A featural analysis of some onset-vowel interactions

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0. Introduction

In this paper I propose a formal analysis of some well known cases of consonant-vowel interactions that are commonly found in Asian languages. In particular, I discuss four effects of onset voicing on the vowel, namely, register genesis, vowel-height split, tonogenesis, and tone split. The theoretical framework I assume includes, first, feature geometry, which holds that distinctive features form a geometrical structure, second, the theory of 'enhancement' (Stevens et al 1986, Stevens & Keyser 1989, cf. also the 'Grounding Condition' of Archangeli & Pulleyblank in preparation), which holds that features that phonetically enhance each other tend to cooccur, and third, the theory of underspecification, which holds that predictable features may be left unspecified in the underlying representation. I will further assume that both onset voicing and vowel register relate to the same feature [±st] ([±stiff vocal cords], following Halle & Stevens 1971, but with modifications to be explained below). Under these assumptions, register genesis is viewed as the spreading of [+st] or [-st] from the onset to the vowel. After register genesis, [+st] or [-st] on the vowel may further triggers the feature [-ATR] ([-advanced tongue root]) or [+ATR] via 'enhancement', giving vowel height split. Alternatively, [+st] and [-st] may trigger the Pitch features ([H] or [L]) via enhancement, giving tonogenesis.

This paper is organized as follows. First, I review register genesis, vowel-height split, tonogenesis, and tone split in section 1. Then I discuss relevant theoretical background in section 2. In section 3, I give the formal derivations of register genesis, vowel-height split, tonogenesis, and tone split. Finally, summary and implications are given in section 4.

1. The problems

Consonant-vowel interactions have been extensively documented in Asian languages. For example, it is generally accepted that tones in Lhasa Tibetan and Vietnamese come from the breakdown of consonants surrounding the vowel (cf. among others, Haudricourt 1954; Matisoff 1970, 1973; Diffloth 1991 for Vietnamese, and Hu 1980; Zhang 1981; Qu 1981 for Tibetan). It is also generally accepted that historically Chinese had four syllable tones, which later underwent tone split conditioned by onset voicing to give up to eight or more syllable tones in some dialects today. Moreover, there is a possibility that the four historical syllable tones in Chinese were derived from the break-down of post-verbal consonants, similar to the case in Tibetan and Vietnamese, although evidence is scarce due to the antiquity of the events.

In this paper we focus on interactions between onset consonants and the vowel. We will not discuss the effects of post-vowel consonants. Specifically, we will look at four well documented effects of onset voicing on the vowel, namely, register genesis, vowel-height split, tonogenesis, and tone split. We review these cases in turn.

1.1. Register genesis In African phonology, the term 'register' is used rather loosely. It often refers to pitch levels, along with other things. In Asian phonology, however, the term 'register' (first introduced probably by Henderson 1952) specifically refers to voice quality in the vowel that is ultimately related to onset voicing (we come to Yip's 1980 uses of 'register' directly below). In this paper I will use 'register' in the Asian tradition. The term 'register genesis' (probably first introduced by Diffloth) refers to a process in which (the loss) of onset voicing leads to changes in the voice quality of the vowel. Such cases are found in Mon-Khmer languages, and are summarized below (cf. Jenner et al 1976):

(1) a. Voiceless onsets:
1st register (clear, head, tense, normal...)
b. Voiced onsets:
2nd register (deep, chest, lax, murmured...)

Typically, vowels with historically voiceless obstruent onsets have the 'first register', whose voice quality is described by such terms as 'clear', 'normal', 'tense', etc., and vowels with historically voiced obstruent onsets have the 'second register', whose voice quality is variously described as 'deep', 'lax', 'chest', 'murmured', etc. Vowels in the first register may also have a higher pitch, and those in the second register a lower pitch, but the pitch difference does not play the major distinctive role. After register genesis, the contrast in onset voicing may be neutralized, with voiced obstruent onsets becoming devoiced. The neutralization does not go the other way, however, that is, voiceless obstruent onsets do not become voiced.

