Contrastiveness Is an Epiphenomenon of Constraint Ranking

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0. Introduction

The theory of phonological representations has standardly been guided by the Jakobsonian view that predictable properties are excluded from the phonological representation (see Anderson 1985, ch. 5), and in particular, that phonetic properties which are not contrastive in any language are excluded from the inventory of phonological features, so as not to predict unattested contrasts. McCarthy (1994), for example, states, "An adequate theory of phonological distinctive features must . . . be able to describe all and only the distinctions made by the sound systems of any of the world's languages." I will argue against the Jakobsonian treatment of contrastiveness, showing (a) that the contrastive or predictable status of features in a sound system falls out from the interaction of certain classes of constraints, rendering the representational restrictiveness of the Jakobsonian approach superfluous; and (b) following Ohala (1990, 1983) and Steriade (1994b), that the phonology must refer even to universally predictable phonetic properties, taking as an illustrative case the duration of voiced and voiceless stops and its role in spirantization.[1]

1. Contrastiveness from Constraint Ranking

1.1. Contrastiveness. Assume the definition of contrastiveness in (1):

(1) **Dfn. *contrastive*:** (a) A feature F is *contrastive in context C* iff for all $\alpha \in \{+,-\}$ an underlying αF specification is always realized in the output as αF in C.
(b) F is *contrastive* (tout court) iff there is some C such that F is contrastive in C.

Any underlying featural distinction which does not meet this definition is, intuitively speaking, unlearnable, and therefore cannot be used to signal distinctions in meaning (the traditional test of contrastiveness). "Feature" is used here in the broadest possible sense: any property of the phonological representation, including prosodic properties. And though the following discussion is couched in terms of binary features, it extends trivially to privative features, by substituting <F, Ø> for <+F, -F>. To simplify the exposition, I will assume full underlying specification.

1.2. PARSE$_F$. I assume an Optimality Theoretic approach (Prince and Smolensky 1993) in which faithfulness is formalized (at least in part) in terms of a set of featural PARSE constraints (Kirchner 1993, Cole and Kisseberth 1994, and Jun 1995).

(2) **PARSE$_F$:** Preserve the underlying value of F in the output.

Thus, a PARSE$_F$ violation is incurred if an underlyingly +F specification is changed to -F on the surface, or vice-versa. As we will see, the existence or non-existence of a corresponding PARSE$_F$ constraint has interesting consequences for the status of F in sound systems.

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[1] My approach has adverse implications for underspecification theory as well, since underspecification theory is essentially a language-particular implementation of the Jakobsonian treatment of contrastiveness with respect to early stages of phonological derivation. Nevertheless, because the inadequacies of underspecification theory, in light of OT (Smolensky 1993, Inkelas 1994, Steriade 1994b) or otherwise (Mohanan 1991, Steriade 1994a), have already received attention, I will not explicitly address them here.

1.3. The Proposition. The contrastive or predictable status of features within a sound system is determined by the ranking of PARSE$_F$ constraints with respect to other constraints which restrict the distribution of the features. More rigorously,

(3) *For all features F, F is contrastive iff*
(1) there is a constraint PARSE$_F$ **and**
(2) for all constraints K which restrict the values of F in some context
(a) PARSE$_F$ » K **or**
(b) there is some feature F' s.t. K refers to F' and
(i) PARSE$_F$ » PARSE$_{F'}$ **or**
(ii) there is no constraint PARSE$_{F'}$.

To prove (3), it is sufficient to show that (A) if the conditions in (3) hold, F is contrastive, and (B), if the conditions in (3) do not hold, F is not contrastive.

A. ***Case 1***: Assume that conditions 1 and 2a are true w.r.t. F. To indicate a distributional constraint which prohibits the occurrence of some value of F in combination with certain values of some number of other features, I use *[αF,βF',...]. (This notation is standardly used for segment-internal ("feature cooccurrence") constraints, but clearly it does not matter for our purposes whether the relation among the features which the constraint prohibits is segment-internal or not.)

