FROM PHONETIC CATEGORIES TO PHONOLOGICAL FEATURES SPECIFICATION: ACQUIRING THE EUROPEAN PORTUGUESE VOWEL SYSTEM

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0. INTRODUCTION

Vowels are the Cinderellas in research on the acquisition of phonology. Little is known about how a system of phonologically contrasting vowels is acquired and what evidence children use to build up such a system. On the one hand, studies in infant perception have shown that children's perception of vowels becomes language specific at a very early, at six months of age (Kuhl 1979, Kuhl *et al*. 1992). In general, infants have been shown to be excellent performers on various language discrimination tasks and they are very good in using statistical patterns in the input language (e.g., Saffran *et al*. 1996). By the time children start to speak they should have a good idea about what vowels pattern in their native language.

Yet, when children start producing words, they do not produce all vowels of the target system, nor do they use all vowels correctly. It has often been noted that low open vowels – i.e. /a/ – appear as the first vowels, an observation which goes at least back to Jakobson (1941/1968) who argued that children start with sounds that are maximally contrasting, hence *papa* and *mama* – a maximally closed labial stop followed by a maximally open vowel /a/. Jakobson further hypothesized, based on the typology of vowel systems, that the next contrast will be open vs. closed, i.e. /a/ vs. /i, u/. However, there are very few studies that have gone beyond the very first steps (cp. Davis & MacNeilage 1990).

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Infant's excellent perception skills has led many people to believe that children must store words appropriately, which essentially means in an adult-like fashion. The fact that they do not produce these vowels should then either be accounted for by children's deviant phonology, or by limitations on articulation. We will argue that this view is too simplistic, and that it is necessarily to distinguish phonetic discrimination from phonological identification, which typically comes into play as soon as lexical representations are involved. This has been shown to be the case for consonant discrimination for both place of articulation features (Fikkert, Levelt & Zamuner 2005, Van der Feest & Fikkert 2005) and laryngeal features (Van der Feest & Fikkert 2005). In these studies children are able to discriminate phonetically and phonologically different segments, yet, they are unable to use these same sounds in word recognition tasks, suggesting that children do not store fine phonetic detail in the mental lexicon. We argue that the same holds for vocalic features.

This paper aims at investigating how children could proceed in interpreting the surface vowels of their language phonologically and what kind of evidence they could use to ultimately arrive at an abstract system of vocalic contrasts. That is, we assume that children have identified the phonetic vowel categories that play a role in their mother language, i.e. all surface vowels. This enables them to do so well on pure discrimination tasks. However, when learning words and storing them in their mental lexicons, children use phonological features, rather than phonetic categories. To do so, they must have learned the phonological make-up of the vowel system. We will argue that children use alternations that occur in the target language for identifying active phonological features. This constitutes the positive evidence on which the vocalic system will be based. This kind of positive evidence is discussed in section 3. Moreover, we argue that children can also make use of indirect negative evidence: the systematic absence of certain vowels may help to determine the phonological system. This is discussed in section 4. Section 5 discusses some implications for acquisition and some preliminary results from actual acquisition data.

When viewing possible evidence, we come to two conclusions. By building up a system of contrast, the vowel categories are divided dichotomously, until each vowel is phonologically distinct from all other vowels. This gives rise to a system with substantial underspecification, as well as featural dependencies. The resulting system accounts elegantly for the attested vocalic processes in EP, and is in many ways superior to the analysis proposed in Mateus & d'Andrade (2000), to which we turn next.

2. THE EP VOWEL SYSTEM

To describe the surface EP vowels, one needs to distinguish stressed and unstressed vowels, and oral and nasal vowels. According to Mateus & d'Andrade (2000), henceforth M&A, EP has seven stressed oral vowels, four unstressed ones, and five nasal vowels, shown in (1):

(1)

Stressed position			*Unstressed position*			*Nasal vowels*		
i		u	i	ɨ	u	ĩ		ũ
e		o		ɐ		ẽ	ɐ̃	õ
ɛ		ɔ						
	a							

Although [ɐ] does appear as stressed on the surface, its appearance in this context is very restricted and predictable, as we will show below. For that reason, M&A do not assume it to be an underlying vowel, but consider it derived. M&A (2000) argue that unstressed vowels are derived from the stressed ones (see section 3.1), and that underlyingly nasal vowels are made up of an oral vowel followed by a nasal. Therefore, they assume that only the seven stressed vowels in (1) are lexical. To determine their feature values, M&A have assumed radical underspecification. They argue that the completely underspecified and default vowel is /i/. This vowel is claimed to be devoid of any features referring to either place of articulation or tongue height. The features that /i/ would have, i.e. [+high] and [coronal], must be default features in other vowels as well, giving rise to general underspecification of [coronal]. As [+high] is unspecified for /i/, it must also be unspecified for /u/. However, M&A need to refer to [-high] to distinguish /e, o/ from /ɛ, ɔ/. They arrive at the system of contrast given in (2):

(2) Phonological vowel contrasts (Mateus & d'Andrade 2000: 35)

	i	e	ɛ	a	u	o	ɔ
[high]		-				-	
[low]			+	+			+
[round] (labial)					+	+	+
[back] (dorsal)				+			

The unstressed vowel system is derived from the stressed system by a complicated set of rules, as we will see in the next section. M&A assume that both [ɨ] and [ɐ] are dorsal, the former being [+high], the latter [-high, -low].

