Patterns of segmental modification in consonant inventories

Contrastive vs. redundant systems and phonology vs. phonetics*

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1. Introduction

Segmental inventories typically display a large degree of symmetry. For instance, voiced obstruents typically have voiceless counterparts, coronal affricates typically have the same place of articulation as coronal fricatives, and labialised velars are typically matched by plain ones, to name but a few common patterns. Counter-examples to such tendencies exist, of course, but are then the focus of inquiry. The symmetrical patterning itself, however, is typically not reflected in language description or analysis, in which the segments of a language are often just listed as a matter of course. In recent years, a number of attempts have been made to account for symmetry in segmental inventories, for instance by deriving the segments of a language from a number of more basic principles (cf. Dresher 2001), usually stated in Optimality Theory (OT) terms (e.g. Pulleyblank 1998). To the extent that constraints on possible feature combinations refer to natural classes, the resulting inventories will reflect these natural classes.

In this paper, we survey the symmetry of inventories with respect to segmental modification, i.e. secondary articulation, phonation types as well as (pre)nasalization. In earlier work (Hinskens & van de Weijer 2003), we investigated the general hypothesis that segmental modification typically occurs on natural classes of segments, rather than on random sets of segments or isolated ones, on the basis of the survey of languages presented in Maddieson (1984). Our results showed that this hypothesis was to a statistically highly significant extent upheld by the facts. We noted in passing that there were, *grosso modo*, two types of patterning: segmental modification is either contrastive or redundant in a segmental inventory. We will illustrate both types of patterning below. In van de Weijer & Hinskens (2003), we

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proposed a formal implementation of the difference between contrastive and redundant modification systems, couched within OT. In the present paper we note that redundant systems differ from contrastive ones in that the former are relatively more well-behaved with respect to our general hypothesis than the latter. The difference may be expressed as involving a distinction between lexical and post-lexical segmental modification, which is an indication that even within a relatively declarative theory like OT at least these two strata need to be recognized.

2. Segmental modification

The types of segmental modification (henceforth: MOD) that we recognize are given in (1). These include traditional secondary articulation types such as labialization and palatalization, phonation types and other modifications of the airstream such as aspiration and ejectivity, and nasal modification, which in our data source includes only prenasalization. We include an abbreviation and the diacritics for each of these types.

(1) a. *secondary articulation (supralaryngeal/oral)*

labialization	LAB	C^{w}
palatalization	PAL	C^{j}
velarization	VEL	$\tilde{C}$
pharyngealization	PHA	$C^{\text{ˤ}}$

b. *phonation types (laryngeal)*

aspiration	ASP	C^{h}
preaspiration	PRA	^{h}C
breathy voice	BRV	$\underset{\cdot\cdot}{C}$
with breathy release	BRR	$C^{\text{ɦ}}$
laryngealization	LAR	$\underset{\sim}{C}$
ejectivity	EJE	C'

c. *nasality*

prenasalization	PRN	^{N}C

The data source for our investigation are the consonant inventories of the 317 different languages surveyed by Maddieson (1984). These 317 languages constitute a quota sample, the quota rule being "that only one language may be included from each small family grouping. […] Each such family grouping should be represented by the inclusion of one language. Availability and quality of descriptions are factors in determining which language to include within a group, but such factors as the number of speakers and the phonological peculiarity of the language are not considered" (Maddieson 1984: 5–6). We accept the obvious criticism that this source is not completely accurate with respect to every phonetic detail reported on

(cf. also discussion in Hinskens & van de Weijer 2003: § 1). This is partly a result of the fact that Maddieson's survey represents an inevitable homogenization of descriptions, differing among themselves in phonetic detail and accuracy, of typologically very different languages. In addition, there may be misprints and copying errors, while inadequacies in Maddieson's sources may have been improved in later analyses. However, because of the large body of relevant observations, the results we report are probably statistically robust enough to test our hypotheses, even if there is a small margin of error in the input data. For the languages that are specifically mentioned in this article, viz. Nootka (Sapir & Swadesh 1955) and Wantoat (Davis 1969), we found no significant mismatches between Maddieson's account and the original grammars that he cites from.[1] We therefore believe Maddieson's survey is reliable enough to investigate rough linguistic patterns such as the ones we report on in this paper.

In our earlier paper we investigated the following hypothesis:

(2) *General hypothesis* (Hinskens & van de Weijer 2003):
In segmental inventories, segmental modification occurs on a natural class of segments, rather than randomly or on isolated segments.

We demonstrated that for the sample of languages in Maddieson (1984), this hypothesis is to a statistically highly significant extent supported by the data.

In the current paper, we will show that this hypothesis is upheld by so-called redundant systems to a significantly larger extent than by contrastive systems. The distinction between both kinds of systems is explored in the next section.