(4)

	Input: [αF,βF',...]	PARSE$_F$	*[αF,βF',...]	PARSE$_{F'}$
+	[αF,βF',...]		*	
+	[αF,-βF',...]			*
	[-αF,βF',...]	*!		

(Thick vertical lines indicate crucial ranking.) As shown in the tableau above, PARSE$_F$ is satisfied, either at the expense of *[αF,βF',...] or PARSE$_{F'}$, depending on their relative ranking. Since, under this ranking, underlying αF is always realized as αF on the surface in this context, by definition (1) F is contrastive.

Case 2 : Assume that conditions 1 and 2b are true w.r.t. F. PARSE$_F$ is then satisfied, regardless of the ranking of *[αF,βF',...] w.r.t. PARSE$_F$ or PARSE$_{F'}$.

(5)

	Input: [αF,βF',...]	*[αF,βF',...]	PARSE$_F$	PARSE$_{F'}$
+	[αF,-βF',...]			*
	[αF,βF',...]	*!		
	[-αF,βF',...]		*!	

(We have already seen in Case 1 that if PARSE$_F$ is ranked above *[αF,βF',...], F is contrastive.) A fortiori, PARSE$_F$ is satisfied if there is no constraint PARSE$_{F'}$. Since underlying αF is always realized as αF on the surface, by definition (1) F is contrastive.

Consequently, the conditions in (3) are sufficient to show that a feature is constrastive.

B. ***Case 1***: Assume condition 1 is false w.r.t. F. If there is no constraint on the distribution of F, F occurs in free variation.

(6)	Input: [αF,...]	(no relevant constraints)
+	[αF,...]	
+	[-αF,...]	

If there is a constraint on the distribution of F, *[αF,βF',...], but one or more of the features referred to in the constraint lack a corresponding PARSE constraint, F again occurs in free variation.

(7)	Input: [αF,βF',...]	*[αF,βF',...]
	[αF,βF',...]	*
+	[αF,-βF',...]	
+	[-αF,βF',...]	

Since free variation means that underlying αF is not always realized as αF on the surface, by definition (1), F is not contrastive.

If, however, there is a constraint *[αF,β_1F$_1$,...β_nF$_n$], and all features F$_1$ through F$_n$ do have corresponding PARSE constraints, then F is predictable in the context β_1F$_1$,...β_nF$_n$.

(8)	Input: [αF,β_1F$_1$,...β_nF$_n$]	PARSE$_{F1}$	...	PARSE$_{Fn}$	*[αF,β_1F$_1$,...β_nF$_n$]
+	[-αF,β_1F$_1$,...β_nF$_n$]				
	[αF,β_1F$_1$,...β_nF$_n$]				*!
	[αF,β_1F$_1$,...-β_nF$_n$]			*!	
	...				
	[αF,-β_1F$_1$,...β_nF$_n$]	*!			

That is, both αF and -αF are realized as -αF on the surface, failing to meet definition (1). As shown above, in other contexts, where there is no such relevant distributional constraint, F occurs in free variation. Therefore, if there is no PARSE$_F$ constraint, F is either freely varying or predictable, but never contrastive.

Case 2 : Assume condition 2 is false w.r.t. F. If PARSE$_{F'}$ and *[αF,βF',...] are both ranked above PARSE$_F$, F is predictable in this context.

(9)	Input: [αF,βF',...]	*[αF,βF',...]	PARSE$_{F'}$	PARSE$_F$
+	[-αF,βF',...]			*
	[αF,-βF',...]		*!	
	[αF,βF',...]	*!		

If either PARSE$_{F'}$ or *[αF,βF',...] is unranked w.r.t. PARSE$_F$, then F occurs in free variation.

(10)	Input: [αF,βF',...]	*[αF,βF',...]	PARSE$_{F'}$	PARSE$_F$
+	[-αF,βF',...]			*
+	[αF,-βF',...]		*	
	[αF,βF',...]	*!		