1.2. Vowel-height split Once register genesis has taken place, vowels may further undergo a split in height. In particular, vowels in the first register may become lower, and vowels in the second register may become higher. Vowel-height split is again found in Mon-Khmer (cf. Jenner et al). A typical example is seen in Rengao (Gregerson 1976)

(2) Vowel-height Split in Rengao

a. Voiceless onsets:	^{e}i	E	a	O	^{o}u	(lower vowels)
b. Voiced onsets:	i	e	ə	o	u	(higher vowels)

Gregerson suggests that vowel-height split is due to the feature [advanced tongue root] ([ATR]); vowels in the second register have [+ATR], which gives higher vowels, and vowels in the first register have [-ATR], which gives lower vowels. I think that Gregerson's insight is fundamentally correct.

1.3. Tonogenesis After register genesis, instead of vowel-height split, the first register vowels may become high-toned, and the second register vowels become low-toned. This process is called 'tonogenesis', a term introduced by Matisoff (1970). Below are two examples in Lhasa Tibetan (Hu 1980)

(3)	Historical	Present		
a.	kho -->	khó	'he'	[´] = high tone
b.	go -->	khò	'hear'	[`] = low tone

After tonogenesis, voiced obstruent onsets often become voiceless. In addition, the register (i.e. voice quality) contrasts in the vowel may also become lost, leaving pitch the only distinctive feature.

1.4. Tone split If vowels originally have tones, not from onset voicing, obstruent onsets may still exert their influence on the vowel and split the existing tones into two sets, a higher set after voiceless obstruents, and a lower set after voiced obstruents. These two sets are respectively called 'Yin' and 'Yang' in traditional Chinese phonology, or [+upper] and [-upper] registers in Yip (1980). Most Chinese languages have undergone tone split in some way, and a good example is seen in Songjiang (Bao 1990, in Chao 1930 letters)

(4)	Ping	Shang	Qu	Ru
Voiceless obstruent onset: (Yin/[+upper])	53	44	35	5
Voiced obstruent onset: (Yang/[-upper])	31	22	13	3

Here the four historical tones, Ping, Shang, Qu, and Ru, have split to eight. It is important to note that, apart from their difference in pitch levels, [+upper] and [-upper] register vowels also differ in voice quality; [+upper] vowels are often described as 'clear', 'normal', etc., and [-upper] vowels are often described as 'muddy', 'murmured', 'breathy', etc. (cf. Sherard 1972 for Shanghai, Zheng-Zhang 1964:32 for Wenzhou). In addition, Duanmu (1990a) argues that, for register contrast, it is voice quality, not pitch, that is distinctive. We will therefore identify [+upper] and [-upper] registers in Chinese with the first and the second register in Mon-Khmer respectively. Like in the case of register genesis, after tone split, the contrast in onset voicing may remain, as in the Wu family of Chinese (e.g. Songjiang, Shanghai, and Wenzhou), or voiced obstruent onsets may become devoiced, as in other Chinese dialect families.

1.5. Summary We have reviewed four effects of onset voicing on the vowel, register genesis, vowel-height split, tonogenesis, and tone split. It is important to note that we have been talking about voicing in obstruent onsets. Although sonorants are also voiced, their effect on the vowel is either random, or depends on the obstruent preceding the sonorant. We will return to this point when we discuss underspecification, where we will suggest that sonorants are underlyingly unspecified for voicing.

2. Theoretical background

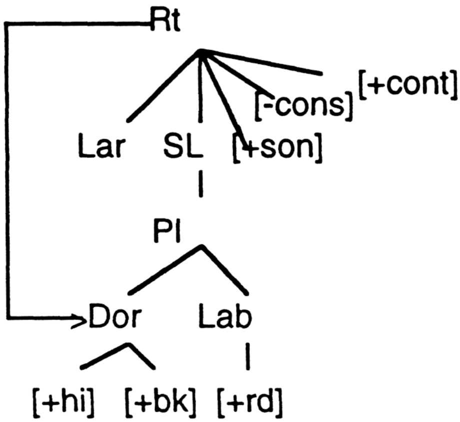
Before we offer a formal analysis of the problems in section 1, we will assume three recent phonological theories, feature geometry, underspecification, and enhancement.

