A Non-Representational Theory of Contrastiveness

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0. Introduction

A fundamental observation of our field, dating back to Saussure (1916), is that out of the rich sound signal of speech, a tiny subset of phonetic properties is treated as distinctive in any given language, and that the members of this subset vary from language to language. In rule-based theories of phonology, there appeared to be only one way to capture this observation: namely, by excluding the non-distinctive phonetic properties from some level of the phonological representation, yielding an abstract categorical representation of the contrasts among the speech sounds (Jakobson 1939). Universally non-contrastive features have generally been assumed to be unspecified throughout the phonological component. Language-particular non-contrastive features have generally been assumed to be unspecified only in early stages of the derivation (e.g. Archangeli and Pulleyblank 1986). Moreover, since the discovery of extensive language-particular gradient alternations (including many alternations once thought to be categorical), it has standardly been assumed that a subsequent phonetic component is needed, to fill in such properties (see generally Pierrehumbert 1994). This model is schematized in Figure 1.

Figure 1:
The standard (representational) treatment of contrastiveness

Underlying Representation ⇓	*(ideally) pure representation of contrast*
Phonological component ⇓	*prosodic structure filled in, non-contrastive phonetic properties may be filled in, particularly if contrastive in other languages*
Phonetic component ⇓	*remaining non-contrastive phonetic properties, including gradient values, filled in*
Phonetic Representation	*representation of all language-specific (or speaker-controlled?) phonetic properties of the utterance*

The crucial property of this model is its representational characterization of contrastiveness: an abstract representation of pure contrast must be assumed, with extensive derivational machinery to mediate between this abstract level and the sea of surface phonetic detail.

2. Previous OT Challenges to the Standard Model

Certain aspects of this model, particularly the assumptions surrounding underspecification theory, have been challenged since the development of Optimality Theory. In particular, Smolensky (1993) has shown that the phonological "inactivity" of predictable features may be attributed to rankings of a particular class of constraints, rather than to the absence of such features from the representation at some stage of a derivation. Assume that the notion of faithfulness is, in part, formalized in terms of the following class of feature-specific PARSE and FILL constraints:

(1) PARSE$_F$: For all $\alpha \in \{+,-\}$ if the feature F is specified α in the input, it is specified α in the output.
FILL$_F$: If ØF in input, then ØF in output.

For example, PARSE$_{back}$ is satisfied just in case an underlyingly [+back] segment is realized as [+back] in the output, and violated if the segment is realized as [-back] (or [Øback], e.g. if the segment is deleted); and FILL$_F$ is violated just in case a specification for back is inserted in the output. Now, for example, the "transparency" of the vowels [i,e] in Finnish backness harmony, traditionally attributed to underspecification of these vowels for [back] when the spreading rule applies, can instead be analyzed in terms of the constraint hierarchy in (2) (modified slightly from Smolensky's presentation).

(2)

		*[-low, -round,+back]	ALIGN(+back, right)	PARSE$_{back}$	*[-low,+round, -back]	*EMBED	FILL$_{back}$
a.	Input: u-I-U						
☞	u-i-u					*	**
	u-I-u	*!					**
	u-i-ü		*!		*		**
	u-I-ü	*!	*		*		**
	ü-i-ü		(vacuously)	*!	**		**
b.	Input: u-i-u						
☞	u-i-u					*	
	u-I-u	*!		*			
	u-i-ü		*!	*	*		
	u-I-ü	*!	*	**	*		
	ü-i-ü		(vacuously)	**	*!*		
c.	Input: u-I-ü						
☞	u-i-u			**		*	
	u-I-u	*!		*			
	u-i-ü		*!	*	*		
	u-I-ü	*!	*		*		
	ü-i-ü		(vacuously)	**	*!*		

I = +high, -round vowel, unspecified for back, U = +high, -round vowel, unspecified for back. I interpret [back] s.t. a surface vowel which is Øback is physically impossible, therefore not generated as a possible candidate.
ALIGN(+back,right): requires that a +back specification spread to the right edge of the word.
*EMBED: prohibits embedding of a -back domain inside a +back domain (i.e. in autosegmental terms, spreading which results in a line-crossing or gapped configuration).