3. Contrastive vs. redundant systems

Languages pattern into two types with respect to the segmental modification types they exhibit: either these can serve a contrastive function or be redundantly present on a range of segments.

A *contrastive* MOD system is one in which there is a segment with MOD_i as well as a corresponding segment without MOD_i.[2] An example is presented in (3), which contains the relevant part of the consonantal system of the Native Canadian West Coast Salish language Nuu-cha-nulth (referred to as Nootka in Maddieson 1984, following his sources):

(3) *Ejectivity and labialization as contrastive MODs*: Nootka

voiceless plosive	p	t̼	k	k^w	q	q^w
vl. ejective stop	p′	t̼′	k′	$k^w{}'$	q′	$q^w{}'$
vl. nonsib. fric.			x	x^w	χ	χ^w

In this language, ejectivity *contrasts* on voiceless stops and labialization *contrasts* on dorsals. Both MOD types therefore occur contrastively in this language.[3]

A *redundant* system, on the other hand, is one in which there is no corresponding segment without MOD_i that matches a segment with MOD_i. An example of a language displaying such modification is given in (4):

(4) *Prenasalization as redundant MOD:* Wantoat

vl. plosive	p	t	k	k^w
PRN plosive	^{m}b	^{n}d	^{ŋ}g	^{ŋ}g^w

In Wantoat, a Polynesian language, all and only voiced plosives are prenasalized. In this language, every voiceless stop is therefore matched by a prenasalized counterpart (the same situation occurs in Fiji, as noted by Maddieson & Ladefoged 1993). Note that in this language, labialization on the velars does behave contrastively. Hence, redundancy vs. contrastiveness has to be established on a MOD-by-MOD basis, and cannot be determined for a language as a whole.

It is important to realize that the distinction between both types of segmental modification systems in principle does not affect the evaluation of the hypothesis given in (2): the relevant data for the languages in Maddieson (1984) show that both can either confirm or disconfirm the hypothesis. The question that is central in this contribution is if there is a systematic relationship between the general patterning of MOD on the one hand and the redundant vs. contrastive nature of MOD on the other.

Cross-linguistically, there appears to be a continuum between fully contrastive MOD and fully redundant MOD. In the perfectly contrastive case, *all* segments with MOD_i have a MOD_i-less counterpart. There are, however, cases in which only a *majority* or *minority* of segments with MOD_i has a MOD_i-less counterpart. Schematically, this can be presented as follows (CONTR = contrastive, S1 to S4 refer to relevant segments in a particular inventory):

(5) *Contrastive systems (CONTR)*

'all'	S1 S1MOD_i	S2 S2MOD_i	S3 S3MOD_i	S4 S4MOD_i
'majority'	S1 S1MOD_i	S2 S2MOD_i	S3 S3MOD_i	– S4MOD_i
'minority'	S1 S1MOD_i	– S2MOD_i	– S3MOD_i	– S4MOD_i

Redundant (RED) MOD can be schematically represented as follows:

(6) *Redundant systems (RED)*

'none'	–	–	–	–
	$S1MOD_i$	$S2MOD_i$	$S3MOD_i$	$S4MOD_i$

For the consonant inventory of each of the 317 languages in Maddieson (1984), we established whether it had one or several types of MOD and, if so, how the MOD type(s) patterned in the consonant inventory. Of the 317 languages, 165 appeared to have one or several instances of MOD. In all, these 165 languages have 283 instances of MOD; for each of these, we established — among other things — its place on the contrastive/redundant continuum. The results of this investigation are presented in Table 1 below. There turned out to be 4 instances of MOD in which exactly half of the MOD_i consonants had MOD_i-less counterparts; these were counted as 'majority'. The results of this part of our investigation are presented in Table 1 below.[4]

Overall, perfect contrastiveness ('all') clearly predominates, with two thirds of the total number of instances of MOD in the sample (190 cases out of 283). Nearly a fifth of the instances of MOD constitute perfect redundancy (55 out of 283). The two intermediate (yet contrastive) types of 'majority' and 'minority' appear to be represented fairly marginally (32 and 6 out of 283).

