Contrastive hierarchies, privative features, and Portuguese vowels

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ABSTRACT. Dresher's (2009) Contrastive hierarchy theory (CHT) is intended to provide a unified account of both sides of phonological primes: contrastivity and behaviour. This article explores the point and the possibility of extending CHT, which is based on binary features, to a system of monovalent elements that is much indebted to Schane's (1984) Particle Phonology. It shows how several aspects of the phonology of European Portuguese nuclei that seem prima facie independent from one another – such as reduction patterns and the inventory of diphthongs and nasal vowels – are constrained by element hierarchy, and, thus, receive a unitary account.

KEY-WORDS. Phonological primitives, feature geometry, contrastive hierarchy, monovalent features, vowel systems, Portuguese phonology.

1- Introduction: bringing contrast and behaviour together

From Dependency Phonology (Anderson & Ewen 1987) to the so-called 'feature geometries' (Clements 1985; 1988; 2001; 2009; Sagey 1986; McCarthy 1988; Keyser & Stevens 1994; Clements & Hume 1995), several phonological frameworks share the assumption that there is an internal structure of segments, in which the elementary components are organized into hierarchies of 'gestures' or 'nodes'. However, the reasons adduced for this assumption remain unclear, and ambiguous as to one basic question: are such hierarchies substantively grounded? Do they directly follow from the structure of the human vocal apparatus? Or, rather, can they be assigned a formal basis? Is the internal structure of phonemes designed to capture generalizations on phonological constraints and processes? Actually, both reasons are simultaneously invoked, e. g. in Clements's (1985) pioneering article, and this raises another problem. If featural organisation is assumed to rest on both anatomical and linguistic grounds, then constraints and

processes are expected to have universal motivation; in other words, they should not point to different hierarchies from language to language. Is this the case? Can the internal structure of segments be shown to be, at least partially, language-specific?

In recent literature, Dresher's (2009) Contrastive Hierarchy Theory (henceforth CHT) gives an affirmative answer to this question. CHT aims to conciliate two often divergent principles which date back to structural phonology: (i) the distinctive features of a phoneme x are those that are necessary and sufficient to distinguish x from all other phonemes of a given system; (ii) only distinctive features are accessible to phonological constraints and rules. Thus, in languages having voice and nasal contrasts without voiceless nasals, both the feature [–nasal] of the voiceless consonant and the feature [+voice] of the nasal consonant should be left unspecified by virtue of principle (i), as shown in (1), and, therefore, should neither spread nor prevent feature propagation according to (ii).

(1)   t d n

       voice   – +

       nasal   – +

However, in such languages as Applecross Gaelic, Ijo, Urhobo, voiceless obstruents block nasal harmony (Piggott 1992), while Latin *ampulla, planta, mentiri, bancu, blancu* gave *embolla, planda, mendir, bango, blango* in Aragonese (Zamora Vicente 1967 : 234-240), with nasals triggering onset voicing. Thus, following the principle under (ii) above, Aragonese and Gaelic should have the systems in (2a,b) respectively, which violate the principle in (i).

(2)   a.   t d n   b.   t d n

       voice   – + +   voice   – +

       nasal   – +   nasal   – – +

According to CHT, the violation of (i) by both languages, as well as the difference between them, can be captured by assuming that contrasts are organized along hierarchical lines, and that the same contrasts are differently

ordered in Aragonese, which has the hierarchy in (3a), and in Gaelic, which has (3b); in both cases, the required features are necessarily specified.

(3) a.
```
        ╱‾‾╲
   −voice    +voice
     |      ╱      ╲
     |   −nasal   +nasal
     |     |        |
    /t/   /d/      /n/
```
b.
```
          ╱‾‾╲
     −nasal    +nasal
    ╱     ╲       |
 −voice  +voice   |
   |       |      |
  /t/     /d/    /n/
```
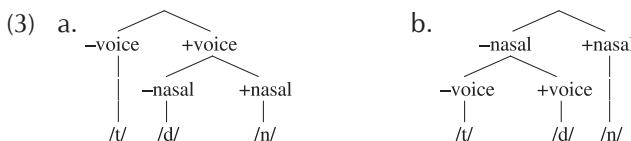
However, as can be seen from this example, such hierarchies suppose a system of binary features.[1] Hence, assuming that privative oppositions and monovalent features can be independently shown to be preferable to binary features – in that they more adequately capture markedness considerations, prevent rule overgeneration, etc. –, CHT runs the risk of being rejected as an artefact of binarism, together with its fundamental idea: infrasegmental structure, if any, reflects the way features combine and behave in a given language, that is both facets of phonological phenomena: representation and computation.