Observe that the correct result is obtained whether we assume an input in which the target vowels are unspecified w.r.t. back (2a), a fully specified input (2b), and even an input whose specifications are *contrary* to the surface values (2c). Since PARSE$_{back}$ is ranked below ALIGN(+back, right), it is better to spread [+back] than to preserve underlying values; and since *[-low,-round, +back] is ranked above PARSE$_{back}$, back unrounded high or mid vowels are ruled out in all contexts. The essential observation here is that low-ranking of a PARSE constraint for a particular feature results in phonologically inert behavior of that feature within the sound system. There is no need for restrictions on the presence of particular features at some level of representation.

On the other hand, Inkelas (1994) has shown that a limited role remains for underspecification in OT analyses. First, given general assumptions of the OT framework, there is no a priori reason to ban underspecified inputs, just as there is no reason to require systematic underspecification. Second, whenever the surface realization of some predictable feature within a morpheme alternates, neither surface value is learnable, therefore the underlying representation must be unspecified with respect to that feature. Finally, underspecification is necessary to describe ternary featural behavior, as in Turkish word-final devoicing, where certain stems are invariantly voiced, others are invariantly voiceless, and a third class of stems exhibit alternations.

(3)	Invariantly voiced:	etüd 'etude'	etüd-ü 'etude-acc.'
	Invariantly voiceless:	sanat 'art'	sanat-I 'art-acc.'
	Alternating:	kanat 'wing'	kanad-I 'wing-acc.'

Generally, however, the determination of the underlying specification of predictable features is grammatically irrelevant. That is, the constraint ranking is such that the correct surface patterns are obtained regardless of the choice of underlying representation, as we saw in (2). Even in the Turkish case, the ternary behavior of the stems does not arise *because* we have posited certain underspecified stems; rather, the possibility of such underspecified stems in Turkish is attributable to the constraint ranking, as is shown in the Appendix.

3. The Program

I will show that these observations of Smolensky's and Inkelas' can be extended to provide a comprehensive treatment of contrastiveness, without resorting to the representational and derivational assumptions of the standard model. This move permits phonological representations to include as much phonetic detail as may be necessary to adequately characterize a given speaker's phonetic competence. A significant derivational residuum, namely the post-phonological phonetic component, is thereby eliminated from the theory, as is shown in Figure 2.

Figure 2:
A constraint-ranking treatment of contrastiveness

Underlying Representation ⇓	*no linguistic restrictions characterize this level of representation*
Phonological component: Gen + H-eval	*contrastive, categorical behavior of particular features falls out from constraint system*
⇓ Phonetic Representation	*representation of all speaker-controlled phonetic properties of the utterance*

Nevertheless, this approach will preserve the ability of phonological theory to distinguish the contrastive and categorical behavior of certain properties from the behavior of the remainder of properties within the sound system.[1]

4. An Input-Output Relational Definition of Contrastiveness

Assume the definition of contrastiveness in (3):

[1]Note that Flemming (in progress) has reached similar conclusions with respect to phonetic detail in phonological representations, though his approach relies on a family of constraints which refer explicitly to the maintaining of contrasts, rather than relying on faithfulness constraints.

(4) **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.

In other words, a feature is contrastive just in case there is some context such that both underlying specifications of the feature map faithfully to the surface values. 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) (Inkelas 1994, Steriade 1995).