We will argue in this paper that there are good reasons to modify this system and propose that all features are monovalent, that there are three places of articulation – [labial], [dorsal], and [coronal] – of which [coronal] is underspecified, and that there are two tongue height features – [high] and [low], and finally that low vowels can be specified for [RTR]. In the next section, we discuss the evidence for the vowel features on the basis of positive evidence available to the child.

3. POSITIVE EVIDENCE: PHONOLOGICAL PROCESSES IN EP

It is generally assumed in generative linguistics that children only use positive evidence to build up a grammatical system. Vowels that alternate in the target system may provide a strong positive cue for featural activity. We will first consider the very general process of vowel reduction in unstressed syllables. Subsequently, we focus on two allophonic processes in section 3.2. We will discuss the morphophonological process of vowel harmony in the verbal system in section 3.3. And finally, the process of vowel deletion is discussed in section 3.4.

3.1. Vowel Reduction in Unstressed Syllables

The EP vowel system exhibits vowel reduction in unstressed position very systematically, as shown in (3a). The high vowels /i/ and /u/ do not show alternation[1], as shown in (3b).

(3) Vowel alternations in stressed vs. unstressed position

a.	ˈm[a]la	'bag'	m[ɐ]ˈlinha	'bag-diminutive'
	ˈs[ɛ]la	'saddle'	s[ɨ]ˈlar	'to saddle'
	ˈm[e]do	'fear'	m[ɨ]ˈdinho	'fear-diminutive'
	ˈm[ɔ]da	'fashion'	m[u]ˈdista	'dressmaker'
	ˈl[o]bo	'wolf'	l[u]ˈbinho	'wolf-diminutive'
b.	ˈl[i]vro	'book'	l[i]ˈvrinho	'book-diminutive'
	ˈt[u]bo	'tube'	t[u]ˈbinho	'tube-diminutive'

According to M&A (2000: 135) vowel reduction is essentially a raising rule. They describe the rule as follows: «in EP all [-high] vowels, that is /e, ɛ, o, ɔ, a/ become [-low], and /e, ɛ, o, ɔ/ also become [+high]». In other words, they describe raising as a feature changing rule[2]. In

[1] Recently, a further optional reduction rule has appeared in the language, which reduces /i/ to [ɨ]. /i/ and /u/ may also disappear completely. We will discuss this below in section 3.4.

[2] We ignore here the question of how the vowels /ɛ, ɔ, a/ become specified for [-high].

addition, the coronal vowels [e, ɛ] become dorsal, presumably by a postlexical process, causing the retraction of non-back vowels. However, we will see that vowel reduction can be straightforwardly accounted for as a unified process in which vowels lose the tongue height feature [low] if we assume a different phonological vowel system.

In unstressed position, stressed coronal vowels merge: /e, ɛ/ both become [ɨ]. Importantly, /i/ does not merge with the other coronal vowels. The dorsal vowel /a/ remains dorsal, but changes to [ɐ]. The labial vowels /o, ɔ/ merge to [u] or maybe to [ʊ]. Finally, /u/ does not change. There are two ways of stating the generalizations giving rise to four vowels in unstressed position in (4a), or five vowels in (4b), depending on how one describes the merger in the labial set of vowels /o, ɔ/. In (4a) only /i/ behaves as a class of its own, whereas in (4b) both high vowels /i, u/ show a similar behaviour.

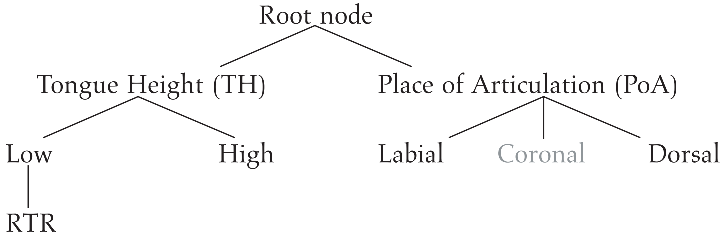
(4) Mergers in unstressed position

a.	/a/	→	[ɐ]	b.	/a/	→	[ɐ]
	/e, ɛ/	→	[ɨ]		/e, ɛ/	→	[ɨ]
	/i/	→	[i]		/i/	→	[i]
	/o, ɔ, u/	→	[u]		/o, ɔ/	→	[ʊ]
					/u/	→	[u]