	Input: [αF,βF',...]	PARSE$_{F'}$	*[αF,βF',...]	PARSE$_F$
+	[-αF,βF',...]			*
	[αF,-βF',...]	*!		
+	[αF,βF',...]		*	

Consequently, for any context in which there is a relevant constraint *[αF,βF',...] which dominates or is unranked w.r.t. PARSE$_F$, and PARSE$_{F'}$ dominates or is unranked w.r.t. PARSE$_F$, F is either freely varying or predictable, but never contrastive.

Therefore, the conditions in (3) are both necessary and sufficient to show that a feature is contrastive, Q.E.D.[2]

1.4. Universally noncontrastive features. Recall that in the Jakobsonian treatment of contrastiveness, phonetic properties which are never contrastive in any language are excluded from the phonological representation. However, I have shown in Part B (Case 1) of the previous section that it suffices to assume that such properties lack a corresponding PARSE$_F$ constraint; regardless of ranking, their surface realization will be either predictable or freely varying. Consequently, we may include any and all phonetic properties in the phonological representation, without thereby expanding the range of contrasts available to UG.

1.5. Gradiency of representations. Further consider the familiar phonological strategy of decomposing a continuous phonetic dimension (e.g. vowel height) into a set of binary features.

(11) Vowel height:

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 <---------------------------------------- -high | +high --------------->
 <------------- + low  | -low ------------------------------------------->
|-----------------------------------------------------------------------------|
         lower                                              higher
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Note that if each "step" along the scale need not be contrastive per se, it is possible to subdivide a phonetic continuum into any number of features, each of which corresponds to some range (in principle, even approaching infinitesimality) within that continuum.

(12) Phonetic dimension X:

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 <----------------------------------- . . .  -------------- +n | -n --------->
 <-------------- +B | -B  ---------- . . .  ------------------------------->
 <---- +A | -A --------------------- . . .  ------------------------------->
|------------------------------------  . . .  -----------------------------------|
not at all X                                              completely X
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Thus, in (12), the X dimension is carved up into *n* binary features. The implicational relations among the features (e.g. if -B then -A) follow from their definition as ranges within a particular dimension. “Categorical” effects can be obtained, notwithstanding the gradient representation of the dimension, by means of feature cooccurrence constraints. For example,

[2] In a multi-stratal grammar (if such exist), F will be contrastive just in case (3) characterizes the constraint ranking w.r.t. F at each stratum. We have shown that, on the first round of evaluation, underlying αF maps to output αF just in case (3) holds w.r.t. F. The output, αF, is then taken as the input for the next round of evaluation. But if (3) characterizes the next stratum as well, the same result obtains, and so on, regardless of the number of levels of computation.

in (12), if there is an undominated constraint *[-A,+n], this would rule out segments with some degree of X-ness which lies between the +A and -n cutoffs.

(13)

	Input: [-A,...,+n]	*[-A,+n]	$PARSE_A$	$PARSE_n$
	[-A,...,+n]	*!		
+	[-A,...,-n]			*
+	[+A,...,+n]		*	

(Underlyingly [-A,+n] segment realized either as +A or -n depending on relative ranking of $PARSE_A$ and $PARSE_n$)

Therefore, gradient phonetic distinctions may be represented in the phonology without expanding the range of contrasts available to UG. In sum, one can envision a phonological representation which, in its detail and gradiency, could be equivalent to what has standardly been called a phonetic representation, generally presumed to be the output of a distinct phonetic component of the grammar.[3] I will not argue here that there is no phonetic component distinct from the phonological component. Nevertheless, I have shown that one of the central arguments for positing such a component -- that phonological representations cannot include gradient distinctions and other non-contrastive phonetic detail -- is without force.