5. Language-Specific Redundant Properties: Aspiration and Voicelessness

Now consider the relation between the ranking of faithfulness constraints and contrastiveness, beginning with aspiration and voicelessness. To capture the aspiration of voiceless stops in English, I posit, as a crude descriptive approximation, the constraint in (5):

(5) ASPIRATE: +sg iff $[\underset{\text{-son,-voi}\atop\text{-cont}}{\_\_\_\_\_}X]_{\sigma'}$ (a voiceless stop is aspirated iff it is the first segment in a stressed syllable)

The English pattern corresponds to the ranking in the tableaux in (6):

(6)

	a. Input: $[p...]_{\sigma'}$	PARSE$_{VOI}$	ASPIRATE	PARSE$_{SG}$
	$[p...]_{\sigma'}$		*!	
	$[b...]_{\sigma'}$	*!		
☞	$[p^h...]_{\sigma'}$			*
	b. Input: $[p^h...]_{\sigma'}$			
	$[p...]_{\sigma'}$		*!	*
	$[b...]_{\sigma'}$	*!		*
☞	$[p^h...]_{\sigma'}$			
	c. Input: $[p...]_{\sigma'}$			
☞	$[p...]_{\sigma}$			
	$[b...]_{\sigma}$	*!		
	$[p^h...]_{\sigma}$		*	*
	d. Input: $[p^h...]_{\sigma'}$			
☞	$[p...]_{\sigma}$			*
	$[b...]_{\sigma}$	*!		*
	$[p^h...]_{\sigma}$		*!	

Tableaux (6a) and (b) show that, regardless of underlying specification for [sg], a voiceless stop in initial position within a stressed syllable is realized as aspirated. Tableaux (6c) and (d) show that, regardless of underlying specification for [sg], a voiceless stop in an unstressed syllable (more generally, any segment in the complement of the context in (5)) is realized as unaspirated. Moreover, we obtain the same result if the stop is unspecified for aspiration:

(7)	Input: $[P...]_{\sigma'}$	PARSE_{voi}	ASPIRATE	PARSE_{sg}
	$[p...]_{\sigma'}$		*!	
	$[b...]_{\sigma'}$	*!		
☞	$[p^h...]_{\sigma'}$			
	Input: $[P...]_{\sigma}$			
☞	$[p...]_{\sigma}$		*!	
	$[b...]_{\sigma}$	*!		
	$[p^h...]_{\sigma}$			

If, however, ASPIRATE is ranked below PARSE_{sg}, then aspiration is contrastive, as is shown in tableau (8):

(8)	a. Input: $[p...]_{\sigma'}$	PARSE_{voi}	PARSE_{sg}	ASPIRATE
☞	$[p...]_{\sigma'}$			*
	$[b...]_{\sigma'}$	*!		
	$[p^h...]_{\sigma'}$		*!	
	b. Input: $[p^h...]_{\sigma}$			
	$[p...]_{\sigma}$		*!	
	$[b...]_{\sigma}$	*!	*	
☞	$[p^h...]_{\sigma}$			*

Under this ranking, the underlying specification for [sg] surfaces unchanged, whether or not aspiration occurs in a stressed syllable. Observe that the contrastive or predictable status of [sg] in the foregoing tableaux is entirely determined by the ranking of PARSE_{sg} with respect to the constraint on its distribution. *The predictable status of aspiration in (5) in no way depends on the feature's absence from any level of phonological representation.*

6. Universally Non-Contrastive Properties: Sub-Phonemic Durational Distinctions

Next, consider a universally non-contrastive property, such as the durational distinction between high and non-high vowels: high vowels are phonetically shorter than their non-high counterparts, typically by 20 to 40 msec. (though this durational distinction is considerably less than the distinction between long and short vowels), (Lehiste 1970). This phonetic property arguably explains the tendency of high vowels to syncopate, as in most dialects of Arabic; the high quality of epenthetic vowels, as in Turkish; the avoidance of stress on high vowels, as in Asheninca; and the ban on long high vowels, as in Yawalmani. Assume a phonetic feature, [slightly longer duration], such that +sld characterizes non-high vowels, and -sld characterizes high vowels. Since sld is universally non-contrastive, we simply assume that UG contains no corresponding faithfulness constraint, PARSE_{sld}. The value of sld is therefore determined by the feature cooccurrence constraints in (9), regardless of its ranking, as is shown in tableau (10) (VÖ = a +sld vowel, V = a -sld vowel).