Thus, vowels sharing place of articulation features merge, with the exception of the high coronal vowel /i/, and possibly the high labial vowel /u/, giving evidence for a division into three sets of place features, which we will call [labial], [coronal] and [dorsal]. If we, furthermore assume, that /i/ is distinguished from the other vowels by being specified as [high], whereas the other vowels, except /u/ are [low], then the process of vowel reduction can be straightforwardly accounted for as the loss of the tongue height feature [low], leaving /i, u/ unchanged. Whether /u/ is specified for [high] or not is an open question. If it is specified for [high], then the mergers follow the pattern in (4b), if not, the pattern in (4a) is followed. In any event, the vowel to which /o, ɔ/ merge is not specified for [high], and this is why we prefer to use the symbol [ʊ] to distinguish it from stressed [u]. The vowels [ɨ], [ɐ] and [ʊ] can then be characterized as, respectively, coronal, dorsal and labial vowels without tongue height features.

Two sets of vowels are not yet distinguished from each other: /e, ɛ/ and /o, ɔ/. We propose that /ɛ, ɔ/ are specified for [RTR], and will come back to this issue in sections 3.3 and 4. If we assume a feature geometry as proposed by Lahiri & Evers (1991), the process of vowel reduction can be described as one in which vowels lose their [low] specification, and hence, also [RTR], which is dependent on [low], in unstressed position:

(5)



Thus, our proposal differs from of Mateus & d'Andrade (2000) in at least two ways. First, we assume that [ɨ] is coronal, rather than dorsal. Coronal vowels merge to [ɨ], dorsal vowels do not. Second, we assume that stressed vowels *lose* features in unstressed position, rather than change and gain feature values.

How can children arrive at this system of contrast? As stressed and unstressed vowels appear in almost every single word that the child hears, the child may quickly notice that stressed and unstressed vowels are somewhat different. There are two generalizations that children may arrive at by inspecting the set of vowels in stressed and unstressed position.

First, all places of articulation that are present in stressed position also occur in unstressed position, i.e. dorsal, labial and coronal. One way the divide the set of vowels is on the basis of place of articulation (6ab). It does not seem to matter for learnability whether [labial] or [dorsal] is determined first, although most children seem to start with dorsal vowels, as we will see in section 5. The child may further notice that only the high vowels /i, u/ occur in both stressed and unstressed position, and hence do not change. All non-high vowels either occur in stressed or in unstressed position. This distinguishes the set of high vowels /i, u/ from the set of non-high vowels (6c). There are only two dorsal vowels, which can be distinguished by specifying /a/ for [low] and hence, leaving the other dorsal vowel unspecified for tongue height features. As stressed positions carry more featural information than unstressed, it is natural to specify /a/ rather than /ɐ/. The feature [low] that is used for dorsal vowels can be extended to labial and coronal vowels, specifying the stressed vowels as [low], and leaving the unstressed ones unspecified. What /ɐ/ shares with /ʊ/ and /ɨ/ is that it generally occurs in unstressed position, and neither of them receive any height specification (6d). The features indicated in (6a-d) is specified to the vowels of the first set in each comparison.

(6) a. {a, ɐ} vs. {o, ɔ, ʊ, u, e, ɛ, ɨ, i } [dorsal]
b. {o, ɔ, ʊ, u} vs. {e, ɛ, ɨ, i } [labial]
c. {u} vs. {o, ɔ, ʊ} and {i} vs. {e, ɛ, ɨ}; i.e. [high]
d. {a} vs. {ɐ}[3], {o, ɔ} vs. {ʊ}, and {e, ɛ} vs. {ɨ} [low]

Children could also start out dividing the vowel set on the basis of the feature [high], rather than place, and still arrive at the same system of contrast.

(7) a. {i, u} vs. {e, ɛ, ɨ, o, ɔ, ʊ, a, ɐ} [high]
b. {e, ɛ, o, ɔ, a} vs. {ɨ, ɐ, ʊ} [low]
c. {u} vs. {i}, {o, ɔ} vs. {e, ɛ, a}, {ʊ} vs. {ɐ, ɨ} [labial]
d. {a} vs. {e, ɛ}, {ɐ} vs. { ɨ} [dorsal]

Based on the vowel reduction phenomena it is not possible to determine how to distinguish the low labial vowels /o, ɔ/ and the low coronal vowels /e, ɛ/. We postpone this discussion until sections 3.3 and 4. Thus, based on the patterning of stressed and unstressed vowels, the child may arrive at the feature specification in (8). From (8) it becomes immediately obvious that if the feature [low] is deleted, the dorsal, the non-high labial and the non-high coronal vowels merge to the vowel that did not receive any tongue height features. This results exactly in the attested patterns, and provides a unified account for vowel «raising» in unstressed position[4].