By analysing some aspects of European Portuguese (EP) vowels, I shall argue that the above idea is worth being considered, and that it can be implemented within a system of unary primes, provided that it is partially based on Schane's (1984) particle phonology.

2- Defining the 'vowels' of EP

The inventory of EP vowels in stressed syllable is shown in (4).[2]

(4) a. Monophhtongs: b. Diphthongs: c. Nasals:

a. Monophthongs		b. Diphthongs			c. Nasals		
i	u	[iʊ]	uɪ		ĩ	ũ ũĩ	
e	o	eɪ eʊ	oɪ		ẽ(ĩ)	õ [õĩ]	
(ɐ)		(ɐɪ)			ẽĩ ɐ̃ ɐ̃ʊ̃		
ɛ	ɔ	[ɛɪ] [ɪɪ]	[ɔɪ]				
a		aɪ ɑʊ					

Diphthongs between brackets stand for arguably underlying hiatus, being mostly attested at morpheme boundaries; they will not be discussed here for the sake of brevity.

Three types of syllable rhymes can be defined in EP according to the following criteria:[3]

(5)	V + /I U N l/	V + /r/	V (+ /s/)
a. Word-final stress	+	+	–
b. Integrity (no resyllabification /_#V)	+	–	–
c. Vowel reduction in pretonic syllable	–	+	+

As was fully discussed in Carvalho (1989), EP has the following stress placement rule by default: it falls on the penultimate syllable if the final syllable is either open or closed by /s/; otherwise, it falls on the final syllable. In most exceptions to this rule, which are often either semantically-marked nouns or morphologically complex verbs (Carvalho 2006), stress goes back up on the previous syllable *ceteris paribus*.[4] Hence, stress can be said to be weight-sensitive in EP, assuming that syllables containing the rhymes in (6a) are light (i.e. worth one 'mora'), and that syllables having those in (6b) are heavy (count for two 'moras').

(6)	Final rhyme	Unmarked stress pattern	Marked stress pattern
a.	V	*suplica* 'he begs'	*súplica(s)* 'plea(s)'
	V + /s/	*suplicas* 'you beg'	
b.	V + /I U/	*jamais* 'never', *calhau* 'stone'	*fáceis* 'easy' (pl.)
	V + /N/	*avelã* 'hazelnut', *sabão* 'soap'	*órfã* 'orphan' (fem.), *sótão* 'attic'
	V + /l/	*capital* 'capital', *anzol* 'fish hook'	*Setúbal* (topon.), *álcol* 'alcohol'
	V + /r/	*suplicar* 'to beg', *colar* 'collar'	*âmbar* 'amber', *açúcar* 'sugar'

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[3] On the phonological interpretation of Portuguese nasal vowels (which is a topic of discussion since the 1940's), see Carvalho (1988). The additional nucleic position arguably associated with nasality – represented by /N/ in (5) – surfaces sometimes as a consonant (homorganic to the following plosive), sometimes as a vocoid, in particular word-finally, where most nasal diphthongs occur, and where [ẽ(ĩ)] is always diphthongized.

[4] The marked character of these exceptions is also supported by several phonological processes through which such words acquire the unmarked stress pattern in many non-standard varieties of Portuguese: loss of the penultimate vowel of proparoxytones (*cântaro > cantro*), monophthongation (*fáceis > faces*), denasalization (*sótão > soto*), *r*-metathesis (*cadáver > cadavre*), etc.

Why, then, does V+/r/ diverge from all other heavy rhymes with respect to its behaviour before word-initial vowels? Indeed, as exemplified in (7), both /-r#/ and /-s#/ are syllabified with the following vowel, if any, whereas diphthongs, nasals and /-l/ resist *liaison*-like phenomena.

