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# On the Acquisition of Phonological Contrasts*

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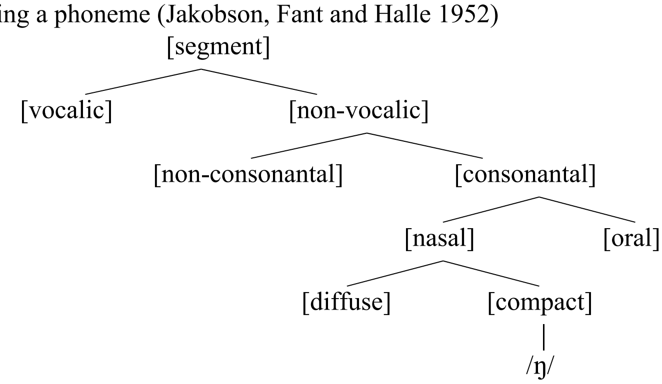
## 1. Contrast, phonological activity, and acquisition

Many discussions of language acquisition at some point include the phrase 'Jakobson...proposed', or 'following Jakobson'. In keeping with this tradition, let me begin by observing that Jakobson, Fant and Halle (1952) proposed that listeners distinguish phonemes by making a series of ordered binary choices that correspond to the oppositions active in their language. For example, suppose we hear [ŋ] in a language in which this is a phoneme. One possible way of ordering the series of binary choices might be as follows:

(1) Identifying a phoneme (Jakobson, Fant and Halle 1952)




Given a segment, the first choice is if it is vocalic or non-vocalic. If non-vocalic, the next choice is consonantal or non-consonantal. If consonantal, there is a contrast between nasal and oral. If nasal, it can be diffuse or compact. If compact, there are no further choices in this language.

Observe that this procedure gives only *contrastive* specifications of /ŋ/. In fact, it *defines* which specifications are contrastive. Conversely, any specification which is not required in the series of choices is by definition *redundant*. Notice that the *ordering* of the choices is crucial: The features [voiced] and [continuant], for example, do not appear because they are ordered too late to matter in the identification of this segment.

Since Saussure, it has been a cliché that contrast is central to linguistic theory. As we have just seen, Jakobson proposed that phonemes are differentiated by their

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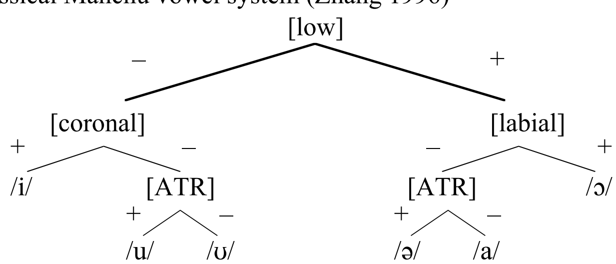
contrastive specifications. Not all theories of phonology, however, have assigned an important role to contrast. In fact, the role of contrast in phonology is still not well understood. Beyond its role in differentiating phonemes, I will assume that there is a connection between contrast and phonological activity, as expressed by the hypothesis in (2).

(2) Hypothesis about contrast and phonological activity
Only contrastive features are *active* in the (lexical) phonology. Redundant features are phonologically *inert*.

The synchronic and diachronic patterning of Manchu vowel systems (Zhang 1996) illustrate the connection between contrastiveness and phonological activity, and support the above hierarchical approach to contrast. Zhang (1996) proposes the contrastive hierarchy in (3) for Classical Manchu, where the order of the features is [low] > [coronal] > [labial] > [ATR].

(3) Classical Manchu vowel system (Zhang 1996)[1]




Part of the evidence for these contrastive specifications comes from the following observations:

a. /u/ and /ə/ trigger ATR harmony, but /i/ does not, though /i/ is phonetically [ATR]. This can be explained if /i/ lacks a phonological specification for [ATR].
b. /ɔ/ triggers labial harmony, but /u/ and /ʊ/ do not, though they are phonetically [labial]. This fact is consistent with the latter vowels being unspecified for [labial].