(8)

	dorsal		labial				coronal			
	a	ɐ	ɔ	o	ʊ	ʊ	ɛ	ɛ	ɨ	i
high						•				•
low	•		•	•			•	•		

3.2. *Allophony*

There are two allophonic rules that give rise to stressed [ɐ] on the surface: /a/ before nasals in the following onset and /e/ before palatal consonants in the following onset both turn into [ɐ]. Examples are given in (9a, b) respectively:

[3] Stressed [ɐ] is discussed in the next section.
[4] Nasal vowels do not reduce in unstressed position. Under the analysis of M&A, in which it is assumed that nasal vowels are oral vowels followed by a nasal underlyingly, vowel reduction only takes place in open syllables, not in closed syllables.

(9) a. Stressed underlying /a/ → [ɐ]/__Nasal consonant

aˈr/aɲ/a	→	aˈr[ɐɲ]a	'spider'
ˈc/an/a	→	ˈc[ɐn]a	'cane'
ˈc/am/a	→	ˈc[ɐm]a	'bed'

b. Stressed underlying /e/ → [ɐ]/__Palatal segment (nasal, liquid or fricative)

deˈs/eɲ/os	→	dɛˈs[ɐɲ]os	'drawings'
aˈb/eʎ/a	→	aˈb[ɐʎ]a	'bee'
boˈch/eʃ/as	→	boˈch[ɐʃ]as	'cheeks'
cerˈv/eʒ/a	→	cerˈv[ɐʒ]a	'beer'

Thus, underlying /a/ and /e/ have two different appearances, depending on the nature of the following consonant, a typical case of allophonic variation. Stressed /a/ can occur as either [a] or [ɐ], stressed /e/ can occur as [e] or [ɐ]. As the occurrence of [ɐ] is entirely predictable, previous analyses (e.g. Mateus 1975; d'Andrade 1977; Mateus & d'Andrade 2000) have assumed that stressed [ɐ] is not part of the inventory of phonological vowels in the language, but assume it to be derived from either /a/ or /e/ (9ab). Moreover, the corresponding unstressed vowels in, for instance, the diminutive forms differ systematically from the forms in (9ab), as shown in (10ab):

(10) a. Underlying /a/

aˈr[ɐ]nha	'spider'	ar[ɐ]ˈnhinha	'spider-diminutive'
ˈc[ɐ]na	'cane'	c[ɐ]ˈninha	'cane-diminutive'
ˈc[ɐ]ma	'bed'	c[ɐ]ˈminha	'bed-diminutive'

b. Underlying /e/

deˈs[ɐ]nhos	'drawings'	des[ɨ]ˈnhinos	'drawings-diminutive'
aˈb[ɐ]lha	'bee'	ab[ɨ]ˈlhina	'bee-diminutive'
boˈch[ɐ]chas	'cheeks'	boch[ɨ]ˈchinhas	'cheeks-diminutive'
cerˈv[ɐ]ja	'beer'	cerv[ɨ]ˈjinha	'beer-diminutive'
ˈl[ɐ]i	'law'	l[ɨ]ˈgal	'legal'

Therefore, the main synchronic argument to postulate different underlying vowels for (10ab) comes from the alternating forms in which the vowels undergo stress reduction. The underlying vowel /a/ in (10a) systematically remains [ɐ], whereas the underlying vowel in (10b) systematically reduces to [ɨ]. As we saw in section 3.1 [ɐ] is the unstressed counterpart of /a/, while [ɨ] is the unstressed counterpart of /e/ (or [ɛ])[5]. This analysis finds support in the fact that in some dialects /a/ surfaces as [a] and /e/ as [e],

[5] Although the general assumption is that the process affects underlying /e/, the situation seems to be more complex. If the palatal consonant is an onset, the preceding vowel

though this is not the case in the Portuguese spoken in Lisbon.

We argue that both processes do not have a unified account. The process changing /a/ into [ɐ] before a nasal is due to the prohibition of the low dorsal vowel /a/ before nasals. There is also a more general constraint prohibiting the low vowels /a, ɛ, ɔ/ before a nasal in the same rhyme. This is evident in the distribution of nasal vowels: /ã, ɛ̃, ɔ̃/ are systematically absent in EP (see section 4).

The process that changes an underlying /e/ into an [ɐ] before a palatal is quite different. Here we propose that the preceding palatal spreads a feature [high] to the coronal vowel /e/ (or /ɛ/). However, now a conflict arises, as vowels cannot be [low] and [high] at the same time. The conflict seems to be solved by realizing the central vowel [ɐ], which we assume is not dorsal, but is a retracted /e/ (or /ɛ/). The vowel does not merge with the high coronal /i/. It is generally assumed that the underlying vowel is /e/. However, it could also be /ɛ/. This is discussed in section 3.3.