(7) a. Resyllabification:

['faʃ] *faz* 'does, ago'   →   [fa.'zɔɾ�3ʃ] *faz horas* 'for hours'

['maɾ] *mar* 'sea'   →   [ma.'rɑɫᵘ] *mar alto* 'open sea'

   b. No resyllabification:

['saɪ] *sai* 'he goes out' → [saɪ.'ⁱoʒᵊ]   *sai hoje*   'he goes out today'

['mɑʊ] *mau* 'bad'   →   ['mɑʊ.ʷ3'migᵘ] *mau amigo* 'bad friend'

['lɐ̃]   *lã*   'wool'   →   ['lɐ̃.3'zuɫ]   *lã azul*   'blue wool'

['mɑɫ] *mal* 'badly, wrong' → ['mɑɫ.iðu'kaðᵘ] *mal educado* 'bad-mannered'

The same occurs word-internally, where such syllabifications as *sai-a* 'skirt' (along with *mal-a* 'trunk') are supported by the fact that Portuguese, unlike Spanish, lacks word-initial glides.

Assuming that only extra-nucleic elements undergo resyllabification, the reason for the divergence between /-r/ and the remaining syllable-final sonorants is that, among the heavy clusters, V+/I U N l/ are complex nuclei, as shown in (8a), not V+/r/; actually, the rhotic has here the very same status as any other consonant occurring, in EP, before a *schwa*, that is an empty nucleus, as in *sabe* 'he knows', *pode* 'he can', *leve* 'light', etc.[5]

(8) a. N   b. N   O   N
        ⟋| | | |
       x   x   x   x   x
       | | | | |
       V {IUNl}   V   C

_____
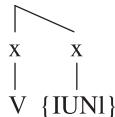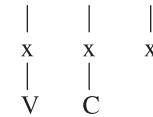
[5] Hence, EP *schwas* have either (underlying) melodic content – as in *pare* 'stop!', *pareceria* 'he would seem' – or no content at all – *par* 'pair', *parceria* 'partnership'; however, contra Veloso (2005), none is epenthetic.

What is more, final *Vr*-clusters generally involve a *schwa* in EP (['maɾᵊ] 'sea'), while /Vl/ rhymes are as strongly coarticulated as diphthongs, the vowel being velarized by a 'dark *l*' (['mɑɫ] 'badly, wrong') which undergoes vocalization in Brazilian Portuguese (> ['mɑʊ]).

A second characteristic of the EP complex nuclei in (8a) is that they escape the normal reduction process that affects unstressed vowels in pretonic and post-tonic syllables, as exemplified under (9) with highly productive morphological alternations; by contrast, the behaviour of complex nuclei is illustrated in (10).

(9) a. [i] ↔ [i]   *v*<u>i</u>*ro* / *v*ⁱ*rar*   'I turn / to turn'
                       af<u>i</u>*rmo* / *af*<u>i</u>*rmar*   'I assert / to assert'
                       r<u>i</u>*sco* / *r*<u>i</u>*scado*   'stripe / striped'

     b. [e] ↔ [ə]   *s*<u>e</u>*co* / *s*<u>e</u>*car*   'dry / to dry'
                       ap<u>e</u>*rto* / *ap*<u>e</u>*rtar*   'pressure / to hold tight'
                       c<u>e</u>*sta* / *c*<u>e</u>*stinha*   'basket / little basket'

     c. [ɛ] ↔ [ə]   *s*<u>e</u>*co* / *s*<u>e</u>*car*   'I dry / to dry'
                       ap<u>e</u>*rto* / *ap*<u>e</u>*rtar*   'I hold tight / to hold tight'
                       p<u>e</u>*sco* / *p*<u>e</u>*scar*   'I fish / to fish'

     d. [a] ↔ [ɜ]   *b*<u>a</u>*to* / *b*<u>a</u>*ter*   'I beat / to beat'
                       p<u>a</u>*rto* / *p*<u>a</u>*rtir*   'I leave / to leave', 'I break / to break'
                       g<u>a</u>*sto* / *g*<u>a</u>*star*   'I spend / to spend'

     e. [ɔ] ↔ [u]   *v*<u>o</u>*to* / *v*<u>o</u>*tar*   'vote, I vote / to vote'
                       c<u>o</u>*rto* / *c*<u>o</u>*rtar*   'I cut / to cut'
                       g<u>o</u>*sto* / *g*<u>o</u>*star*   'I like / to like'

     f. [o] ↔ [u]   *c*<u>o</u>*zo* / *c*<u>o</u>*zer*   'I cook / to cook'
                       g<u>o</u>*rdo* / *g*<u>o</u>*rdinho*   'fat / a bit fat'
                       g<u>o</u>*sto* / *g*<u>o</u>*star*   'taste / to like'

     g. [u] ↔ [u]   *f*<u>u</u>*ro* / *f*<u>u</u>*rar*   'hole, I make a hole / to make a hole'
                       f<u>u</u>*rto* / *f*<u>u</u>*rtar*   'theft, I steal / to steal'
                       c<u>u</u>*sto* / *c*<u>u</u>*star*   'cost, I cost / to cost'