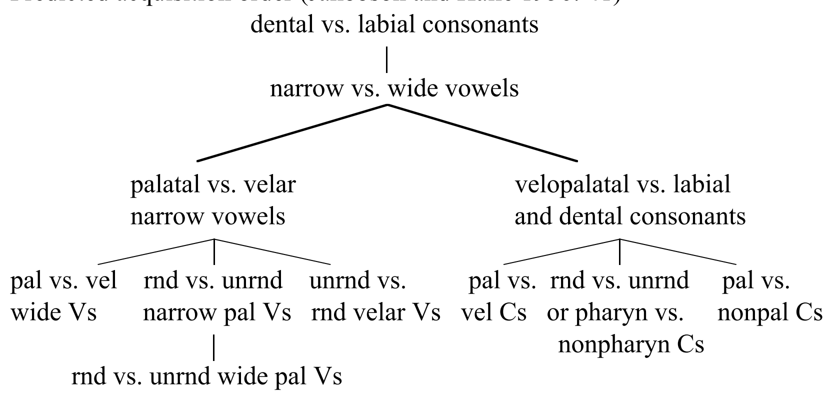
Jakobson, Fant and Halle go so far as to state that the 'dichotomous scale', which I will call a *contrastive hierarchy* (Dresher 2003a, b), 'is the pivotal principle of the linguistic structure.' Following Jakobson, then, I will henceforth assume that (a) there is a significant relationship between contrast and phonological activity; and (b) the dichotomous scale, i.e., the contrastive hierarchy, is the proper way to assign contrastive feature specifications

Jakobson and Halle (1956) suggest further that distinctive features are necessarily binary because of how they are *acquired*, through a series of 'binary

[1] Zhang (1996) assumes privative features: [F] vs. the absence of [F], rather than [+F] vs. [–F]. The distinction between privative and binary features raises a number of interesting issues, some of them relevant to how contrast is to be interpreted, but it is not crucial to the matters under discussion here.

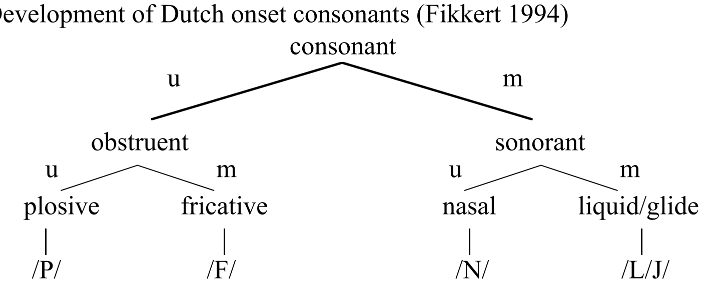
fissions'. They propose that the order of these contrastive splits is partially fixed, thereby allowing for certain developmental sequences and ruling out others. For example, they predict the acquisition sequences for oral resonance (primary and secondary place) features shown in (4). In this diagram, a contrast at a node must be acquired before a contrast at its daughter nodes, but sister nodes can be expanded in any order.

(4) Predicted acquisition order (Jakobson and Halle 1956: 41)




The notion of a contrastive hierarchy has been fruitfully applied in acquisition studies, where it is a natural way of describing developing phonological inventories (Pye, Ingram and List 1987, Ingram 1989, Levelt 1989, Dinnsen et al. 1990, Dinnsen 1992). For example, Fikkert (1994) follows Jakobson in accounting for the development of segment types in onset position in Dutch:

(5) Development of Dutch onset consonants (Fikkert 1994)




In Stage 1 there are no contrasts. The value of the consonant defaults to the least marked onset, namely an obstruent plosive, designated here as /P/. The first contrast (Stage 2) is between obstruent and sonorant. The former remains the unmarked option; the sonorant defaults to nasal, /N/. At this point children differ. Some expand the obstruent branch first (Stage 3a), bringing in marked fricatives, /F/, in contrast with plosives. Others (Stage 3b) expand the sonorant branch, introducing marked sonorants, which may be either liquids, /L/, or glides, /J/. Continuing in this way we will eventually have a tree that gives all and only the contrasting features in the language.