(9) +SLD↔-HIGH: +sld iff -high

(10)

	a. Input: i	PARSE$_{high}$	+SLD↔ -HIGH
	iÖ		*!
☞	i		
	aÖ	*!	
	a	*!	*
	b. Input: iÖ		
	iÖ		*!
	i		
☞	aÖ	*!	
	a	*!	*

	c. Input: a	PARSE$_{high}$	+SLD↔ -HIGH
	iÖ	*!	*
	i	*!	
☞	aÖ		
	a		*!
	d. Input: aÖ		
	iÖ	*!	*
	i	*!	
☞	aÖ		
	a		*!

Regardless of underlying specification, high vowels surface as -sld and non-high vowels as +sld. Once again, the non-contrastive behavior of the feature in question emerges from the constraint system; not from the assumption that such properties are excluded from phonological representation, or from any level of representation within the phonological component. The distinction between this case and the previous one is that sld is non-contrastive under *any* ranking, due to the lack of a PARSE$_{sld}$ constraint; and since rankings are all that distinguish phonological systems in OT, this amounts to showing that the feature is non-contrastive universally.

7. Generalizing the Result: the Contrastiveness Theorem

The ability to characterize the predictable or contrastive status of features in terms of the constraint system (either under particular rankings or universally), rather than in terms of representational restrictions, is not limited to the cases just considered, but rather is fully general: the theorem in (11) completely expresses the conditions under which a feature will have contrastive status within a sound system.

(11) **The Contrastiveness Theorem**
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$_{F'}$.

A formal proof of this theorem is given in Kirchner (1995). The Contrastiveness Theorem may be restated, in somewhat more intuitive form, as follows: a particular feature is contrastive just in case there is a corresponding PARSE constraint ranked such that it is *active* in the constraint hierarchy, i.e. crucial in ruling out certain candidates for some input (Prince and Smolensky, p. 82). This condition corresponds straightforwardly to the definition of contrastiveness in (4). If there is some context such that both underlying specifications for a feature are always faithfully realized in that context, it can only be because the constraint which requires faithful mapping of the feature, namely the corresponding PARSE constraint, is active in the constraint hierarchy.

8. Categorical Effects with Continuous Representations

It is standardly claimed that "phonological" representations are categorical, whereas "phonetic" representations are gradient. Consider a property such as vowel height, which corresponds to a physical dimension: articulatorily, in terms of the physical distance between tongue body and palate: or acoustically, in terms of the frequency of the first formant. For purposes of phonological analysis, this physical continuum is standardly divided into three regions, low, mid and high, which are formally represented in terms of two binary features: ±low and ±high, as is shown in (12).

(12) Vowel height continuum subdivided using two binary features:

```
<--------------------------------------- -high | +high -------------->
<------------ + low  | -low ----------------------------------------->
|---------------------+-------------------------+---------------------|
       lower                                          higher
```

Clearly, the claim of phonological categoricalness cannot mean that there can be at most a binary distinction for any phonetic dimension; for at least a ternary distinction in vowel height is required. If, however, the claim of phonological categoricalness is that the phonology represents phonetic dimensions in terms of some number of binary features, then the claim is vacuous, since this technique can be applied iteratively to yield a quasi-continuum.

(13) Vowel height continuum (in terms of frequency of F1 in Hz) subdivided using 1000 binary features, yielding a quasi-continuum:[2]

```
 <------------------------------------- . . . ----- ≤ 1199 | > 1199 ->
                                        . . .
 <------- ≤ 2 | > 2 ------------------- . . . ------------------------>
 <- ≤ 1 | > 1 ------------------------- . . . ------------------------>
0 | > 0 ------------------------------- . . . ------------------------>
 |-----+-----+------------------------- . . . --------------+----------|
   higher                                                  lower
```

As shown in (13), the F1 frequency continuum, from 0 to 1200 Hz, can be divided into increments of 1 Hz, defined in terms 1200 binary features of the form [± F1 > X Hz]. This scale is certainly fine enough for any linguistic phonetic analysis, but if a closer approximation to a true continuum were required, we could simply subdivide the dimension into an even greater number of binary distinctions, such that the increments approach infinitesimality.