(10) a. [eɪ]   *[əɪ]   *deito* / *deitar*   'I throw / to throw'
         [aɪ]   *[ɜɪ]   *pairo* / *pairar*   'I soar / to soar'
         [ɑʊ]   *[ʌʊ]   *pauto* / *pautar*   'I settle / to settle'
         [oɪ]   *[uɪ]   *açoito* / *açoitar*   'I whip / to whip'
         [uɪ]   *cuido* / *cuidar*   'I care / to care'

     b. [ĩᴺ]   *pinto* / *pintar*   'I paint / to paint'
         [ẽᴺ]   *[ə̃ᴺ]   *tento* / *tentar*   'I try / to try'
         [ɐ̃ᴺ]   *[ɜ̃ᴺ]   *canto* / *cantar*   'I sing / to sing'
         [õᴺ]   *[ũᴺ]   *monto* / *montar*   'I ride / to ride'
         [ũᴺ]   *junto* / *juntar*   'I gather / to gather'

     c. [iɫ]   *filme* / *filmar*   'film / to film'
         [eɫ]   *[əɫ]   *feltro* / *feltrar*   'felt / to felt'
         [ɛɫ]   *[əɫ]   *relva* / *relvado*   'turf, grass / lawn'
         [ɑɫ]   *[ʌɫ]   *salto* / *saltar*   'jump, I jump / to jump'
         [ɔɫ]   *[ʉɫ]   *solto* / *soltar*   'I free, I untie / to free, to untie'
         [oɫ]   *[ʉɫ]   *solto* / *soltar*   'free / to free, to untie'
         [ʉɫ]   *multa* / *multar*   'fine / to fine'

Assuming that vowel reduction (henceforth VR), in autosegmental terms, is nothing but feature disassociation, its absence in (10) can be seen as an effect of Honeybone's (2005) principle according to which "sharing makes us stronger": the more slots a melodic element is associated with, the more robust it is. Hence, as shown under (11), the elements of complex nuclei should interact in such a way that at least one melodic prime is linked to two positions.[6]

(11) Internal structure of some EP complex nuclei (provisional account):

a. [eɪ]   N   b. [aɪ]   N   c. [ɐ̃ᴺ]   N   d. [ɐ̃õ]   N

A   I   A   I   A   N   A   U

                                                                         N

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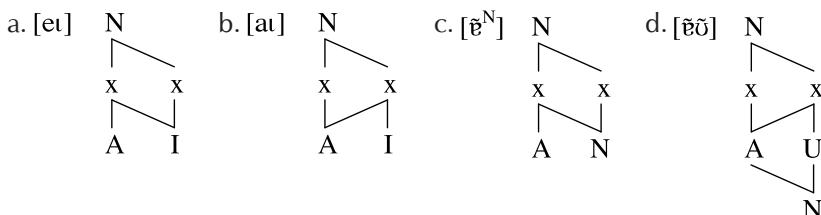
[6] This is also in line with Caratini's (2009: 478 ff.) hypothesis on the difference between diphthongs and hiatuses in a strict CV approach: if both suppose a VCV portion of the skeleton (C being an empty position), the former, unlike the latter, involve such melodic interactions.

The concept 'vowel' will be understood as the set of all nucleic configurations; as can be seen, contrary to what emerged from the inventory in (4), it comprises /Vl/ clusters in EP, as they behave like diphthongs and nasals. Thereby, the behaviour of phonological segments turns out to be a 'built-in' property of their internal structure.

Unlike /Vs/ and /Vr/ clusters, EP complex nuclei involve phonotactic constraints that strongly restrict the number of possible contrasts: for example, there are front, but not round, homorganic diphthongs; mid-high and mid-low vowels contrast in stressed positions, except in nasal nuclei; there are nasal diphthongs, but not diphthong+/l/ nuclei.[7] The existence of phonotactic constraints is not surprising, since complex nuclei involve melodic interactions, as assumed above. Could it, then, be the case that the internal structure of nuclei accounts for such constraints as well? If so, and since satisfaction of these constraints is clearly language-specific, is it possible to maintain that featural organisation is universal?