2. Motivation for Predictable Phonetic Properties in the Phonological Representation

Although I have demonstrated that Jakobsonian representational restrictiveness is superfluous to an adequate account of phonological contrastiveness, it could still be the case that, as an empirical matter, universally predictable phonetic properties play no role in conditioning phonological phenomena, therefore the phonological representation need not refer to such properties. However, Ohala (1983) and Steriade (1994b) have presented evidence against this claim, namely that the predictable aerodynamic properties of voicing play a large role in explaining the distribution of voiced segments. Similarly, Browman and Goldstein (1992) have argued that subphonemic distinctions in degree of overlap among articulatory gestures can explain a variety of assimilation phenomena. The remainder of this paper concerns itself with a further case of a universally predictable phonetic property which plays a role in conditioning phonological phenomena.

2.1. The problem. The relation between voicing and lenition is a long-standing problem of phonological theory (Foley 1977, Lass and Anderson 1975, Harris 1990, Bauer 1988). For example, in most dialects of Spanish (Harris 1969, Lozano 1979, Castillo and Bond 1987), voiced stops spirantize in certain environments (14a, 15a), while voiceless ones never do (14b, 15b).

(14)
a. pa**β**a 'turkey hen' la**ð**o 'side' to**ɣ**a 'toga'
b. pa**p**a 'potato' la**t**o 'I throb' to**k**a 's/he plays'

(15)
a **b**aɾkos ‘ships’ aj **β**aɾkos ‘there are ships’
dewðas ’debts’ aj **ð**ewðas ‘there are debts’
ɡanaðo ’cattle’ aj **ɣ**anaðo ‘there is cattle’

b. **p**almas ‘palm trees’ *aj **ɸ**almas
toɾos ‘bulls’ *aj **θ**oɾos
kokos ‘coconuts’ *aj **x**okos

[3]Interestingly, this view is consistent with recent research on speech perception, e.g. Pisoni 1992, which suggests that speakers retain in long-term memory all sorts of non-contrastive perceptual information associated with particular tokens of lexical items, including voice characteristics and speaking rate.

Similarly, in Tümpisa Shoshone (Dayley 1989), spirantization (in certain environments) is obligatory in (singleton) voiced stops (16a), but optional in voiceless ones (16b).

(16)	a.	ta**ß**eʧːi̥	'sun'	ʦi**ð**oːhi̥	'push'	tu**ɣ**ʷãnːi	'night'
	b.	taha(**ϕ**/**p**)i̥	'snow'			hußiarɨ(**x**/**k**)i̥	'sing'

In fact, I am aware of no languages in which spirantization which applies to voiceless stops to the exclusion of voiced stops. Nevertheless, despite the well-known and widely attested relation between voicing and lenition, no previous phonological framework has done more than stipulate, by some means or other, that voiced stops are "weaker" than voiceless ones, therefore in some sense closer to continuants.

2.2 Stop duration. The problem can be solved once we take into consideration certain predictable phonetic properties: voiced stops are phonetically shorter than voiceless ones (Lehiste 1975). In Breton, for example, average closure durations for intervocalic voiced stops (averaging across place of articulation) is 49.9 msec, whereas for voiceless stops it is 102.3 msec. Similarly, Homma (1981) reports that in Japanese, voiced stops have an average closure duration of 44 msec, whereas for voiceless stops it is 67 msec. As discussed in the previous section, we can carve up the duration continuum into any number of binary features; but for our purposes a single cutoff point suffices, which we can refer to as [±longer duration].[4]

(17) [longer duration] ([ld]): a segment is [+ld] if its duration is greater than k msec. A segment is [-ld] if its duration is less than or equal to k msec. (For the sake of concreteness let $k = 60$).

It is not crucial to this analysis *why* voiced stops are [-ld], though Ohala (1976, 1983) has suggested some plausible aerodynamic bases for this pattern.[5] I will simply stipulate a feature cooccurrence constraint, *[αvoi, αld, -cont]. Since [ld] is universally non-contrastive, there is no PARSE_{ld} constraint, therefore this feature is universally predictable in stops from the specification of [voi], regardless of ranking.