## 2. Two approaches to determining contrast

Though all this appears quite simple and straightforward, and we have been following Jakobson, we don't find these branching trees in most accounts of phonological systems. So what happened to the contrastive hierarchy, 'the pivotal principle' of linguistic structure? It turns out that it is possible to 'follow Jakobson' in an entirely different direction. For the contrastive hierarchy is not the only way of arriving at contrastive values for an inventory. Phonologists, including Jakobson, have vacillated between two different, and – as I will show – incompatible approaches to determining contrastiveness:

(6) Two Theories of Contrast
Approach 1: Extraction of contrastive features from full specifications via *minimal pairs*
Approach 2: Derivation of contrastive features by successively splitting the inventory by a *hierarchy of features*

I will argue that approach (1), based on minimal pairs, is inadequate, both empirically and conceptually. This leaves approach (2), the contrastive hierarchy. Thus, the contrastive hierarchy is not only a useful way to describe developing inventories; it is also the only viable theory of contrast proposed to date.

### 2.1 Minimal pairs method

Martinet (1964:64) assumes that French labial consonants, though potentially having the specifications in (7a), are contrastively specified as in (7b). The missing specifications are predictable, and can be filled in as shown in (7c).

(7) French /p b m/ (Martinet 1964:64)

a. Full specification

| | p | b | m |
|---|---|---|---|
| voiced | – | + | + |
| nasal | – | – | + |

b. Contrastive specification according to Martinet

| | p | b | m |
|---|---|---|---|
| voiced | – | + | |
| nasal | | – | + |

c. Redundancy rules: [0 voiced] ⟶ [+voiced]
[0 nasal] ⟶ [–nasal]

The specifications in (7b) cannot be derived by a contrastive hierarchy: neither the ordering [voiced] > [nasal] nor the ordering [nasal] > [voiced] yields these specifications. Evidently, Martinet arrived at them by another route. We observe that the listed specifications in (7b) are just those that distinguish minimal pairs. /p/

and /b/ contrast only with respect to [voiced]: /p/ is [–voiced] and /b/ is [+voiced]. /b/ and /m/ contrast only with respect to [nasal]: /b/ is [–nasal] and /m/ is [+nasal].

An algorithm for arriving at just such contrastive specifications was proposed by Archangeli (1988). She did not intend it to be successful; rather, she presented it as an argument against Steriade's (1987) theory of Contrastive Specification. It isn't what she thought it was (see Dresher, Piggott and Rice 1994 for discussion), but it does make explicit the practice of many phonologists.

(8) Pairwise Algorithm (Archangeli 1988)

a. Fully specify all segments.
b. Isolate all pairs of segments.
c. Determine which segment pairs differ by a single feature specification.
d. Designate such feature specifications as 'contrastive' on the members of that pair.
e. Once all pairs have been examined and appropriate feature specifications have been marked 'contrastive', delete all unmarked feature specifications on each segment.

An illustration of how this algorithm is supposed to work is given in (9), which shows a typical five-vowel system characterized by the features [high], [low], and [back]. Features that do not distinguish minimal pairs are shaded.

(9) Five-vowel system, features [high], [low], [back]

| | i | e | a | o | u | *Minimal pairs* |
|---|---|---|---|---|---|---|
| high | + | – | – | – | + | {i, e}; {o, u} |
| low | – | – | + | – | – | {a, o} |
| back | – | – | + | + | + | {i, u}; {e, o} |

The minimal pairs method has been perhaps the main method used by phonologists in arriving at underspecified distinctive feature specifications. Typically, this has to be inferred – the method used was often left implicit. Also, since the minimal pairs method doesn't actually work, as I will show, its results often need to be 'adjusted' in ways that are hard to reconstruct.

Extraction from fully specified minimal pairs was evidently employed by Trubetzkoy (1969). For example, he writes(1969:68–9) that *d* and *n* 'are the only voiced dental occlusives' in Standard French. He observes further that 'neither voicing nor occlusion is distinctive for *n*, as neither voiceless nor spirantal *n* occur as independent phonemes.' That is, Trubetzkoy understands a feature to be distinctive in a phoneme if there is a phoneme that is identical except for that feature. This definition is consistent with the minimal pairs approach, as shown in (10a), where specifications that are contrastive in this sense are unshaded.