Moreover, it appears that oral MOD types show relatively few instances of

Table 1. The contrastive/redundant nature of the 283 instances of MOD in the sample (empty cell = 0)

		CONTR.			RED.	total
		all	maj.	min.	none	
LAR	ASP	62	6		28	96
	BRR	2				2
	BRV	6		1		7
	EJE	33	8	2	7	50
	LAR	19	4	1	3	27
	PRA	2				2
ORA	LAB	41	6			47
	PAL	12	6	1	1	20
	PHA	6				6
	VEL	2	1		4	7
NAS	PRN	5	1	1	12	19
total		190	32	6	55	283

redundancy, while nasal MOD types claim relatively few cases of perfect contrastiveness. Proportionately, most redundancy occurs among nasal MOD types and most perfect contrastiveness occurs among oral MOD types.[5]

After this background, we turn to one aspect of the contrastive-redundant dimension that is the focus of the present inquiry. We suspected that redundant MOD systems behaved differently vis-à-vis the general hypothesis given in (2) above than redundant MOD types. More precisely, redundant modification types are predicted to provide more positive evidence for this hypothesis than contrastive ones. This idea is formulated as the following specific hypothesis:

(7) *Specific hypothesis*
Redundant MOD systems occur on natural classes of segments more often than contrastive ones.

We will present our findings with respect to this hypothesis in the next section, and briefly discuss its implications in the concluding section.

4. Contrastive vs. redundant: Phonology vs. phonetics?

According to our general hypothesis, segmental modification occurs on a natural class of segments, rather than randomly or on isolated segments (see (2) above). In this section we demonstrate that redundant systems support this general hypothesis to a much larger extent than contrastive systems, as predicted by the specific hypothesis in (7).

For the instances of MOD in Maddieson's (1984) sample of languages, evidence *pro* and *contra* the general hypothesis comes in three different degrees. Instances of MOD occurring on a single consonant were scored as genuine counterexamples to the general hypothesis (indicated as −−). Languages with MOD on two or more consonants showed a number of different patterns; if a natural class of more than two consonants had one segment without the expected MOD type, this was considered as mild counterevidence (marked as +/−). Cases in which a specific type of MOD occurred on a natural class as well as on a single additional consonant which could not be considered as a member of that class were also analysed as mild counterexamples (marked as +/−). If a set of consonants with MOD formed a natural class and in the language at issue there were no other consonants belonging to this class, this was considered as positive evidence (marked as ++).

Table 2 contains the outcomes of the part of our analyses that are relevant to the evaluation of the specific hypothesis in (7). As an illustration of how to read the results in this table, consider the ++ row. The table shows that there are 184 cases of MOD fully supporting the general hypothesis that MOD occurs on natural

Table 2. Evaluation of the general hypothesis vis-à-vis the contrastive-redundant continuum

	CONTR.			RED	Total
	all	maj	min	none	
++	126	16	2	40	184
+/−	28	11	1	5	45
−−	36	5	3	7	51
Total	190	32	6	52	280[a]

[a] In 3 cases, MOD is not relevant for the general hypothesis. The total number of 280 MOD cases referred to here occurred in 164 different languages.

classes rather than randomly or on isolated segments. 126 out of these 184 instances of MOD are perfectly contrastive, 40 are completely redundant, while 16 and 2 occupy intermediate positions on the contrastive-redundant continuum.

According to the outcomes of the chi square test ($\chi^2 = 15.57$, df = 6, $p < .02$), there is a very significant relationship between the position of MOD on the contrastive-redundant continuum on the one hand and the degree to which it supports or contradicts the general hypothesis on the other. However, the nature of the relationship between the position of MOD on the contrastive-redundant continuum and the way in which it supports or contradicts the general hypothesis is not immediately clear from the figures in Table 2. In order to bring out this pattern more clearly, we will limit our interpretation to the 'clear cases', i.e. the four corner cells in the table. In other words, we will restrict our interpretation to the figures for perfect contrastiveness ('all') and complete redundancy ('none') on the one hand and genuine counterevidence (−−) and positive evidence to the general hypothesis (++) on the other. In all, we thus concentrate on 209 out of 280, i.e. three quarters of the relevant instances of MOD; it should be stressed that in doing so we do not restrict the quantitative analyses to the four 'ideal types'.

Table 2a below contains part of the information in Table 2, adding row percentages, and focuses on the extremes of the contrastive-redundancy dimension.

Table 2a. Evaluation of the general hypothesis, highlighting 'all' vs. 'none'

Gen. hyp.	all		none		Total	
	N	%	N	%	N	%
++	126	68.48	40	21.74	184	100
−−	36	70.59	7	13.74	51	100

As is evident from the figures in Table 2a, perfectly contrastive MOD claims 2.11mv percentage points more genuine counterevidence than positive evidence to the general hypothesis. Completely redundant MOD, on the other hand, claims 8.00 percentage points more positive evidence than genuine counterevidence to the general hypothesis.