2.1. Feature geometry In the distinctive feature theory of Chomsky & Halle (1968), a segment is represented by a set of unordered features; there is no structure among features. For example, [u] may be represented as follows[1]

$$\text{(5)} \quad [\text{u}] = \begin{bmatrix} \text{-cons} \\ \text{+lab} \\ \text{-cor} \\ \text{+rd} \\ \text{-ant} \\ \text{+bk} \\ \text{+son} \\ \text{-asp} \\ \ldots \end{bmatrix}$$

Clements (1985) proposes that distinctive features have internal structures. His major argument comes from assimilation and deletion processes, in which features appear and disappear in groups. For example, the features [lab] and [rd] often occur together under assimilation, and disappear together under deletion. Similarly, [cor] and [ant] often appear and disappear together. On the other hand, [asp] and [rd] never appear or disappear together, except when a whole segment is inserted or deleted. To reflect the internal grouping of features, Clements proposes a structure in which features are organized in a tree, now called 'feature geometry'. Specific details of feature geometry are still under active research, yet the idea that features have internal structures has already been widely accepted. Below we give an abbreviated feature geometry of [u], in the system of Sagey (1986)[2]

(6) Feature Geometry of [u]



Besides having a structure, (6) differs from (5) in several ways. First, there are two kinds of nodes in (6), nonterminal nodes, such as Labial and Place, and terminal nodes, such as [cont], [son], [rd] and [bk]. Only terminal nodes are considered features. Thus, [lab] is feature in (5), but not in (6). Instead, Lab in (6) is an 'articulator', which immediately dominates a terminal feature. Second, in (6), there are two kinds of features, those directly dominated by the Root node, and those not dominated by Root; the former (manner or stricture features) are not executed by any particular articulator, but the latter always are. Thus, for example, [bk] and [hi] are executed by Dorsal. Finally, if there are two or more articulators, one must be the 'major articulator', pointed to by an arrow from the Root, as Dor in (6).

Let us take a closer look at voicing and tonal features under Laryngeal, since this is going to be our concern. Following Halle & Stevens (1971), Sagey proposes the following laryngeal structure (omitting aspiration features)

(7)
```
Laryngeal
  / \                  [st] = [stiff vocal cords]
[st] [sl]              [sl] = [slack vocal cords]
```

(8)

	FEATURES	AS VOICING	AS TONE
a.	[-st, -sl]	sonorants	mid tone
b.	[-st, +sl]	voiced obstruents	low tone
c.	[+st, -sl]	voiceless obstruents	high tone
d.	*[+st, +sl]		

The same features [st] and [sl] are used for both voicing and tone, depending on whether they occur on a consonant or a vowel. Excluding (8d) as logically impossible, there are three possible combinations (8a-c). When (8a-c) occur on consonants, they respectively give sonorants, voiced obstruents, and voiceless obstruents. When (8a-c) occur on a vowel, they respectively give a mid tone, a low tone, and a high tone. Note that the stiffness of the vocal cords change the voicing in obstruents but not in vowels. The reason is, according to Halle & Stevens, that vowels have little supraglottal constriction, hence a greater transglottal pressure, which can set the vocal cords in motion whatever their stiffness. In contrast, obstruents have great supraglottal constriction, hence a small transglottal pressure, which can set the vocal cords in motion only if the vocal cords are slack. [+voice] is therefore not a primitive feature and should be replaced by [+st] and [+sl].

The laryngeal model of Halle & Stevens have a number of shortcomings (cf. Anderson 1978 for some criticisms). One is that it provides only three tonal levels, while several reported languages have five (e.g. Chang 1953, Shi et al 1987). The other is that voicing is not always tone. For example, unlike what Halle & Stevens predict, the loss of onset voicing does not create tones on the vowel in Mon-Khmer, but registers (changes in voice quality). In addition, if voicing and tone have the same features, how can there be the process of tone split, in which onset voicing splits existing tones into two sets? We will revise the laryngeal model (7) later in the paper.

2.2. Underspecification The basic idea of underspecification is that predictable features need not be stated in the underlying representation. This view is already expressed, partly, in Chomsky & Halle (1968:176), where the feature [voice] is used only for consonants, since all vowels are predictably [+voice]. Recent work on underspecification has shown that some predictable features MUST be underlyingly absent, and attentions have been focused on whether all predictable features are underlyingly absent (e.g. Archangeli & Pulleyblank 1989) or only some predictable features are, namely, those that are not contrastive (e.g. Steriade 1987, Mester & Ito 1989). The former view is called 'Radical Underspecification', and the latter 'Restricted

Underspecification'. Their difference is shown in the following English sounds

(9)		[n]	[t]	[d]
	a. Radical:			+voice
	b. Restricted:		-voice	+voice

Since voicing is not contrastive in sonorants, neither of (9a, b) specifies it for [n]. In obstruents, voicing is contrastive, so (9b) specifies it for both [t] and [d]. On the other hand, if we specify voicing for voiced obstruents, we can predict that unspecified obstruents are voiceless (or vice versa). Thus, (9a) specifies voicing only for [d] and not for [t] (or vice versa).