(10) Some French consonants, bilateral oppositions (Trubetzkoy 1969:68–9)

a. Specifications: Noncontrastive features (by minimal pairs) shaded

| | t | d | n | p | b | m | s | z | k | g |
|---|---|---|---|---|---|---|---|---|---|---|
| voiced | – | + | + | – | + | + | – | + | – | + |
| continuant | – | – | – | – | – | – | + | + | – | – |
| place | dnt | dnt | dnt | bil | bil | bil | alv | alv | dor | dor |
| nasal | – | – | + | – | – | + | – | – | – | – |

b. Bilateral oppositions, with contrastive and noncontrastive features

| *Pair* | *In common* | *Pair* | *In common* |
|---|---|---|---|
| t ~ d | [dnt, –nasal] | d ~ n | [dnt, +voiced, –cont] |

This approach to contrast, however, poses a problem for Trubetzkoy's notion of a bilateral opposition, which is an opposition whose members share a unique set of contrastive features. Trubetzkoy asserts (without evidence) that both /t/ ~ /d/ and /d/ ~ /n/ form a bilateral opposition in French. However, the only contrastive feature that /d/ and /n/ share is [dnt]. This would make the /d/ ~ /n/ opposition multilateral, since [dnt] is shared also by /t/. It is only by adding the noncontrastive features [+voiced] and [–continuant] that this opposition can be viewed as bilateral. As can be seen in (10b), even /t/ ~ /d/ do not form a bilateral opposition without the non-contrastive feature [–nasal]. To escape this dilemma, Trubetzkoy concedes that sometimes noncontrastive features must be considered in assessing if an opposition is bilateral. This concession undermines his theory of the connection between distinctiveness and phonological content, and is inconsistent with his approach in other places in the book, as we shall see.

Jakobson (1949) apparently took a similar approach to the specification of the features of Serbo-Croatian. I say 'apparently' because he does not state explicitly how he arrived at his specifications, but we can work backwards to infer what the method was. I present his specifications of oral and nasal stops (only features relevant to this example are included). The shaded squares are those that Jakobson leaves unspecified. With one exception, they are precisely the specifications that do not distinguish between minimal pairs.

(11) Specifications of Serbo-Croatian oral and nasal stops (Jakobson 1949)

| | p | b | m | t | d | n | ć | đ | ń | k | g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| voicing | – | + | | – | + | | – | + | | – | + |
| nasality | | – | + | | – | + | | – | + | | |
| saturation | – | – | – | – | – | – | + | + | + | + | + |
| gravity | + | + | + | – | – | – | – | – | | + | + |

The exception is the specification of /m/ for [saturation], which may be a mistake. Note the parallel positions of /m/ and /ń/; as expected, the latter has only one specification for the place features:

(12) Place specifications of nasal stops

| | m | n | ń |
|---|---|---|---|
| saturation | – | – | + |
| gravity | + | – | |

Deriving contrastive features by extraction from full specifications via minimal pairs is unworkable for several reasons. First, it fails to adequately contrast segments that are not minimal pairs. Consider again French /p b m/ in (7). The contrastive specification in (7b) distinguishes /b/ from /p/ on one side and from /m/ on the other; but what about the contrast between /p/ and /m/? /p/ is [–voice] and /m/ is [+nasal]; since these are not privative features but truly binary, we cannot conclude that the absence of a specification is necessarily distinct from a specification. Without running through the redundancy rules, we cannot decide if /p/ is distinct from /m/ or not. But then we have failed to arrive at a proper contrastive specification. Thus, the Pairwise Algorithm fails the Distinctness Condition proposed by Halle (1959), which states that 0 is not distinct from a plus or minus value in a binary feature system that is not privative.

One can argue about whether contrastive specifications ought to meet the Distinctness Condition (I think they do, but Stanley 1967 is one of a number who disagree). However, the minimal pairs method faces much more severe problems of adequacy, in that there are two types of common situations in which it fails by any measure to distinguish the members of an inventory.