(18)

	Input: [+voi,+ld]	$\text{PARSE}_{\text{voi}}$	*[αvoi,αld,-cont]
	[+voi,+ld]		*!
+	[+voi,-ld]		
	[-voi,+ld]	*!	
	[-voi,-ld]	*!	*

[4]The feature [ld] is obviously reminiscent of the notion that voiceless stops are specified [+tense] or "fortis"; although [ld] refers to pure duration, whereas [tense] ostensibly refers to the tension of the vocal tract, and the terms fortis and lenis have never had consistent phonetic definitions. However, it matters little whether the [ld] feature is viewed as an original proposal or a revival of an old idea. By Jakobsonian logic, since neither [ld] nor [tense] is contrastive in consonants, neither feature should be included in the representation of consonants. Consequently, phonological motivation for either feature constitutes a refutation of the Jakobsonian position.

[5]Briefly, voiced stops must be short so as to avoid passive devoicing (cessation of Bernoulli vibration of vocal cords due to build-up of oral air pressure during a stop). Voiceless (unaspirated) stops, on the other hand, must be long so as to be simultaneous with the glottal abduction (devoicing) gesture, which has a relatively fixed duration, varying somewhat from speaker to speaker, but rarely less than 60 msec (Weismer 1980) (if the timing is not simultaneous, the devoicing will "spill" onto neighboring sonorants, violating the constraint *[+son,-voi]). If this is the correct explanation, we would expect the value of k in the definition of [ld] to vary somewhat among speakers, due to variation in size of the oral cavity, as well as varying depending on place of articulation (the more anterior the closure, the longer the voicing can last).

	Input: [-voi,-ld]	PARSE_{voi}	*[αvoi,αld,-cont]
	[-voi,-ld]		*!
+	[-voi,+ld]		
	[-voi,-ld]	*!	
	[+voi,+ld]	*!	*

2.3. <u>Spirantization as undershoot</u>. Following Zipf (1949), Lindblom (1984), and others, I assume that articulation (and all other physical activity) is governed by a basic imperative of effort minimization, which I formalize as the following Optimality Theoretic scalar constraint.

(19) LAZY: Minimize articulatory effort

Regardless of precisely how articulatory effort is determined (cf. Westbury and Keating 1986, Lindblom 1990), it seems uncontroversial that for a given closure gesture, the more the duration of the gesture is reduced, the more effort is required to achieve it (at least, provided that the closure is not so long that special effort is required to maintain it, as is perhaps the case in geminates). By the same token, if effort is held constant, the more reduced the duration, the less the magnitude (constriction degree) of the gesture. The tendency of voiced stops to spirantize can now be explained: in a [-ld] segment, in the interest of conserving effort, complete closure may be sacrificed, yielding a continuant. In other words, spirantization can be naturally viewed as a case of articulatory "undershoot" (Lindblom 1963).

2.4. <u>Spanish</u>. To formalize this in OT terms, let X equal the amount of effort required to achieve complete closure in a [-ld] segment. Like all scalar constraints in OT (see Prince and Smolensky, ch. 5), LAZY may decomposed into a set of binary constraints, whose ranking w.r.t. each other is determined by Pāɳini's Theorem (i.e. the Elsewhere Condition).

(20) LAZY_X: Do not exert effort ≥ X.

(21) ... » LAZY_{X+1} » LAZY_X » LAZY_{X-1} » ...

The Spanish spirantization facts can now be accounted for in terms of the following constraint ranking:

(22) {PARSE_{voi}, *[αvoi,αld,-cont], LAZY_X} » PARSE_{cont}

Tableaux (23) and (24) demonstrate that under this ranking, voiced stops spirantize, whereas voiceless stops do not.

(23)

	Input: [+voi,-ld,-cont]	PARSE_{voi}	*[αvoi,αld,-cont]	LAZY_X	PARSE_{cont}
	[+voi,-ld,-cont]			*!	
+	[+voi,-ld,+cont]				*
	[+voi,+ld,-cont]		*!		
	[-voi,-ld,-cont]	*!			