3- Back to particles

There are two interesting facts about the EP low vowel. On the one hand, VR applies to /a/ as in (12a); note that the reduced allophone of /a/ remains distinct from that of /e, ɛ/, as shown by [pɜ'gaɾ] *pagar* 'to pay' (cf. *p*[a]*go* 'I pay') *versus* [pə'gaɾ] *pegar* 'to take' (cf. *p*[ɛ]*go* 'I take'). On the other hand, when two reduced allophones of /a/ happen to be in contact at morpheme boundaries, they regularly contract into one (short) [a] – a process traditionally known as 'crasis' –, as exemplified in (12b).

(12) a. VR: /a/→ [ɜ] in unstressed syllables

    b. Crasis:

[ɜ] + [ɜ'migɜ] → [a'migɜ]	*a amiga*	'the friend' (fem.)
['kazɜ] + [ɜ'zuɫ] → ['kaza'zuɫ]	*casa azul*	'blue house'
['pagɜ] + [ɜ'kõⁿtɜ] → ['paga'kõⁿtɜ]	*paga a conta*	'pay the bill!'
['ɛrɜ] + [ɜ'li] → ['ɛra'li]	*era ali*	'it was there'

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[7] On the basis of Portuguese orthography, it could be argued that this also the case in *r*-closed syllables. However, it follows from the representation assigned in (8b) to /Vr/ 'rhymes' that a word like *par* 'pair' has the same syllabic structure as *pare* 'stop!' and *paire* 'he soar' (subj.), whereas the monosyllabic *sal* 'salt' differs from the dissyllabic *vale* 'valley' and *baile* 'dance', as shown by its strong(er) velarization, which disallows diphthongs.

If we bring both facts together, it seems that /a/ equals '[ɜ] + [ɜ]', or that it consists of two A-elements, in the line of Schane's (1984) Particle phonology, where, as shown in (13), the representation of vocalic aperture rests on the 'weight', that is the number of occurrences, of an A-particle.

(13)   /i/ = {I}   /u/ = {U}
        /e/ = {I, A}   /o/ = {U, A}
                    /ʌ/ = {A}
        /ɛ/ = {I, A, A}   /ɔ/ = {U, A, A}
                    /a/ = {A, A}

Within this framework, thus, when /a/ undergoes VR, one of its A-elements, and only one, is lost. A tempting generalization is that VR itself is nothing but resonance decrease by loss of one A-element.

However, looking at the general pattern of EP VR in (14), two questions arise. First, if, according to Schane's model, /e o/ differ from /ɛ ɔ/ in that the latter have one more A-particle than the former, why do both mid-high and mid-low vowels reduce alike? If VR involves the loss of only one A-particle, such processes as /e/ → [ə] and /ɛ/ → *[e] should be expected. Second, why is it that, when this resonance element A is deleted, the 'tonality' elements I and U exhibit asymmetric behaviour, the former being also deleted while the latter is preserved?

(14)   /i/ /e/ /ɛ/ /a/ /ɔ/ /o/ /u/
         | \ / | \   \ /
        [i]   [ə]   [ɜ]   [u]   / unstressed syllable
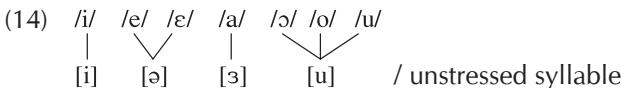
Assuming that the process in (14) is constrained by infrasegmental structure, the answer to both questions, as illustrated in (15a,b), is that (i) VR applies to a 5-vowel system, where the contrast between mid-high and mid-low vowels is previously neutralized (EP sharing this merger with all dialects of Portuguese), so that no more than two elements are required for each segment, and that (ii) I and U have different hierarchical status with respect to A: in mid vowels I is 'dominated' by A, while U 'dominates' A, so that A-delinking involves I- but not U-deletion (Carvalho 1994).