First, the Pairwise Algorithm fails when there are too many features relative to the number of phonemes. We have seen that the algorithm succeeds in the three-dimensional feature space in (9). But recall that the algorithm is supposed to start from *fully specified* specifications; the limitation of the feature space to three features is arbitrary and unjustified. Full phonetic specification implies that the vowels be specified for *all* vowel features. Even adding just one more feature, say [labial], causes the Pairwise Algorithm to fail. The results are shown in (13), where specifications that are noncontrastive according to the algorithm are shaded.

(13) Five-vowel system, features [high], [low], [back], [labial]

| | i | e | a | o | u | *Minimal pairs* |
|---|---|---|---|---|---|---|
| high | + | – | – | – | + | {i, e}; {o, u} |
| low | – | – | + | – | – | |
| back | – | – | + | + | + | |
| labial | – | – | – | + | + | |

The only minimal pairs are {i, e} and {o, u}, based on [high]; the addition of the fourth feature turns what used to be minimal pairs into pairs distinguished by more than one feature. The features [back] and [labial] are each redundant given the other, but one of them has to be retained: the Pairwise Algorithm cannot decide which. It is not clear, then, that the minimal pairs approach can handle even the simplest sound systems, once all features are taken into account.

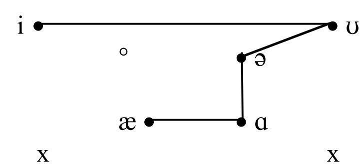
There is another type of case in which the Pairwise Algorithm fails, and this does not involve extra features, but rather the way members of an inventory are dispersed over the space defined by the feature set. That the Pairwise Algorithm gives a contrastive specification at all, whether correct or not, is due to the connectedness of the paths through the space defined by the set of features. Archangeli (1988) points out that not every five-vowel system can be assigned a contrastive set of specifications by the Pairwise Algorithm. An example of such an inventory is the vowel system of Maranungku (Tryon 1970). This vowel system is given in (14); again, specifications not designated contrastive are shaded.

(14) Maranungku, features [high], [low], [back]

| | i | æ | ɑ | ə | ʊ | *Minimal pairs* |
|---|---|---|---|---|---|---|
| high | + | – | – | – | + | {ə, ʊ} |
| low | – | + | + | – | – | {ɑ, ə} |
| back | – | – | + | + | + | {i, ʊ}; {æ, ɑ} |

We can model the space corresponding to the inventory in (14) and the minimal pair paths through it with a diagram as in (15). In this case, /i/ and /æ/ have the same contrastive specification because they occupy parallel positions in a contrast, as shown graphically in (15), but have no other neighbours that could further differentiate them in terms of this algorithm. An empty circle represents an unoccupied node, and x represents an impossible combination of [+high, +low].

(15) Maranungku, features [high], [low], [back]




Whether or not an inventory has paths that make its members distinguishable by the Pairwise Algorithm is an accidental property, and should not be the basis of a theory of contrastiveness.[2]

## 2.2 Contrastive specification by a hierarchy of features

The second approach to contrastiveness, the one exemplified in §1, also has roots in the earliest work on contrast in phonology. The idea is that to determine contrastiveness of features, it is necessary to determine their relative *scope,* or *ordering.*

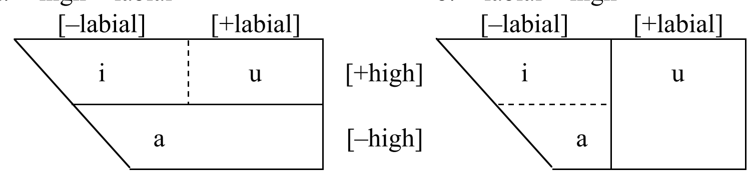
Consider, for example, a simple three-vowel system specified for the features [high] and [labial]. We can first divide the vowels on the basis of [high] (16a); then

[2] Hall (to appear) argues that the existence of phonetic enhancement (Stevens, Keyser and Kawasaki 1986), which heightens phonetic contrasts by increasing the number of featural distinctions between phonemes, dooms the Pairwise Algorithm to failure. That is, any method relying on phonetic minimal pairs distinguished by only one feature is based on the wrong intuition about how segments in an inventory are distributed in the space of features.