We will not determine which of (19a,b) is correct, nor whether voicing is 'privative' (cf. Mester & Ito). For exposition, we will often assume (19b).

2.3. Enhancement In the feature geometry of Sagey, cooccurrence relations among features are reflected by their articulatory closeness. For example, [back] and [high] often go together, because they are executed by the same articulator Dorsal. There are, however, many cooccurrence relations that are not reflected in Sagey's geometry. For example, back vowels are often rounded, but in Sagey's geometry, [back] and [round] are executed by different articulators. Similarly, although both aspiration and voicing features are dominated by Laryngeal, it is unexplained why [+s.g.] ([+spread glottis], or aspirated) tends to cooccur with [+st] ([+stiff vocal cords], or voiceless), rather than with [+sl] ([+slack vocal cords], or voiced).

Stevens & Keyser (1989) provide a solution in terms of 'enhancement', which says that features that phonetically enhance each other tend to cooccur (a similar idea is expressed by the 'Grounding Condition' of Archangeli & Pulleyblank in preparation). Below are some examples of cooccurring feature pairs, and what they phonetically enhance ([s.g.] = [spread glottis])

(10)	FEATURE PAIRS	ENHANCING
	a.[+bk], [+rd]	longer front cavity, lower F2
	b.[-bk], [-rd]	shorter front cavity, higher F2
	c.[+st], [+s.g.]	lack of voicing
	d.[+sl], [-s.g.]	voicing

Because of enhancement, the presence of one feature may trigger the presence of another. For example, if a vowel becomes [+bk], it tends to become [+rd] as well. In addition, enhancement is mutual. For example, while [+bk] may trigger [+rd], [+rd] may also trigger [+bk]. Finally, enhancement is not a necessity, but a tendency. For example, although, cross-linguistically, [+bk] and [+rd] tend to cooccur on the vowel, many languages nevertheless have unrounded back vowels, or rounded front vowels.

3. The analysis

We are now ready to address the problems in section 1. First, I will assume the following laryngeal model

```
(11)    Laryngeal
          /    \                 V/R = Voicing/Register
        V/R   Pitch              [st] = [stiff vocal-cords]
         |     / \
        [st]  [H] [L]
```

This model is based on the works of Halle & Stevens, Yip (1980), Meredith (1988), Bao (1990), and Duanmu (1990a). It follows Halle & Stevens in using [st], not [voice], for voicing. It also follows Halle & Stevens, in spirit, in identifying consonant voicing with some vowel feature; however, instead of identifying consonant voicing with tone, (11) identifies it with register (hence the V/R node). In addition, since the voicing of sonorants can be handled by underspecification, (11) has just one feature [st] under V/R, instead of two, [st] and [sl], as proposed by Halle & Stevens. Articulatorily, I suggest, V/R correlates with vocal cord tension, and Pitch correlates with vocal cord thickness, via cricothyroid movement.

In Yip (1980), 'tone' has two components; the first is given the feature [+upper], and the second the feature [+H]. Similar ideas are proposed in Bao (1990). (11) follows Yip and Bao in assuming two components of tone. The first component, which corresponds to 'Yin/Yang' in traditional Chinese phonology, is represented by V/R, and the second by Pitch. But unlike Yip and Bao, who give just one feature [+H] under Pitch, (11) gives two, [+H] and [+L], hence (11) allows three Pitch levels ([+H, -L], [-H, -L], [-H, +L], excluding [+H, +L] as impossible). Combined with [+st] under V/R, (11) permits a total of six contrasts in level tones. Moreover, while for Yip and Bao, both Register and Pitch phonetically correlate with F_0 (the fundamental frequency), for (11) the phonetic correlate of Register is not F_0, but voice quality (cf. Duanmu 1990a for arguments).