(15) a. /i/   /E/   /a/   /O/   /u/
          ↓   ↓   ↓   ↓   ↓
          [i]   [ə]   [ɜ]   [u]   [u]

b.   x   x   x   x   x
          | ǂ | | |
          •   A   A   U   U
          | | ǂ   ǂ
          I   I   A   A   •
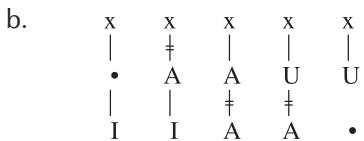
Crucially, VR is congruent with other aspects of EP vowels, which minimizes the risk of circularity. Thus, the first of the three constraints mentioned above on the structure of complex nuclei is directly captured by the element hierarchy in (15b). As can be seen in (4b,c), there are front, but not round, homorganic diphthongs. Indeed, unlike I in (16a), U cannot spread without involving A-propagation as well, whence [oː], not a diphthong. Assuming that languages lacking long vowels precisely forbid dominant elements to associate with two slots, (16b) is naturally disallowed in EP.[8]

(16) a. [eɪ]   x   x   b. *[oː]   x   x
               | | |
               A   •   U
 | |
               I   A
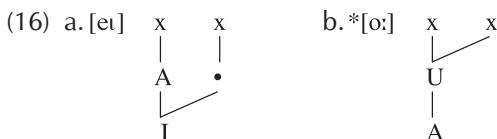
Also, underlying /eo, ea/ and /oa/ hiatuses behave differently, the former regularly involving diphthongization, not the latter: /ˈʃea/ → [ˈʃeʲɜ] *cheia* 'full (fem.)' *vs* /ˈboa/ → [ˈboʷɜ] *boa* 'good (fem.)'.

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[8] Old Galician-Portuguese (which lacked VR) had an *ou* diphthong that survives in standard EP (and Brazilian Portuguese) either as a short monophthong [o] that, like diphthongs, does not undergo VR (e. g., *p*[o]*po / p*[o]*par* 'I/to save, spare'), or as [oɪ] – some words showing both (lexicalized) variants. In EP, this monophthong behaves like a few other pretonic vowels that escape VR, and whose elements must be viewed as lexically anchored (e. g., *pr*[ɛ]*gar* 'to preach', *p*[a]*deiro* 'baker', *c*[ɔ]*rar* 'to flush'). In certain European dialectal varieties, *ou* also gave a central round mid vowel [ɵ]. A problem for the present analysis may come from zones of northern Portugal which preserve *ou* as a diphthong with a round off-glide (while showing VR). Further research is required on that subject; it should be noted, however, that a widespread realization of *ou* in these zones is a dissimilated [ɐu] diphthong, which does not raise any problem for the representation assumed in (15b).

4- From particle ordering to contrastive hierarchies

At this stage, one question arises: what does the internal structure of the basic 5-vowel system in (15b) involve as to the overall organization of vocalic contrasts in EP? Within a theory of phonological primitives based on privative elements, the I/U-asymmetry revealed by VR is likely to support the autosegmental representation of monophthongs in (17). As can be seen, each tier corresponds to one and only one element, which may be either present or absent.

(17)   /i/   /e ɛ/   /a/   /o ɔ/   /u/

$$
\begin{array}{ccccc}
x & x & x & x & x \\
| & | & | & | & | \\
\text{—•—•—•— U — U — L}_1 \\
| & ‡ & | & ‡ \\
\text{—•— A — A— A— • — L}_2 \\
| & | & | & | \\
\text{—I — I —•— •— —•— L}_3 \\
 & & ‡ & \\
\text{—•—(A)— A —(A)—•— L}_4
\end{array}
$$
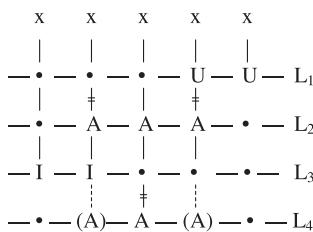
However, (17) offers a somewhat misleading picture of EP VR: if /a/ → [ɜ] did follow from A_4-delinking, then, as was pointed out above, /e ɛ/ and /o ɔ/ should be expected to reduce to [e] and [o], not to [ə] and [u], respectively; conversely, if /e ɛ/ → [ə] and /o ɔ/ → [u] resulted from A_2-delinking, then /a/ → [ə] (like in Catalan) should be expected, instead of [ɜ].

This supports the assumption that hierarchies do not involve mere isolated elements, but *contrasts*. In (18), tiers do not necessarily bear one single element, but both privative (e. g., /e/ ~ /i/) and equipollent (e. g., /e/ ~ /a/) oppositions. In (18), VR is naturally captured in terms of loss of one A-element that contrasts either with I or with U, according to the tier in which A is located. Unlike (17), accounts for the behaviour of both /a/ and /E O/.