[labial] is relevant only as a contrast among the [+high] vowels. /i/ and /u/ are ‘partners’, and /a/ is neutral. In this ordering, [high] > [labial], all vowels are contrastive for [high], but only /i/ and /u/ are contrastive for [labial] (17a).

(16) Three-vowel system, features [high] and [labial]

a. high > labial  b. labial > high




(17) Contrastive specifications corresponding to (16)

a. high > labial

| | i | a | u |
|---|---|---|---|
| high | + | – | + |
| labial | – | | + |

b. labial > high

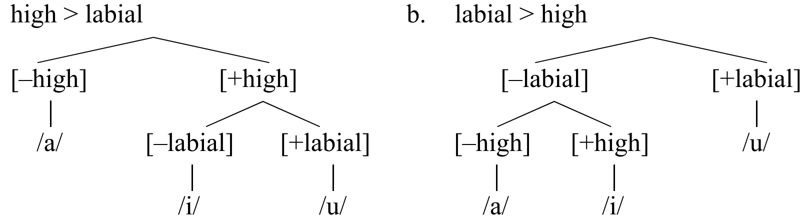
| | i | a | u |
|---|---|---|---|
| high | + | – | |
| labial | – | – | + |

Alternatively, we can first divide the vowels on the basis of [labial] (16b). Now, [high] is relevant only among the [–labial] vowels: /i/ and /a/ are ‘partners’, /u/ is neutral. In this ordering, [labial] > [high], all vowels are contrastive for [labial], but only /i/ and /a/ are contrastive for [high] (17b).

The two orderings yield different contrastive hierarchies:

(18) Two different contrastive hierarchies

a. high > labial  b. labial > high




We might expect that the two vowel systems will pattern differently. For example, system (a) might show alternations or neutralization between /i/ and /u/; in system (b), /i/ might be more closely related to /a/ than to /u/.

In his discussion of the Polabian vowel system, Trubetzkoy (1969:102–3) observes that a ‘certain hierarchy existed’ whereby the back ~ front contrast is higher than the rounded ~ unrounded one, the latter being a subclassification of the front vowels. Trubetzkoy’s rationale for this analysis is that palatalization in consonants is neutralized before all front vowels (and before ‘the maximally open vowel *a* which stood outside the classes of timbre.’). Also, the oppositions between back and front vowels are constant, but those between rounded and unrounded vowels of the same height are neutralizable (after *v* and *j* to *i* and *ê*). The vowel system, according to Trubetzkoy’s contrastive distinctions, is given in (19). The diagram suggests that the feature [back] has wider scope than [rounded].

(19) Polabian (Trubetzkoy 1969:102–3): [low] > [back] > [rounded]

| front (unrounded) | front rounded | back |
|---|---|---|
| i | ü | u |
| ê | ö | o |
| e | | α |
| ɑ | | |

To take another example, Trubetzkoy (1969:126, 143) observes that Greek has a bilabial stop /p/ and labiodental fricatives /f v/, and a postdental stop /t/ and interdental fricatives /θ ð/. Is the primary contrast one of stop vs. fricative or of place? Trubetzkoy appeals to 'parallel' relations between stops and fricatives at different places. In the sibilant and dorsal series (/ts s z/ and /k x ɣ/, respectively), the contrast is unambiguously one of stop vs. fricative, since stops and fricatives occur at exactly the same place of articulation. By parallelism, Trubetzkoy proposes that the same contrast should apply to the ambiguous cases, which leads to the conclusion that the minor place splits are phonologically irrelevant. The picture that emerges is given in (20).