Below we give the feature geometry of English [n t d] in Restricted Underspecification (omitting details under SL)

```
(12) a. [n] = Root       b. [t] = Root     c.  [d] = Root
              /|\                 /|\                 /|\
        Lar SL [+son]      Lar SL [-son]     Lar SL [-son]
              |              |    |            |    |
             ...            V/R ...           V/R  ...
                             |                 |
                           [+st]             [-st]
```

In (12a), [n] is unspecified for voicing or aspiration, since English sonorants do not contrast in these features. In (12b), [t] is specified for [+st]. In (12c), [d] is specified for [-st]. There is no specification for aspiration in [t] and [d], since it is predictable from voicing. Finally, none of [n t d] bears tone in English, so none has the Pitch node. Thus, [n] has just a bare Lar node. It is arguable that even Lar is absent in [n], but for exposition, I will not pursue this possibility.

Let us now consider some vowel representations

```
(13)a. [a] = Root        b. [à] = Root   c. [á] = Root
              / \                 / \                / \
          Lar  SL             Lar  SL            Lar  SL
                |              |    |             |    |
               ...           Pitch ...          Pitch ...
                               |                  |
                             [+H]               [+L]
```

(13a) represents an English [a]. Since English vowels do not contrast in tone, voice quality, or aspiration, (13a) has a bear Lar. (13b) represents a high toned [a], and (13c) a low toned [a]. In (13b), there is no [-L], since it is predictable from [+H]. Similarly, there is no [-H] in (13c). Finally, assuming that (13b, c) do not contrast in register, neither has the V/R node.

In feature geometry, each node lies on a separate tier. Assimilation is viewed as the spreading of a node from one feature tree to another. However, spreading is possible only if there is no similar node in the way, otherwise spreading would be blocked. For example, consider a case of tone spreading, such as [tápa]-->[tápá], where the high tone of the first [a] spreads to the toneless second [a]. An abbreviated representation is given below

```
(14) [ t    á     p     a ] ---> [ t    á     p     á ]
     ...    |     |     |        ...    |     |     |
           Lar   Lar   Lar             Lar   Lar   Lar
            |     |                     |     |
          Pitch  V/R                  Pitch  V/R
            |     |                     |     |
          [+H]  [+st]                 [+H]  [+st]
```

The Pitch node of the first [a] is spread to the second (shown by a line). The spreading line can go through [p], which does not have Pitch; [p]'s V/R lies on a different tier and so is not in the way. However, we can not spread Lar from the first [a] to the second, since Lar in [p] will block it.

3.1. Register genesis Let us now look at register genesis. The process is analyzed as the spreading V/R from the onset to the vowel

```
(15) a.   [ p  a] --> [p   a1]      b.  [ b   a] --> [ b   a2]
            |  |        |   |             |   |        |   |
           Lar Lar     Lar Lar           Lar  Lar     Lar Lar
            |           |  /              |            |  /
           V/R         V/R               V/R          V/R
            |           |                 |            |
          [+st]       [+st]             [-st]        [-st]
```

[a1] = 1st register [a]
(tense, clear, normal, higher pitch,...)
[a2] = 2nd register [a]
(lax, muddy, murmured, lower pitch,...)

Although the precise acoustic correlates of each register remain to be determined, [+st] agrees with the traditional terms tense, clear, normal, higher pitch, etc., that are attributed to the first register, and [-st] agrees with the terms lax, muddy, lower pitch, murmured, etc., that are attributed to the second register. After register genesis, [b] may be devoiced by a separate step, which we will ignore. (In Radical Underspecification, voicing may be unspecified for voiceless obstruents, and so there is nothing to spread from the voiceless onset to the vowel. The first register will then be the 'normal' register. But then we have to account for sonorant onsets, which are also unspecified for voicing but which do not always give rise to the first (normal) register. I leave this alternative open.)   Let us now look at register genesis with sonorant onsets. Recall that sonorants have no V/R (cf. (12)). This predicts that sonorants either have no effect on register genesis, or have random effects. This prediction seems to be correct. In addition, if a sonorant is preceded by an obstruent, register genesis will depend on the voicing of the obstruent. For example, [pna] will give a first register, and [bna] will give a second register, as shown below

(16)

```
a. [p   n   a] --> [p   n   a1]  b. [b   n   a] --> [b   n   a2]
    |   |   |       |   |   |        |   |   |        |   |   |
   Lar Lar Lar     Lar Lar Lar      Lar Lar Lar      Lar Lar Lar
    |                \     /         |                 \     /
   V/R                 V/R          V/R                  V/R
    |                   |            |                    |
  [+st]               [+st]        [-st]                [-st]
```

The V/R of [p] and [b] can spread right across [n], because [n] has no V/R to block it. To my knowledge, this prediction is correct (cf. 'Purtle's Law', cited in Edmondson & Quan 1989).