If there is any truth to the claim of phonological categoricalness, it lies in the observation that a small number of points along the phonetic dimension will be contrastive in any given language. *But this is simply a special case of distinguishing between contrastive and non-contrastive properties, which can be adequately handled in terms of the constraint system, without representational restrictions, as shown in the preceding sections.*

To make this clear, let us adopt a quasi-continuous representation of vowel height, as in (13), to describe a language with a three-way distinction of vowel height. We simply need to identify the two features which serve as the boundaries between mid and non-mid vowels for the relevant speaker: for the sake of concreteness, say ± F1 > 600 Hz and ± F1 > 1000 Hz:

(14)	- F1 > 600 Hz	=	+high	=	high
	+ F1 > 600 Hz, - F1 > 1000 Hz	=	-low, -high	=	mid
	+ F1 > 1000 Hz	=	+low	=	low

To capture the three-way contrast, it suffices to assume that PARSEF1>600Hz and PARSEF1>1000Hz are active in the constraint hierarchy, and that the remaining possible

[2]The "higher" and "lower" labels switch position because of the inverse relation between vowel height and F1 frequency.

distinctions in F1 frequency, e.g. $\pm$ F1 > 522 Hz, either lack corresponding PARSE constraints universally, or these constraints are inactive due to low ranking.

The class of constraints which might systematically render certain faithfulness constraints inactive are the dispersion constraints, which militate in favor of maximal dispersion of the values within the relevant phonetic dimension (Liljencrants and Lindblom 1972, cf. Flemming in progress), thereby enforcing a sort of phonetic categoricalness.

(15) DISP(F1,binary): F1 = 200 or 1200 Hz
DISP(F1,ternary): F1 = 200, 700 or 1200 Hz
DISP(F1,quaternary): F1 = 200, 533, 867, or 1200 Hz
etc.

Under the ranking shown in tableau (16), only a ternary surface distinction in vowel height is possible (200, 700 or 1200 Hz), regardless of input values for F1, notwithstanding the presence of a constraint PARSE$_{F1>522Hz}$ within the hierarchy.[3]

(16)

	a. Input: F1=804	DISP(tern)	PARSE$_{>600}$	PARSE$_{>1000}$	PARSE$_{>522}$	DISP(bin)
	F1 = 200		*!		*	
	F1 = 1200			*!		
	F1 = 523	*!	*			*
☞	F1 = 700					*
	b. Input: F1=523					
☞	F1 = 200				*	
	F1 = 1200		*!	*	*	
	F1 = 523	*!				*
	F1 = 700		*!			*
	c. Input: F1=1019					
	F1 = 200		*!	*	*	
☞	F1 = 1200					
	F1 = 523	*!		*		*
	F1 = 700			*!		*

Of the three surface values permitted by DISP(F1,ternary), the one assigned to a particular input value is the one which involves crossing no significant "boundaries", i.e. violating no active PARSE constraints. Thus, in (16a), going from an underlying value of 804 Hz to a surface value of 700 Hz does not cross the 600 or 1000 Hz boundaries enforced by the active constraints PARSE$_{>600}$ and PARSE$_{>1000}$; if, however, the input is lower than 600 Hz, as in (16b), the surface value which crosses no significant boundary is 200 Hz (though it violates the inactive PARSE$_{>522}$). Again, the ternary surface distinction is attributable entirely to the constraint system; it does *not* depend on input representations which contain nothing but categorical distinctions in vowel height.