(20) Greek: major place, voicing, occlusion > minor place

| | Labial | Apical | | Dorsal |
|---|---|---|---|---|
| voiceless stops | p | t | ts | k |
| voiceless fricatives | f | θ | s | x |
| voiced fricatives | v | ð | z | ɣ |

In French, however, Trubetzkoy (1969:126–7) argues for a split labial series. 'For in the entire French consonant system there is not a single phoneme pair in which the relation spirant : occlusive would occur in its pure form.' Indeed, he follows this analysis to its logical conclusion and disputes that there is an opposition between occlusives and spirants in French, because degree of occlusion cannot be regarded independently of position of articulation. Trubetzkoy does not give a chart, so I adapt the one in (21) from Martinet (1964), whose analysis is clearly influenced by Trubetzkoy.

(21) French obstruents (based on Martinet 1964:65)

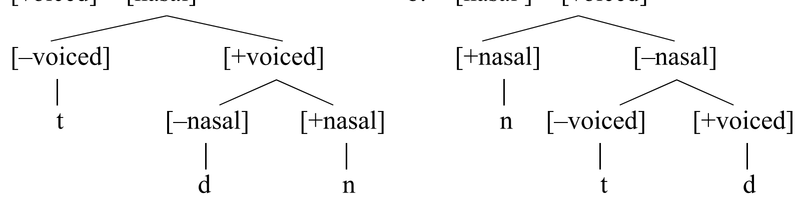
| | bilabial | labiodental | apical | alveolar | pre-palatal | dorso-velar |
|---|---|---|---|---|---|---|
| voiceless | p | f | t | s | š | k |
| voiced | b | v | d | z | ž | g |

Thus, Greek and French require a different ordering of [continuant] relative to minor place features. In French, minor place > [continuant]; in Greek, [continuant] > minor place. Moreover, Trubetzkoy's discussion suggests a principle that guides the choice of ordering: place features take scope over occlusion (French) unless an occlusion contrast is needed anyway (parallelism, Greek).

This analysis is inconsistent with Trubetzkoy's discussion, earlier in the book, of bilateral oppositions in French. Here, the determination of bilateral relations comes about as a *consequence* of establishing the relevant contrasts, and is not apparent at the outset. In a hierarchical approach to contrastive specification, voicing is not always redundant for /n/. For example, if [voiced] is ordered above [nasal], then the voicing contrast includes in its purview the nasal consonants as well, as shown in (22a). In this ordering, /d/ ~ /n/ participate in a bilateral opposition, but /t/ ~ /d/ do not. If the features are ordered as in (22b), then nasals are not specified for voicing, /d/ ~ /n/ do not form a bilateral opposition, but /t/ ~ /d/ do. The tree diagrams in (22) show one characteristic of specification by a top-down hierarchy: feature values that are logically redundant, such as [+voiced] for /n/, or [–nasal] for /t/, may still be designated as contrastive.

(22) French dental obstruents and nasals:

a. [voiced] > [nasal]  b. [nasal ] > [voiced]




In the minimal pairs approach, the analysis *begins* with the identification of bilateral oppositions (or minimal pairs). In a contrastive hierarchy approach, identification of these relations comes at the *end* of the analysis. In the former approach, these relations are fixed for a set of features; in the latter, they vary.

A natural way of determining contrast, then, is by splitting the inventory by means of successive divisions, governed by an ordering of features. A simple algorithm corresponding to this idea is given in (23) (Dresher 1998a, 1998b, based on Jakobson and Halle 1956).

(23) Successive Division Algorithm (SDA)

a. Begin with no feature specifications: assume all sounds are allophones of a single undifferentiated phoneme.
b. If the primordial allophonic soup is found to consist of more than one contrasting member, select a feature and divide the set into as many subsets as the feature allows for. (With binary features, it becomes the Successive Binary Algorithm.)
c. Repeat step (b) in each subset: keep dividing up the inventory into sets, applying successive features in turn, until every set has only one member.

This algorithm solves the problems encountered by the Pairwise Algorithm: (a) it adequately contrasts all members of an inventory; (b) it is guaranteed to work in all inventories; (c) it does not have to adopt auxiliary mechanisms for multiple logical redundancies; and (d) it does not assume prior full specification – a child's detailed *phonetic* perception is not equivalent to a *phonological* representation.