3.2. Vowel-height split Let us now look at vowel-height split. We will assume that this process happens after register genesis. In addition, for exposition, we will assume that the second register raises the vowel, rather than the first register lowering the vowel (but cf. Jenner 1966, cited in Gregerson 1976: 335). Moreover, we will follow Gregerson (1976) and assume that vowel-height split is a split in the feature [ATR] ([advanced tongue root]); first register vowels have [-ATR], and second register vowels have [+ATR]. Now consider [E1]-->[e1]

```
(17)   [E1] -->  [e1]           [e] = [E] with [+ATR]
        |         / \
       Lar      Lar  TR
        |        |    |
       V/R      V/R
        |        |    |
       [-st]    [-st] [+ATR]
```

Once [E] gets [-st] after register genesis (from a voiceless onset), [-st] further triggers [+ATR] (the precise location of [+ATR] in feature geometry does not concern us), and [E] becomes [e]. But why does [-st] trigger [+ATR]? The answer, I suggest, is enhancement. Both [-st] and [+ATR] enhance voicing. [-st] laxes the vocal cords, so they are easier to be set in motion. [+ATR] expands the pharyngeal cavity and reduces the supraglottal impedance, which also makes vocal cord vibration easier. On the other hand, [+st] and [-ATR] both hinder vocal cord vibration, so they occur together on first register vowels.

If the second register lowers original vowels, and the first register keeps the original vowel heights, what happens to original high vowels? Why are there no high vowels in the first register?

Diffloth (p.c. 1991) points out that high vowels in the first register may change to the second register. In our analysis, this process may again be attributed to enhancement. We will assume that the process involve two steps. First, the high vowel acquires [+ATR], and then [+ATR] triggers [-st]. The derivation is given below (abbreviating feature geometry, [i] = [I] with [+ATR])

```
(18)
  [ I1 ]   ---->        [ i1 ]       ---->        [ i2 ]
   /  \               /   |   \                 /   |   \
[+st] [+hi]   [+st] [+ATR] [+hi]   [-st] [+ATR] [+hi]
```

We have already discussed the second step, namely, both [+ATR] and [-st] enhance vocal cord vibration, so they may trigger each other. The first step, [+hi] triggering [+ATR], is due to a process which may be called 'articulatory enhancement', or the 'Grounding Condition', proposed by Archangeli & Pulleyblank (in preparation), according to which [+hi] and [+ATR] tend to cooccur because both features move the tongue in the same direction.

3.3. Tonogenesis A feature may have more than one phonetic correlate, so it can be enhanced by different features. For example, while [-st] helps vocal cord vibration and is enhanced by [+ATR], it also gives, as a matter of physical law, a lower F_0, and so can be enhanced by [+L], which also gives a lower F_0. Similarly, [+st] can be enhanced by [+H], both giving a higher F_0. This, I suggest, is what happens in tonogenesis. Below is the derivation of two typical examples (´ = [+H], ` = [+L], 1 = first register, 2 = second register)

```
(19)  [k   o1] ---> [k   ó1]      [g   o2] ---> [g   ò2]
       |    |        |    |        |    |        |    |
      Lar Lar       Lar Lar       Lar Lar       Lar Lar
       |  /          |  / \        |  /          |  / \
      V/R           V/R Pitch     V/R           V/R Pitch
       |             |    |        |             |    |
      [+st]        [+st] [+H]     [-st]        [-st] [+L]
```

Here, tonogenesis is seen as a two-step process. The first step is register genesis, as we discussed before. After register genesis, instead of opting for vowel-height split, we may have tonogenesis. In other words, vowel-height split and tonogenesis are two optional steps after register genesis. A natural question is, is it possible that vowel-height split and tonogenesis take place together in the same language? In principle it should be possible in our analysis, although to my knowledge no such cases have been reported. It may simply be lack of data, or it may be that languages do not tend to develop redundant contrasts all at the same time, due to the Principle of Economy perhaps. Again [g] in (19) may devoice independently, which we will ignore.