[3]Note that not all possible rankings of DISP and PARSE constraints for a particular phonetic dimension give rise to plausible surface patterns. Specifically, if more than one DISP constraint for a given dimension is active within the hierarchy, the result will be a composite set of surface values, e.g. {200, 533, 700, 1200}, which is not itself optimally dispersed. We must therefore stipulate a ranking condition such that at most one DISP constraint for a given dimension may be active. Furthermore, Flemming (in progress) claims that dispersion only comes into play with respect to contrastive features. This generalization, if correct, might be captured in terms of a ranking condition such that no constraint may be crucially ranked between the PARSE constraints and any active DISP constraint for a given phonetic dimension. See Flemming (in progress) for an alternative approach to formalizing dispersion and contrastiveness.

A possible objection to this approach is that it appears, ironically, to be *too* categorical, i.e. predicting a narrow set of precise and invariant surface values for F1 frequency, when in fact we observe a great deal of surface variation. However, we can reintroduce variation into the picture in a number of ways. To the extent that the variation within a particular idiolect is completely free, the dispersion constraints, rather than identifying precise values, might specify permissible *ranges* of values. To the extent that the variation is contextually determined, the dispersion constraints could be outranked in particular contexts by competing constraints, e.g. articulatory constraints favoring vowel reduction in shorter syllables. Finally, with respect to *inter*-speaker variation, I have no answers at this point; nor does anyone else, so this deficiency cannot be taken as an objection to my approach.

9. Gradient Phonology: Japanese Tone Structure

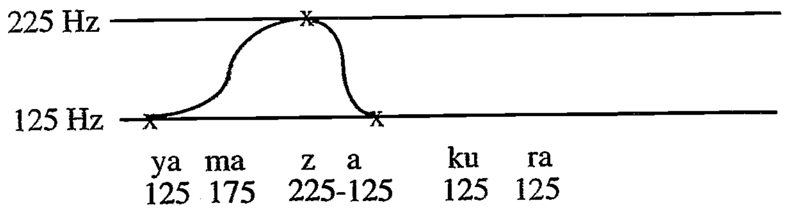
As an illustration of the extension of Optimality Theoretic phonology to gradient phenomena, consider the case of Japanese tone structure. In the framework of Pierrehumbert and Beckman (1988), highly underspecified lexical tonal representations (at most one tone, a HL contour, per prosodic word) interact with rules of boundary tone assignment as shown in (17):

(17)
```
         HL
         |
/yama-zakura/          ('wild cherry')

L%       HL
 \       |
 ya ma  za ku ra
```

Finally, in phonetic realization, F0 values for the remaining unspecified syllables are filled in by interpolation between the H and L "targets" (modulo downdrift and downstep), as shown in Figure 3:

Figure 3:
Interpolation of F0 values



However, the absence of a rich lexical tonal system may be attributed to constraints, without recourse to lexical or phonetic underspecification:

(18) L%: Phrase begins with low F0 value (125 Hz).
1TONE: At most 1 sharply falling F0 contour (225-125) within a prosodic word.
PARSE$_{HL}$: Preserve sharply falling F0 contour.
LAZY: Minimize modulation of F0 values (for articulatory reasons?)
PARSE$_{F0}$: Preserve (other) F0 properties

For purposes of assessing violations of LAZY, I assume that F0 modulation = the sum of the squares of the differences between each F0 value and the following F0 value:

(19) 213 141 225-125 225-125 151
ya ma za ku ra

Modulation = $(213-141)^2 + (141-225)^2 + (225-125)^2 + (125-225)^2 + (225-125)^2 + (125-151)^2 = 42916$

125 125 125 125 125
ya ma za ku ra

Modulation = 0

(20)

Input: 213 141 225-125 225-125 151 ya ma za ku ra	L%	1TONE	PARSEHL	LAZY	PARSEF0
213 141 225-125 225-125 151 ya ma za ku ra	*!	*		42916	
125 125 225-125 225-125 125 ya ma za ku ra		*!		30000	213→125 141→125 151→125
213 141 225-125 125 125 ya ma za ku ra	*!		*	22240	151→125
225 225 225-125 125 125 ya ma za ku ra	*!		*	10000	213→125 141→125 151→125
125 125 225-125 125 125 ya ma za ku ra			*	20000 !	213→125 141→125 151→125
☞ 125 175 225-125 125 125 ya ma za ku ra			*	15000	213→125 141→175 151→125
125 125 125 125 125 ya ma za ku ra			**!	0	213→125 141→125 151→125