If a stressed vowel occurs with a right adjacent palatal fricative, this obstruent may optionally cause diphthongization. That is, forms with and without the glide [j] are in free variation, as shown in (11). This again shows that the palatal spreads the feature [high], shared by /i/ and /j/.

(11) Palatal fricative may cause diphthongization of preceding vowel

bo'ch[ɐʃ]as	~	bo'ch[ɐjʃ]as	'cheeks'
cer'v[ɐʒ]a	~	cer'v[ɐjʒ]a	'beer'

EP also has diphthongs, which are traditionally analyzed as underlying /e/ followed by a palatal glide, as shown in (12). Vowel-Glide sequences never undergo vowel reduction, as shown in the second column of (12a) and in (12b). As the underlying vowel occurs in a palatal environment, cf. (9b), the vowel surfaces as [ɐ][6].

(12) a. Underlying /e/ plus palatal glide

'qu[ɐj]jo	'cheese'	qu[ɐj]'jinho	'cheese-diminutive'
'r[ɐj]	'king'	r[ɐj]'nado	'kingdom'
'p[ɐj]xe	'fish'	p[ɐj]'xinho	'fish-diminutive'
'l[ɐj]te	'milk'	l[ɐj]'tinho	'milk-diminutive'

surfaces as [ɐ]. However, if the palatal consonant is in coda position the vowel remains [e], except when followed by a palatal glide, i.e. if vowel and glide form a diphthong: 'l[ɐ]j ('law'). [ɛ] plus palatal consonant in the following onset is rarely attested.

[6] In this sense, vowel-glide sequences mimic vowel-nasal sequences in that bipositional rhymes do not reduce.

b. No reduction in vowel-glide sequences
p[aw]'sado 'slowly'
c[aj]'xinha 'box-diminutive'
pn[ew]mo'nia 'pneumonia'

To conclude, allophonic variation occurs in specific phonological contexts: /a/ is realized as [ɐ] before a nasal due to a constraint on adjacent [dorsal] [low], [RTR] vowels and nasal consonants. An underlying /a/ therefore loses its tongue height features before a nasal and surfaces as [ɐ]. On the other hand, /e/ or /ɛ/ is realized as [ɐ] before a palatal consonant, which we assume involves the spreading of [high]. As vowels cannot be [high] and [low], we propose that the resulting vowel is a retracted coronal vowel, which resembles [ɐ]. However, underlying /aj/ diphthongs remain [aj], as can be seen in (12b). Perceived [ɐj] always corresponds to a coronal diphthong, not to a dorsal one.

A special case of allophonic variation involves the vowels /a/ and /e/ or /ɛ/ before a palatal nasal, as in this context neutralization appears. Fikkert & Freitas (2004) have shown that children learn to deal with the variation before nasals much earlier than with the variation before palatals, the latter being a more complex process.

3.3. *Vowel Harmony in Verbs*

EP also exhibits a morphophonological process, referred to as vowel harmony, affecting the low coronal and labial vowels, which is the topic of this section. In general, verbs contain a root followed by a thematic vowel (TV), which is followed by tense-mood-aspect and person-number markers, which we will not tease apart here. The TV can be either /a/, /e/, or /i/, as shown in (13). Some verbal roots, i.e. the ones with non-high coronal and labial vowels are sensitive to a process called vowel harmony. Vowel harmony only occurs if the TV is in hiatus, which is the case in the first person singular of the present indicative, and in most forms of the present subjunctive. The TV itself is deleted in hiatus (i.e. in the first p. sg. in (13ab)), but it leaves a trace on the preceding vowel if it is «mid», as seen in (13b), but not if the root vowel is /a/, as in (13a). Here, we only present the first and second person sg. indicative, as they sufficiently illustrate the process:

(13) 1st and 2nd person singular, present indicative

		/a/-paradigm	/e/-paradigm	/i/-paradigm
a.	inf.	falar [fɐláɾ]	bater [bɐtéɾ]	partir [pɐɾtíɾ]
		'to speak'	'to beat'	'to leave'
	1p.	/fal+a]$_{Stem}$-o fálu]	/bat+e]$_{Stem}$-o [bátu]	/part+i]$_{Stem}$-o [páɾtʊ]
	2p.	/fal+a]$_{Stem}$-s [fálɐs]	/bat+e]$_{Stem}$-s [bátɨʃ]	/part+i]$_{Stem}$– s [páɾtɨʃ]
b.	inf.	levar [lɨváɾ]	mover [mɔvéɾ]	dormir [duɾmíɾ]
		'to take away'	'to move'	'to sleep'
	1p.	/lev+a]$_{Stem}$-o [lɛ́vu]	/mov+e]$_{St}$-o [móvu]	/dorm+i]$_{St}$-o [dúrmʊ]
	2p.	/lev+a]$_{Stem}$-s [lɛ́vɐs]	/mov +e]$_{St}$-s [mɔ́vɨʃ]	/dorm +i]$_{St}$-s [dɔ́ɾmɨʃ]ɛ́