Table 2b. Evaluation of the general hypothesis, highlighting the positive and negative evidence

Gen. hyp.	all		none	
	N	%	N	%
++	126	66.32	40	76.92
−−	36	18.95	7	13.46
Total	190	100	52	100

Table 2b contains part of the information in Table 2, adding column percentages, and focuses on the positive and genuinely negative evidence to the general hypothesis. The figures in Table 2b show that positive evidence to the general hypothesis attracts 10.60 percentage points more completely redundant than perfectly contrastive MODs. Genuine counterevidence to the general hypothesis, on the other hand, attracts 5.49 percentage points more perfectly contrastive than completely redundant MODs.[6]

In short, completely redundant MOD systems confirm the general hypothesis that MOD occurs on natural classes rather than randomly or on isolated segment to a considerably larger extent than perfectly contrastive MOD systems, as predicted by the specific hypothesis in (7). Against the background of the empirical fact that, cross-linguistically, redundancy and contrastiveness constitute a continuum rather than a binary variable, this means that the distribution of MOD throughout a consonant inventory is less predictable the more contrastive it is. This, in turn, gives rise to the supposition that contrastive MOD must be available in the lexical representation, whereas redundant MOD is not present before the postlexical level or even the level of the phonetic implementation. These insights are summarized in Table 3.

5. Conclusion

With respect to segmental modification (MOD) in consonant inventories, we find that in principle and in fact there are two predominant language types: perfect contrastiveness and complete redundancy. There are also systems which are in

between these two extremes at several different points, but cross-linguistically these systems form a minority.

It turned out that contrastive MOD systems support the general hypothesis that segmental modification occurs on a natural class of segments rather than randomly or on isolated segments (see (2) above) — proportionately to a much smaller extent than redundant systems. In terms of older phonological theory, this resembles the distinction between lexical and postlexical phonology: lexical phenomena (e.g. rules) may have lexical exceptions, while postlexical phonology is automatic and exceptionless (cf. Lexical Phonology models, Neogrammarian sound laws, etc.). The distinction between contrastive and redundant systems can be related to the distinction between lexical and postlexical strata, respectively. In such a stratal framework, redundant MOD is not present at the lexical level. In that case, the underlying structure of (part of) the phoneme inventory of a language like Wantoat (4), which has redundant prenasalization, would be the following:

(8) Wantoat

vl. plosive	/p	t	k	k^w/
vd. plosive	/b	d	g	g^w/

In a language like this, a postlexical rule supplying MOD would result in the surface prenasalized segments that were given in (4) above: every voiced plosive will be prenasalized. Because postlexical rules tend to apply automatically, the fact that MOD occurs on a natural class is to be expected. Note that this makes the prediction that for this class of segments nasality cannot play a role at the lexical level.

In contrastive systems, on the other hand, such as Nootka ejectivity and labialization (see (3)) but also Wantoat labialization as in (8), the distinction between MOD_i-ful and MOD_i-less segments needs to be stipulated in the lexicon, where idiosyncrasies and other unpredictable properties of lexical items, such as their phonological shape, are stored.[7] In a situation like this, MOD is not necessarily expected to occur on a natural class of segments.

Table 3. Contrastive vs. redundant systems as lexically vs. postlexically determined

	← CONTR	RED →
confirmation of the general hypothesis	−−	++
predictability of segmental distribution of MOD	−−	++
at which level is MOD present?	underlying; lexical	postlexical; phonetic implementation

Current mainstream OT does not recognize the lexical-postlexical distinction. Hence our results are an indication that different strata may have to be recognized, also in OT grammars, a position that is also taken in much other earlier and recent work (see, for instance, many of the contributions to Roca 1997, and Kiparsky, forthcoming).

Notes

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1. In Hinskens & van de Weijer (2003), we did the same for the language Yurak, and also found no discrepancies between Maddieson's source and his interpretation.

2. Note that there is no implicational (i.e. directional) relationship between the segment with and without MOD_i.

3. Of course, contrastive MOD may be neutralized in certain positions. This is the case, for instance, with palatalization in Russian, which is normally contrastive, but the distinction between palatalized segments and non-palatalized ones is neutralized before front vowels. In such cases palatalization is still contrastive in other positions, and will therefore be counted as contrastive in the language as a whole. Maddieson (1984) does not present evidence regarding neutralization of MOD in certain positions or phonological contexts.

4. In this table, 'all', 'majority', 'minority' and 'none' are possible answers to the question of how many consonants with MOD_i have a MOD_i-less counterpart in individual languages (cf. (5) and (6)).

5. With $\chi^2 = 35.63$, df = 6, $p < .001$. Cf. van de Weijer & Hinskens (2003: §3) for further details and considerations.

6. Note that these interpretations would not have been legitimate if the available data had been limited to perfectly contrastive and completely redundant MODs and to genuine counterevidence and positive evidence to the general hypothesis *alone*. In that case, the outcomes of the chi square test ($\chi^2 = 1.1975$, df = 1) would not have pointed towards a significant dependence between the two variables.

7. Hence, minimal pairs based on just the presence vs. absence of a particular MOD type are expected to occur in contrastive systems, not in redundant ones.

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