(24)

	Input: [-voi,+ld,-cont]	PARSE_{voi}	*[αvoi,αld,-cont]	LAZY_X	PARSE_{cont}
+	[-voi,+ld,-cont]				
	[-voi,+ld,+cont]				*

More generally, in this sort of framework, lenition is analyzed as some degree of LAZY dominating some $\text{PARSE}_{\text{manner feature}}$ constraints (see Kirchner 1994).[6] The environments for spirantization can be obtained by blocking spirantization (or even requiring fortition) in particular environments, by means of higher-ranked constraints, which are not directly relevant here.

2.5. Tümpisa Shoshone. This analysis can readily be extended to account for the optional spirantization of voiceless stops in Tümpisa Shoshone, while still capturing the relation between voicing, closure duration, and spirantization. We simply need to identify the amount of effort required to achieve complete closure in a voiceless stop: call this Y. The optionality of spirantization can be captured by leaving LAZY_{Y} and $\text{PARSE}_{\text{cont}}$ unranked w.r.t. each other.[7]

(25)

	Input: [-voi,+ld,-cont]	*[αvoi,αld,-cont]	LAZY_{X}	$\text{PARSE}_{\text{cont}}$	LAZY_{Y}
+	[-voi,+ld,-cont]				*
+	[-voi,+ld,+cont]			*	
	[-voi,-ld,-cont]	*!			

Crucially, since the duration of the voiceless stops is longer than the voiced stops, X is less than Y; so by Pāṇini's Theorem LAZY_{X} is universally ranked above LAZY_{Y}. Consequently, it is impossible to have a system in which the longer (voiceless) stops spirantize, while the shorter (voiced) ones do not.

3. Conclusion

I have shown that, contrary to the Jakobsonian view, an adequate treatment of contrastiveness does not require the exclusion of universally predictable features from the phonological representation. Rather, the predictable or contrastive status of features falls out from the ranking of PARSE_{F} constraints w.r.t. constraints which restrict the distribution of these features; and universally predictable features simply lack a corresponding PARSE_{F} constraint. Consequently, phonological representations may contain an unlimited amount of phonetic detail, including gradient distinctions, without thereby increasing the range of contrasts available to UG. Furthermore, I have presented an example of a phonological phenomenon, the relation between stop voicing and spirantization, which is conditioned by a universally predictable phonetic feature, namely the durational distinction between voiced and voiceless stops. Therefore, enrichment of phonological representation to include some predictable phonetic features is not only feasible: it is empirically necessary. The question of which predictable phonetic features, beyond stop duration, are relevant to phonological

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[6]See Jun (1995) for a similar treatment of place assimilation.

[7]The problem of optional rules is a non-trivial one in constraint-based formalisms. The device of indeterminate ranking, seems too powerful, in that it fails to characterize just the sorts of variation typically encountered within a given idiolect. Lindblom (1990) has observed that intra-speaker variation typically involves variation along a hypoarticulation - hyperarticulation continuum, where hypoarticulation maximizes ease of articulation, and hypoarticulation maximizes preservation of acoustic cues. In Kirchner (1994), this notion is modeled within OT by assuming that the input to phonological computation contains not only the underlying representation, but also some information about the current extralinguistic state of the system, including tiredness, preoccupation, etc. This information might take the form of a numerical index, which augments or diminishes by some constant function the "effort" cost associated with each articulatory gesture. Variation in the value of this index would, in effect, correspond to adjustment of feedback gain in Lindblom's H&H model. In the present case, it suffices to assume that under hypoarticulation conditions, the "effort" index boosts the cost of a voiceless stop gesture to X (and the cost of a voiced stop to something greater than X).

phenomena becomes a wide-open field of empirical inquiry, now that the blinders imposed by the Jakobsonian treatment of contrastiveness have been removed.

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