3.4. Tone split Let us finally consider tone split. We mentioned in section 1.4 that although tones in what Yip calls the [+upper] register usually have higher F_0 than tones in the [-upper] register, the two registers also differ in voice quality. Specifically, the voice quality of [+upper] is like that of the Mon-Khmer first register, and the voice quality of [-upper] is like that of the Mon-Khmer second register. We will thus analyze tone split in the same way as we analyze register genesis, both being the spreading of V/R from the onset to the vowel. Below are the derivations of two examples

```
(20) a. [p    á] --> [p    á1]           b. [b    á] --> [b    á2]
          |     |        |     |                  |     |        |     |
         Lar   Lar      Lar   Lar                Lar   Lar      Lar   Lar
          |     |        |  /  |                  |     |        |  /  |
         V/R  Pitch    V/R  Pitch                V/R  Pitch    V/R  Pitch
          |     |        |     |                  |     |        |     |
       [+st] [+H]    [+st] [+H]              [-st] [+H]    [-st] [+H]
```

[á1] = Yin/[+upper]/first register [a] with H tone.
[á2] = Yang/[-upper]/second register [a] with lowered H.

Again, after tone split, voiced obstruent onsets may become devoiced by an independent step, which we will ignore.

4. Summary and implications

We have proposed a laryngeal model (11) and suggested that register genesis is the spreading of V/R from the onset to the toneless vowel. Tone-split is the spreading of V/R from the onset to the vowel that already has tone (the Pitch node). Vowel-height split is the insertion of [+ATR] or [-ATR], triggered respectively by [-st] or [+st] via 'enhancement'. Tonogenesis is the insertion of [H] or [L], respectively triggered by [+st] or [-st], again via enhancement.

Our discussion intends to shows that, with current phonological theories, it is now possible to give a unified analysis to a number of consonant-vowel interactions. Admittedly, there are loose ends. For example, we made important use of the enhancement theory and the Grounding Condition, but we did not discuss whether they are based on articulatory terms, or acoustic terms, or perceptual terms, or all the three. Part of the reason is that the theory is still developing. Pulleyblank (1991) suggests that the Grounding Condition may be based on all the three terms, while Stevens & Keyser (1989) seem to suggest acoustic enhancement alone. In addition, we did not choose between Radical and Restricted Underspecifications, even though their predictions may differ considerably. Clearly, further studies in Asian phonology have direct bearings on phonological theories.

If our analysis is basically correct, an important implication is that tone, or the Pitch node, is segmental, namely, it is part of the feature tree, just as [+nasal] and [+round] are segmental, as suggested by Clements (1985, 247). This agrees with the fact that, while Pitch may spread across an obstruent (which does not have Pitch), V/R cannot (since obstruents have V/R), unless the intervening obstruent changes its voicing accordingly. Thus, the popular practice of drawing tones on a different tier, separate from the segmental tier, can be no more than a convenient notation. A further implication is that, just as the bearer of [+nasal] and [+round] is the segment, the tone bearing unit must also be the segment, rather than the rime or the syllable.

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Notes

1 The features are customarily abbreviated as follows [cons] = [consonantal], [lab] = [labial], [cont] = [continuant], [cor] = [coronal], [rd] = [round], [ant] = [anterior], [bk] = [back], [son] = [sonorant], [asp] = [aspirated], [hi] = [high], etc.

2 The nodes are abbreviated as follows: Rt=Root, Lar=Laryngeal, SL=Supra-laryngeal, Pl=Place, Dor=Dorsal, and Lab=Labial.

References

Anderson, S.R. 1978. 'Tone features', in V. Fromkin, ed. Tone: A Linguistic Survey, N.Y., Academic Press.

Archangeli, D. & D. Pulleyblank. 1989. 'Yoruba vowel harmony', Linguistic Inquiry 20.2:173-217.

---. in preparation. Grounded Phonology, MIT Press.

Bao, Z.M. 1990a. On the Nature of Tone, Ph.D. dissertation, MIT.

Chang, K. 1953. 'On the tone system of the Miao-Yao languages', Language 29.3:374-378.

Chao, Y.R. 1930. 'A system of tone letters', Le Maitre Phonetique 45: 24-27.

Chomsky, N & M. Halle. 1968. The Sound Pattern of English, N.Y.: Harper & Row.

Clements, G.N. 1985. 'The geometry of phonological features', Phonology Yearbook 2:225-252.

---. 1989. 'The representation of vowel height', Conference on Features and Underspecification, MIT, October 7-9; ms., Cornell University.

---. 1991a. 'Vowel height assimilation in Bantu languages', Proceedings of BLS 17: Special Session on African Languages, 1991.

