowed interconsonantally.

7. English: Lexical/Post-lexical Constraint Dichotomies

Borowsky (1989) observes the following about English syllables: medial syllables of more than two rime positions (VVC, VCC) are rare in underived and Level One forms (for example, in.ter.nal, vo.wel, an.swer, pre.scrip.tion, me.di.al). She claims that in the lexical phonology, prosody is constrained by Structure Preservation (Kiparsky, 1985) in that rimes of more than two positions are disallowed throughout Level One. Borowsky provides evidence for Structure Preservation from the rule of Long Vowel Shortening. In underived domains, and in Level One morpho-phonology, rimes are limited to two positions, crucially allowing an extra-prosodic position form-finally. Therefore, in a form like *kept* (from *keep*), the Level One morphology triggers vowel shortening, so that the p may be syllabically incorporated into the maximally bipositional rime, leaving the inflectional morpheme extraprosodic as Level Two is reached. In the Level Two morpho-phonology, Structure Preservation is turned off, and all segments may be incorporated into syllables:

```
(17)      Level One:
                         kE  p                    kEp t
                         |/\ |                    ||| |
                         XXX(X)                   XXX(X)
                          |/                       |/
                          r                        r
                          |                        |
                          σ                        σ

          Level Two:
                         kE p                     kEpt
```

```
                         |/\|                      ||||
                         XXXX                      XXXX
                          |//                       |//
                          r                         r
                          |                         |
                          s                         s
```

Compare a form containing a Level One affix with one containing a Level Two affix (mean/meanly):

```
(18)     Level One:               Level Two:
                         mi  n                     mi nli
                         |/\ |                     |/\|||
                         XXX(X)                    XXXXXX
                          |/                        |// |
                          r                         r   r
                          |                         |   |
                          σ                         σ   σ
```

A Level Two affix attaches after Structure Preservation has been turned off, and thus fails to trigger long vowel shortening.

In general, rimes larger than VX are found only at (a) word edges, (b) inside compounds, and (c) preceeding Level Two affixes:

(19) a. severe, traipse
b. worldwide, bandsman
c. childhood, apartment

All of these tripositional rimes are predicted if the bipositional rime constraint holds only at Level One, and if word-final consonants are syllabified late (i.e. post-lexically).

Borowsky then considers apparent exceptions to the Level One bipositional rime constraint, some of which appear in (20).

(20) (a) angel, dainty, laundry, chamber
(b) shoulder, poultry, moisture, doldrums
(c) empty, plankton, scrumptious

In (a), tripositional rimes of the form VVN appear in underived forms. In (b), Level One rimes of the form VVC appear, and in (c), Level One VCC rimes are observed. Borowsky makes the following crucial observation about these apparent exceptions to the constraint: all tripositional rimes contain initial consonants which share their place of articulation with the following consonant. In other words, rimes may be tripositional just in case they contain only a single consonantal place node. The two observed paradigms are schematically represented in (21).

```
(21)          [place]                [place]
                /\                     /\
              V CC                    VCCC
              |\||                    ||||
              XXXX                    XXXX
              |//|                    |//|
              r  |                    r  |
                 s                       s
```

Borowsky accounts for these exceptional forms by positing the following filter which holds through Level One:

(22) English coda condition (Level One)

```
              * XX]σ
                 |
              [+cons]
```

In words, this filter employs the Linking Constraint so that superheavy rimes (i.e. branching codas) disallow their final element to be singly linked for place. Doubly-linked codas, of course, pass the filter unaffected.

In addition to the problems involved in invoking the Linking Constraint in the formulation of a filter, Borowsky's analysis possesses the problem of considering the second part of a long vowel as associated with the coda (this is her only way of accounting for the acceptability of V<u>VC.C</u> structures). She offers no evidence in support of this hypothesis, thus rendering her filter particularly suspect.

I now offer an alternative analysis of the English data, suggesting that within the English lexical phonology, the language patterns much as Finnish does. In the post-lexical phonology however, Structure Preservation is turned off, and more complex structures may result.

(23) English rime constraint (Level One):

rimes are maximally bipositional, with an extra timing slot conditionally available

As in Finnish, this extra timing slot is limited to segments which do not disrupt particular constraints holding on segmental strings. But where Finnish prohibits aperture positions from being added to the representation, English prohibits the addition of place nodes. Further, where Finnish allows solely gemination and default fill-in, English allows any segment to fill the extra position, provided no place nodes are added to the representation:

(24) The English segmental string -- Level One (maximally specified):

```
place tier     :    p p p  p   p  p p  p   p  p p  p
                    | | | / \ / \ | | / \ / \ | | / \
melodic tier   :    C V V/C C/C C/V V/C C/C C/C V/C C
                    | |  |   |   |   |   |   |   |  |
skeletal tier  :    X X  X   X   X   X   X   X   X  X
```

English may now take its place in the syllable structure complexity hierarchy along with the other languages investigated herein. English allows branching rimes, branching nuclei, and branching codas. However, a given rime may not possess both a branching nucleus and a branching coda; either one or the other, but not both, is allowable. Furthermore, codas may possess multiple aperture positions, but only a single place node. Intervocalic clusters may possess multiple aperture positions, as well as multiple place nodes. English may therefore be maximally classified as a Class 9C language. However, this classification holds only through Level One. At Level Two, more complexity is allowed.

8. Conclusion

We have now preliminarily formally accounted for rime and contact complexity in the simplest possible system (Fasu), a relatively simple system (English), and several languages falling somewhere in-between.

The complexity trees in (2) account for differing complexity allowances across languages by permitting binary variation along several hierarchically organized parameters. Looked at in this fashion, potentially all cross-linguistic variation in syllable structure complexity may theoretically be accounted for by isolating exactly which parameters exist, and over which domain they hold (e.g. rime, coda, contact, onset, syllable, etc.). Thus within any given parameter, any two languages should bear a more-or-less subset/superset relationship to one another.

Furthermore, our investigation has supported the notion that codas and contacts are phonologically real domains, and that aperture positions are phonologically real entities: languages can and do constrain their cluster complexity allowances by making crucial reference both to degree of complexity allowable within the coda, and degree of complexity allowable within the contact. Furthermore, certain constraints have been shown to target aperture positions, providing support for their phonological reality.

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