If the root vowel is /a/, the TV is deleted in the 1st p. sg. but the root vowel itself does not change. However, if the root vowel is a mid vowel /e, o/, the height of the vowel is variable, and depends on the height of the TV, which itself undergoes deletion. Although it is usually assumed that the effected vowels are underlyingly /e, o/, which are subsequently lowered, we argue here that they are underlyingly /ɛ, ɔ/, as in the 2nd p. sg. forms, as no further lowering process needs to be assumed. In general, the low RTR coronal vowels seem to be the most sensitive to change, and, as we will see in section 5, the last to be acquired. In Brazilian Portuguese, the reduction process is different in pretonic and posttonic position. In pretonic position /e, o/ and /ɛ, ɔ/ merge to /e, o/ (which we describe as the loss of [RTR]). In posttonic position they merge also with the high vowels to /i/, losing also the feature [low]. Here too, the vowels /ɛ, ɔ/ are the most vulnerable to change[7].

Rather then describing the process as one of vowel harmony, we argue that the tongue height node of the TV is replacing the tongue height node of the root vowels /ɛ, ɔ/, if the TV itself cannot be realized. In our analysis, the different TVs have the following features under the tongue height node.

(14) Tongue height features specification of the TVs

/a/:	[low, RTR]
/e/:	[low]
/i/:	[high]

On the assumption that the root vowels /ɛ, ɔ/ take on the tongue height features, we expect /ɛ, ɔ/ to remain as such if the TV is /a/, as they

[7] If this logic is applied to the previous section as well, this suggests that palatals affect the coronal low RTR vowel /ɛ/, rather than /e/, as [RTR] vowels appears to be most sensitive to change.

have the same tongue height features underlyingly. However, /ɛ, ɔ/ become /e, o/ if the TV is /e/, and hence only have [low] specified in the tongue height dimension , and /i, u/, if the TV is /i/, and thus specified for [high]. Root vowels keep their own Place of Articulation. In other words, the process affecting the mid vowels in the verbal paradigm also receives a unified account, as the adoption of the tongue height features of the theme vowel, when the theme vowel itself cannot be realized due to its position in hiatus. Its presence can thus be felt on the root vowel. Under this analysis, no additional lowering process needs to be assumed for the forms in the second person singular, such as [lɛ́vɐs], as this follows straightforwardly from the analysis.

The process described in this section is not a general phonological process, but only occurs if the TV itself cannot be realized. By leaving its tongue height features behind on the stem vowel, the TV remains recoverable[8].

3.4. *Vowel Deletion and Insertion*

The deletion of unstressed vowels is a very frequent process in EP. The vowel that most often undergoes deletion is [ɨ]. This vowel is completely underspecified in our analysis, and this, we claim, makes it so vulnerable to deletion. Unstressed [ʊ] is also frequently deleted, but if so, it often labializes the preceding consonant, i.e. it leaves a trace of its place of articulation feature [labial], its only specified feature. Unstressed [i] is seldom deleted, but it may reduce to [ɨ], in which case it loses its feature [high], and hence becomes unspecified. Unstressed [ɐ] never undergoes deletion. Its only feature specification [dorsal] is very stable, and as we will see in section 5, the first one to be established in acquisition. In that sense, the different grades of vulnerability of vowel deletion confirms Jakobson's claim, based on comparative evidence from acquisition and aphasia (Jakobson 1941/1968), that what is acquired first, is the last to get lost.

In general it seems that only vowels that lack tongue height features can be deleted. Coronal vowels are more vulnerable than labial vowels, which in turn are more vulnerable than dorsal vowels.

Although an important characteristics of EP is the large amount of vowel reduction and deletion, there are also two contexts in which vowels

8 How children acquire this process has not yet been investigated. Our prediction is that this is a late process, as it requires knowledge of verbal paradigms, and non-local comparisons of various forms.

can be inserted: after a word final liquid, and between two members of an onset cluster. In all these cases the inserted vowel is the completely unspecified vowel [ɨ] (see also Freitas 2004).

4. NEGATIVE EVIDENCE: CO-OCCURRENCE RESTRICTIONS

Although the general assumption in acquisition is that children do not make use of negative evidence, this still is an empirical question. If children form categories of all the vowels they encounter, as in (1), they could readily notice the existence of gaps. For instance, children could notice that all vowels can be nasal, except /a, ɛ, ɔ/. We argue that children in principle can make use of his kind of indirect negative evidence. In fact, it may help them to figure out cooccurence constraints of features, and the patterning of sounds as a group. The feature that /a, ɛ, ɔ/ share is [low]. However, we assumed that also /e, o/ are low. Thus, the set of low vowels /a, ɛ, ɔ/ may share another feature: [RTR], which we argued was also necessary to account for the «vowel harmony» data in 3.3. If nasals are intrinsically ATR, the constraint may involve one against vowels that are both [RTR] and [ATR]. The constraint is not only prohibiting RTR nasal vowels, but also the sequencing of RTR vowels plus a following nasal in the onset position.