---. 1991b. 'Scalar rules in phonology', paper presented at FLSM 2, Ann Arbor, May 10.

Diffloth, G. 1991. 'Vietnamese as a Mon-Khmer language', paper presented at the First Annual Conference of Southeast Asian Linguistic Society, Detroit, May 9-11.

Duanmu, S. 1990a. 'Phonetic correlates of register in Shanghai', paper presented at the Second Northeast Conference on Chinese Linguistics, May 4-6, Philadelphia.

---. 1990b. A Formal Study of Syllable, Tone, Stress, and Domain Chinese Languages, Ph.D. dissertation, MIT.

Edmondson, J.A. & Y. Quan. 1989. 'Phonological geometry in Kam-Sui: contours, edges, and dimorphism', ms., University of Texas at Arlington and Central Institute of Nationalities, Beijing, China.

Gregerson, K.J. 1976. 'Tongue-root and register in Mon-Khmer', in P.N. Jenner et al, pp. 323-369.

Halle, M. & K. Stevens. 1971. 'A note on laryngeal features', RLE Quarterly Progress Report 101, pp. 198-213, MIT.

Haudricourt, A-G. 1954. 'De l'origine des tons en viètnamien', Journal Asiatique 242:68-82.

Henderson, E. 1952. 'The main features of Cambodian pronunciation', BSOAS 14.1: 149-174.

Hu, Tan 1980. 'A tonal study of Lhasa Tibetan', Minzu Yuwen 1: 22-36.

Jenner, P. 1966. Khmer Phonemes and Syllables, ms., University of Hawaii.

Jenner, P.N., L.C. Thompson & S. Starosta (eds.) 1976. Austroasiatic Studies Part I, University of Hawaii Press.

Matisoff, J.A. 1970. 'Glottal dissimilation and the Lahu high-rising tone: a tonogenetic case-study', Journal of the American Oriental Society 90.1: 13-44.

---. 1973. 'Tonogenesis in Southeast Asia', in L.M. Hyman, ed., Consonant Types and Tone, Southern California Occasional Papers in Linguistics 1.

Meredith, S. 1988. 'Distinctive features: diachronic, synchronic, and phonetic levels', ms., MIT.
---. 1990. Issues in the Phonology of Prominence, MIT Ph.D. dissertation.
Mester, R.A. & J. Ito. 1989. 'Feature predictability and underspecification: palatal prosody in Japanese mimetics', Language 65.2: 258-293.
Pulleyblank, D. 1991. 'Grounding the tongue root: the (non-)autonomy of phonology', talk given at MIT.
Qu, A.T. 1981. 'Zhangyu de shengdiao jiqi fazhan' (Tone and its development in Tibetan), Yuyan Yanjiu 1981.7:177-194. Originally presented at the 12th International Conference on Sino-Tibetan Linguistics.
Sagey, E.C. 1986. The Representation of Features and Relations in Nonlinear Phonology, Ph.D. dissertation, MIT, Cambridge, Massachusetts.
Sherard, M. 1972. Shanghai Phonology, Ph.D. dissertation, Cornell University.
Shi, F., L. Shi & R.R. Liao. 1987. 'An experimental analysis of the five level tones of the Gaoba Dong language', Journal of Chinese Linguistics 15.2: 335-361.
Steriade, D. 1987. 'Redundant values', in A. Bosch, B. Need & E. Schiller (eds.) Papers from the 23rd Annual Regional Meeting of the Chicago Linguistic Society, Part 2: Parasession on Autosegmental and Metrical Phonology.
Stevens, K. & S. J. Keyser. 1989. 'Primary features and their enhancement in consonants', Language 65.1:81-106.
Stevens, K., S. J. Keyser, & H. Kawasaki. 1986. 'Toward a phonetic and phonological theory of redundant features', in J. Perkell & D. Klatt (eds), Symposium on Invariance and Variability of Speech Processes, Hillsdale: Lawrence Erlbaum, 432-469.
Yip, M. 1980. Tonal Phonology of Chinese, Ph.D. dissertation, MIT.
Zhang, J.C. 1981. 'Zangyu Lhasa hua shengdiao fenhua de tiaojian' (Conditions on the tonogenesis in Lhasa Tibetan), Minzu Yuwen, 1981.3: 14-18.
Zheng-zhang, S.F. 1964. 'Wenzhou yinxi' (Wenzhou phonology), Zhongguo Yuwen 1964.1:28-60.