(18)   /i/   /e ɛ/   /a/   /o ɔ/   /u/

$$
\begin{array}{ccccc}
x & x & x & x & x \\
| & ‡ & | & | & | \\
\text{—•— A — A— U — U — L}_1 \\
| & | & ‡ & ‡ \\
\text{—I — I — A— A— • — L}_2 \\
 & & & \\
\text{—•—(A)—(A)—(A)— • — L}_3
\end{array}
$$
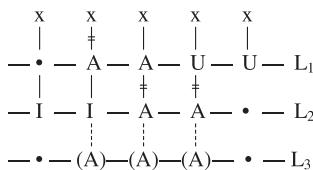
Interestingly, there is one common element to all tiers in (18), and A is this element among vowels. The basic oppositions are, in EP, those in (19), where the 'voweliness' represented by A successively contrasts with the tonality elements U and I. EP is supposed to have this hierarchy; other languages may have the opposite tier ordering.

(19) U   A   — L1 low-pitch ~ voweliness
   I   A   — L2 high-pitch ~ voweliness
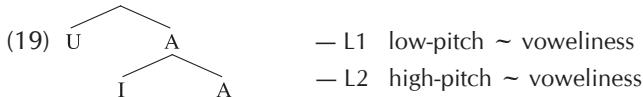
An interesting consequence of (18) is that /a/ has now *three* A-elements. I shall only stress two points supporting this representation. First, crasis in (12b) turns out to be a slightly more complex process than the '1 + 1 = 2' formula suggested in § 3; rather, as each of the primitive A's is linked to one timing position, the three resulting A's associated with one slot show that one position changes into an A-element. This is consistent with the view that, within Schane's approach, A-'particles' may share with timing slots a quantitative role in phonological representations (Carvalho 1994). Secondly, the three A's in (18) can be shown to correspond to the gradual realization of EP /a/ in terms of resonance: $\{A_1\}$ represents its reduced allophone in unstressed syllables (transcribed here as [ɜ]), $\{A_1A_2\}$ underlies its stressed mid allophone before nasal onsets ([ɐ]), and $\{A_1A_2A_3\}$ its full prototype ([a]).

We shall now see how this approach accounts for the last two constraints mentioned in § 2 on the structure of complex nuclei, which involve the two segments that are specifically associated with the second position: /N/ and /l/. Just like /I U/, these have strong anti-resonant effects on the preceding vowel, which is either nasalized by /N/ or velarized by [ɫ]. The problem is about the contrastive consequences of these phonetic effects: as regards nasality, why do mid-high and mid-low vowels contrast in stressed positions, except in nasal nuclei?

This simply follows from the overall hierarchy of vocalic contrasts in (20), where the N-element will be seen as the second member of the equipollent opposition carried by L_3.

(20) U   A   — L1 low-pitch ~ voweliness

        I   A   — L2 high-pitch ~ voweliness

          N   A   — L3 nasality ~ voweliness
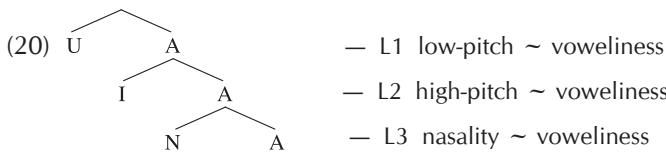
Assuming that lexical ambiassociation of two elements of the same tier represents a marked configuration,[9] contrasts between mid-high and mid-low nasalized vowels, which would require A_3 and N be lexically ambiassociated in mid-low vowels, appear as disadvantaged, and are, indeed, impossible in EP.[10] Nasal diphthongs, however, depend on the higher-level I/U-elements, and are therefore naturally allowed, as shown in (21).

(21) a. [ẽ(ĩ)]   x   x   b. [ẽõ]   x   x

                  A   • L_1 A   U L_1

                  I   • L_2 A   • L_2

                    N L_3 N L_3
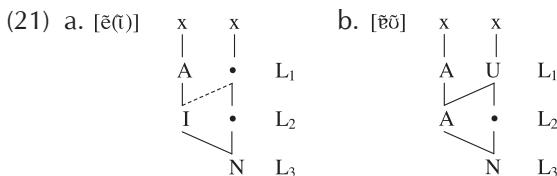
As regards /Vl/ nuclei, the question is: why are there nasal diphthongs – cf. (4c) –, but not diphthong + /l/ nuclei? As a velarized consonant, /l/ consists of a low-pitch element U.[11] If this element is located in its respective tier – L_1 in (18) –, then, as shown in (22), not only is U naturally allowed to spread onto the left position, whatever the melodies associated with it, but it also prevents diphthongization, as it already occupies the place allotted to off-glides.