Other systematic gaps concern the diphthongs. Labial vowels followed by a labial glide are systematically absent:*/ow/, *uw/, */ɔw/. This gaps suggests that the two parts that constitute a diphthong must differ in Place of Articulation. Diphthongs in which the two parts share [high], i.e. */ij/ and */uw/, are also prohibited.

The cases of allophonic variation, discussed in section 3.2., could in fact be seen as systematic gaps: stressed /a/ does not appear before nasals, and stressed /e/ does not appear before palatals. Again, this kind of indirect negative evidence may be help the child to discover constraints on feature combinations and to the specification of vowels.

5. IMPLICATIONS FOR ACQUISITION AND PRELIMINARY ACQUISITION DATA

In the previous sections, we have shown that there is evidence for the activity of the tongue height features [high], [low] and [RTR], the latter being dependent on [low], and also for the grouping of vowels in three Places of Articulation: Dorsal, Labial and Coronal. The data on vowel deletion showed coronal vowels are most vulnerable to deletion, subsequently followed by labials and dorsals.

This ranking of vulnerability: coronal > labial > dorsal seems to reflect the order of acquisition, in the sense that those features acquired first are least vulnerable to deletion. Our preliminary analyses of EP acquisition data is based on the child language database collected by Freitas (1997). This database contains longitudinal data from seven monolingual children acquiring EP in Lisbon. The age of the children varied between 0;10 and 3;7, and the children were taped monthly for the period of at least a year. We investigated the early data of two children to see which vowels are first produced in stressed position; and (b) which vowels are produced variably. This provides evidence supporting the claim that Place of Articulation features dominate Tongue Height features. The analysis of the vowels of children's first produced words shows that children start producing the stressed vowels [a] and [ɐ]. Moreover, they produce them more or less in free variation. In other words, children start producing dorsal vowels, but the height features do not seem to be established yet (15a). Subsequently, coronal vowels /e, ɛ, i/ appear, also in variation (15b), followed by labial vowels (15c)[9]. The first grouping of vowels appears to be made on the basis of Place of Articulation. The variation seems to involve mostly TH features.

(15)	a. Dorsal:	dá	'give'	[da], [dɐ]	IN (1;00.25)
		papá	*idem*	[ɐː//ˈpa], [ɐˈpɐ]	JP (0;10.02)
	b. Coronal:	bebé	'baby'	[bibi], [bebe]	IN (1;01.30)
		Ines	*idem*	[neˈne], [niˈni]	IN (1;01.30)
		é	'it is'	[e], [ɛ], [i]	JP (1;01.02)
	c. Labial:	corda	'rope'	[kɔ], [ko]	IN (1;5.11)
		bola	'ball'	[βowɨ], [βu]	JP (1;9.11)

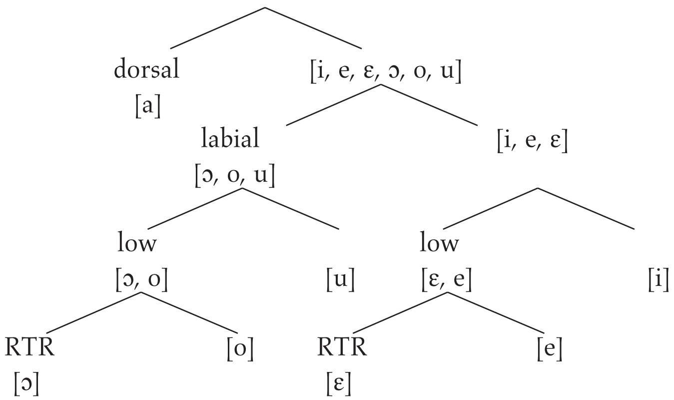
To arrive at the feature specification for vowels, we used all surface vowels, rather than just the stressed «lexical» vowels. The vowel system cannot be successfully acquired on the basis of stressed vowels only. We furthermore demonstrate here that the model, originating from Jakobson (1941/1968), and revived in the Continuous Dichotomy Hypothesis (Dresher 2004ab), can nicely accounts for how the available data lead to a minimally specified system of vowel contrast. Jakobson & Halle

[9] Labials are produced later than coronals. However, importantly, the first contrast seems to be between dorsal–nondorsal. This means that at early stages, possibly only dorsal is specified. When the labial–coronal contrast appears in the child's system, a further specification needs to be made.