The point here is not that the underlying representation of this word includes all these unlearnable F0 values, but that even if it did, we would still obtain the appearance of lexical underspecification of tone, due to LAZY outranking PARSEF0: the F0 values of the output are determined by considerations of articulatory economy and other distributional constraints, regardless of the underlying values (except for one HL contour, which is preserved). Note that LAZY enforces the "gradiency effect" that the second syllable in the winner has an F0 value intermediate between that of the first and third syllable (to minimize modulation), just as if that value were filled in by linear interpolation, but without requiring a distinct, post-phonological level of representation. The representation above is temporally categorical, i.e. F0 values are presented in syllable-sized temporal units; but we could easily adopt a more continuous temporal representation, without changing the substance of the analysis.

10. Conclusion

I have shown that some standard assumptions concerning phonological representation, and the "phonetics-phonology interface," warrant reevaluation in light of OT. Specifically, the motivation for excluding non-contrastive properties from the phonological representation, or any derivational stage therein, evaporates under Optimality Theoretic analyses which include feature-specific PARSE constraints. As the Contrastiveness Theorem states, the contrastiveness of a particular property depends entirely on the ranking of the corresponding PARSE constraint relative to other constraints which restrict its distribution. This result extends even to properties which are not contrastive in any language, if we simply assume that such properties lack a correspond PARSE constraint. Finally, the distinction between categorical and gradient properties, standardly assumed to characterize the difference between phonological and phonetic representation, proves to be a special case of the previous result. Consequently, we may capture the categorical and contrastive *behavior* of particular phonetic properties (and the predictable or gradient behavior of the remainder) in terms of constraint systems, while using *representations* which in principle may contain complete phonetic detail, including gradient properties.

Apendix: Ternary Featural Behavior

Consider the ternary featural behavior of stem-final obstruents in Turkish (3). Such behavior is attributable to the ranking PARSE$_{voice}$ » {FINAL DEVOICING, PRE-VOCALIC VOICING}: the FINAL DEVOICING and PRE-VOCALIC VOICING constraints therefore come into play only when the stem-final obstruent has no voicing specification which it must be faithful to. But we now face the question: how do we characterize the grammatical distinction between a language such as Turkish, with ternary behavior, and languages where stem-final plosives are always invariantly voiceless or voiced, but never alternating, such as French. It is not a sufficient to stipulate that Turkish has a class of unspecified stems whereas French does not: for we are assuming that the only constraint on underlying representation is the extra-grammatical constraint of learnability. Nor can we explain the different underlying representations of French and Turkish in terms of the surface pattern, for we have then fallen into circular reasoning: Turkish has alternating surface forms because it has underspecfied stems, because it has alternating surface forms. The solution involves the FILL$_{voice}$ constraint: specifically, if FILL$_{voice}$ is ranked low, it is possible to have an underlying representation which is unspecified wrt voice, and thereby satisfies the higher-ranked PARSE$_{voice}$, FINAL DEVOICING, and PRE-VOCALIC VOICING constraints, thereby giving rise to the alternating forms as in Turkish:

(21)

	PARSE$_{voice}$	FINAL DEVOICING	PRE-VOCALIC VOICING	PARSE$_{other}$ consonant features	FILL$_{voice}$
kanaT → kanat					*
kanaT → kanad-I					*

If however, FILL$_{voice}$ is ranked high, specifically above PARSE$_{other\ consonant\ features}$, any consonant which is underlyingly unspecified for voice will delete in all contexts.

(22)

		FILL$_{voice}$	PARSE$_{other}$ consonant features
	kanaT → kanat	*!	
☞	kanaT → kana		*

Consequently, under this ranking, there *is* no mapping of an underspecified stem-final obstruent to voiced and voiceless alternants. This is sufficient to capture to rule out ternary featural behavior, as in French.

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