(22) [V̰ɫ]   x   x

              X   U L_1

              Y L_2

_____

[10] Northern varieties of EP show a low [ã] for [ẽ]. However, lexical contrasts between /ẽ ẽ õ/ and /ɛ̃ ã ɔ̃/ are unattested. That N and A_3 are lexically incompatible in EP also appears from the fact that the only case of /e ɐ o/ ~ /ɛ a ɔ/ contrasts before nasal consonants (e. g., t[e]mo 'I fear' ~ r[ɛ]mo 'oar, I row', cant[ɐ]mos 'we sing' ~ cant[a]mos 'we sang', t[o]mo 'volume' ~ t[ɔ]mo 'I take') precisely involves denasalization. Otherwise, only crasis may trigger a low nasal vowel, e. g. ['kazɐ] + [ɐ̃ⁿtigɐ] → ['kazãⁿtigɐ] casa antiga 'old house'.
[11] And some consonantal element that distinguishes it from the [-ʊ] off-glide.

5- Are infrasegmental hierarchies lexical?

There is, finally, a crucial piece of evidence for assuming that tiers represent contrasts between elements, not single elements. VR occurs in word-initial onsetless unstressed syllables: thus, /a/ normally surfaces as [ɜ]: cf. [ɜ]*rder* 'to burn'. However, since EP has a constraint forbidding [#ə], the mid archiphoneme /E/ is realized as [i], instead of [ə], as exemplified in (23a).

(23) a. *erguer*   'to erect'   b. *oliveira*   'olive'
        Helena   'Helen'   *ovelha*   'ewe'
        exemplo   'example'   *obrigado*   'thank you'
        exército 'army'   *orar*   'to pray'
        edifício 'building'   *operário*   '(manual) worker'

Clearly, the satisfaction of *[#ə] leads the I and A components of /E/ to swap their hierarchical roles, so that I becomes the dominant element of /E/ in word-initial position. What is interesting is that, in this context, as shown in (23b), /O/ surfaces as [o], instead of the expected [u], and, thus, fails to undergo VR.

Both facts – as well as the normal reduction of /a/ – are captured by assuming that I/A permutation in /E/ actually follows from general interchange of U/A and I/A *tiers*, implying the permutation of U and A in /O/. It remains to be explained why elements preserve their capacity for association, which is presupposed by the mechanism in (24);[12] I see no other explanation, however, for the absence of VR in /O/, as there is no *[#u] constraint in EP.

(24) a.   [i]   [ə]   [ɜ]   [u]   [u]   b.   [i]   [i]   [ɜ]   [o]   [u]   / # _

           x   x   x   x   x   x   x   x   x   x
           | | | | | | | ⋮   ⋮
         —•— A — A — U — U—   —I — I — A — A — •—
           | | | |
         —I — I — A — A — •—   —•— A — A — U — U—

_____
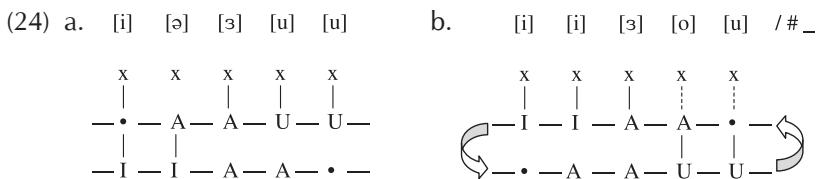
[12] For a model of what the metaphorical term '(autosegmental) association' may cover, see Carvalho (2007).

Let us remark in passing that (24a,b) brings up the following important problem: are such infrasegmental hierarchies lexical? Assuming with Optimality Theory that markedness constraints concern surface forms, the possibility for the hierarchy in (24b) to be preferred to the one in (24a) on the grounds that the latter violates *[#ə] confers on both the status of 'candidates'. This needs further discussion that space does not permit here. In any event, if it were eventually shown that different contrast hierarchies compete in each language, this would prove that they belong to grammar, that they are language-specific constructions, not a matter of anatomy.

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