(1956: 60–61) describe the continuous dichotomy hypothesis as follows: «The binary opposition is a child's first logical operation. Both opposites arise simultaneously and force the infant to choose one and to suppress the other of the two alternatives».

In (16) and (17) we present the dichotomous branching tree for vowel features, on the assumption that the first contrast to be acquired is indeed the contrast between dorsal and non-dorsal vowels, followed by a contrast between labial and coronal vowels. Subsequently, low vowels are distinguished from non-high vowels, high vowels from non-high vowels, and finally, RTR vowels from non-RTR vowels. The difference between (16) and (17) is that the contrasts in (16) are established on the basis of stressed vowels only, while in (17) all oral surface vowels are taken into account.

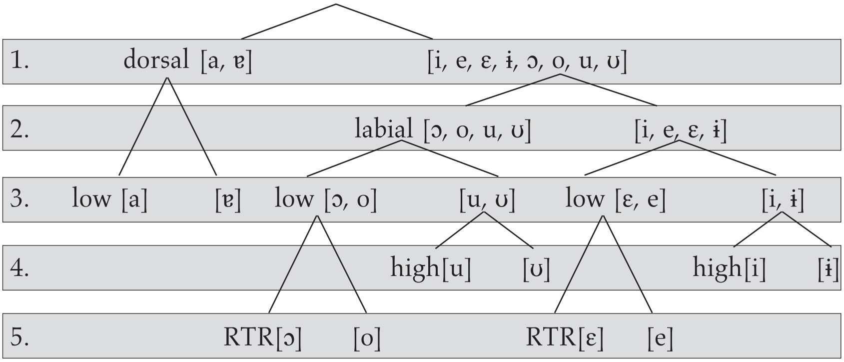
(16)



An important consequence of the dichotomy in (16) is that neither the low dorsal [a], nor the high vowels [u] and [i] are specified for tongue height features. With this system of feature contrast, the process of vowel reduction is not straightforwardly accounted for. This is different in (17).

The hierarchy in (17) reflects the way in which the contrasts are established during acquisition. The RTR contrast seems to come in very late, and this is also the contrast that is most vulnerable to reduction. Further research on acquisition data should establish whether the hierarchy is empirically adequate, but the data considered so far, seem to conform the hierarchy.

(17)



What the hierarchy does not express is that fact that [a] behaves in «vowel harmony» as if it is [RTR], while it is not specified for it in (17). Another implication of the hierarchy in (17) is that tongue height features depend on place of articulation features. We have accounted for vowel reduction as the loss of tongue height features, but we have not encountered any processes involving the loss of place of articulation. Moreover, children hardly make mistakes regarding the place of articulation of vowels, but «mistakes» in the dimension of tongue height features are abundant, indicating that tongue height features are acquired late.

6. CONCLUSION

The traditional view that all vowels in the lexicon have the specification of stressed vowels, the unstressed ones being derived from the stressed ones is not the position with which children start out setting up a system of vowel contrasts. To acquire such a system it is necessary to consider both stressed and unstressed vowels. By comparing stressed and unstressed vowels, children may detect on what basis vowels are grouped together. Place of articulation features are established before tongue height features. Feature specification is based on contrast and only contrastive features can be active. There is not necessarily a universal hierarchy of features, but if phonological activity plays an important role, we expect children acquiring the same language to follow the same learning path.

Although this paper focused more on the logical problem of acquisition than on real acquisition data, our preliminary analysis of acquisition data seems to support the analysis proposed. Moreover, many of the phonological processes involving the EP vowel system now receive a simple and straightforward explanation.

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SUMMARY: IIn questo articolo si tratta il modo in cui i bambini stabiliscono un sistema di contrasti vocalici basandosi sulla distribuzione superficiale delle vocali in portoghese europeo, in particolare si approfondisce l'evidenza che i bambini usano ed i possibili percorsi d'apprendimento che possono seguire. Si sostiene l'idea che i bambini usino soprattutto evidenza positiva per fissare le contrapposizioni vocaliche: vale a dire, i processi funzionanti in una lingua apportano forti indicatori riguardo a quali tratti fonologici sono attivi in quella lingua. Si assume che soltanto i tratti attivi vengano specificati. Il processo di riduzione vocalica ha un ruolo di rilievo nell'acquisizione, poiché fornisce evidenza significativa sui modi in cui le vocali sono raggruppate in una lingua. Altri processi analizzati in questo articolo: variazione allofonica, cancellazione/inserzione di vocale, armonia vocalica. Si sostiene, inoltre, che evidenza anche di tipo negativo (p.es. l'assenza sistematica di alcuni pattern) possa aiutare il bambino a stabilire un sistema di contrasti vocalici. Si propone un sistema di contrasti che fornisce una spiegazione unificata a molti dei processi vocalici del portoghese europeo.