The contrastive hierarchy had its heyday in the 1950s, when Jakobson and Halle explicitly argued for it in a series of publications, under the name 'dichotomous scale' (Jakobson and Halle 1956) and 'branching diagrams' (Halle 1959). Nevertheless, their use of it was inconsistent, perhaps because they were unable to arrive at a single universal hierarchy that could apply to all the languages they studied.

While they gave conceptual and acquisition arguments for the contrastive hierarchy, they did not present empirical arguments that would connect it to phonological activity. The use of 'branching diagrams' was challenged on various grounds by Stanley (1967); they do not appear in Chomsky and Halle (1968). Though the contrastive hierarchy disappeared from generative phonology, the intuition that 'there is obviously some kind of hierarchical relationship among the features which must somehow be captured in the theory' (Stanley 1967) continued to haunt generative phonological theory, and has reappeared in various guises in markedness theory, feature geometry, and theories of underspecification.

## 3. The contrastive hierarchy in OT[3]

Optimality Theory (OT, Prince and Smolensky 1993) puts many central issues of phonological theory in a new light, and one might ask whether a special theory of contrast is still required in OT. Thus, it has been claimed (Itô, Mester and Padgett 1995, Kirchner 1997) that contrasts 'emerge' from OT constraint rankings, so one might think that there is no need to say anything more about it. But an arbitrary constraint ranking will not express a connection between contrast and phonological activity. If there is such a connection, it should be captured in phonological theory. I have also argued that the relevant contrasts that play a role in a phonology must be imposed by the analyst and do not simply emerge from surface phonetics or from laying out the segmental inventory of a grammar.

Some ways of implementing the contrastive hierarchy are inconsistent with assumptions commonly made in OT. Two of these are (a) no necessary underspecification; and (b) no limitations on underlying inventories. These issues concern implementation of the contrastive hierarchy, and are orthogonal to the notion of a hierarchy of contrastive features itself.

In converting a contrastive hierarchy into an OT constraint set, we must make some assumptions about the output and the input.

*Output:* I will assume that the output of an OT version of the SDA (23) is the same as the output of the algorithm itself: a set of contrastive specifications from which redundant feature specifications are excluded.[4]

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[3] This section is based on joint work with Sara Mackenzie. See further Mackenzie (2002) and Mackenzie and Dresher (2003). I have also benefited from discussions of these issues with Kiyan Azarbar and Daniel Currie Hall.

[4] This model therefore presupposes a version of serial OT: the output of this evaluation is the input to the phonology proper.

*Input:* I will assume for now that the input consists of fully-specified representations. The analysis can easily be extended to include underspecified inputs, but I shall not do so here.

*Constraints:* This model employs two basic constraint types as in (24).

(24) Constraints used to model a contrastive hierarchy

a. IO-IDENT F: 'Correspondent segments must have the same value of the feature F (either + or –)'.

b. *[F, Φ]: 'Exclude feature F in the context Φ', where Φ is the set of features (with wider scope than F) forming the context of F.'

To illustrate, I will use the Classical Manchu vowel system that was mentioned earlier. Recall that the proposed feature hierarchy for this language is low > coronal > labial > ATR.

The first feature in the hierarchy is [low]; hence, in the highest stratum we place the constraint IO-IDENT [low]. This feature has no exclusions, because there is no vowel feature with wider scope. The effect of this is to require that any underlying value of [low] must be preserved.

The second feature is [coronal]. It is excluded with [+low]. Therefore, in the next stratum we place the constraint *[coronal, +low], and ranked below that, IO-IDENT [coronal]. That is, where a segment has the feature [+low], any underlying value of [coronal] will be filtered out, since a segment specified [+low] may not have a value for [coronal]. Segments bearing the feature [–low] must retain the underlying value of [coronal].

The third feature is [labial], excluded with [–low]. Hence, the next two constraints are *[labial, –low] followed by IO-IDENT [labial].

The fourth feature is [ATR]. It is excluded with [+coronal] and [+labial]. We thus have the two constraints *[ATR, +coronal] and *[ATR, +labial], ranked equally, followed by IO-IDENT [ATR].

All other features are redundant and are excluded by the general constraint *[F].

The constraint set corresponding to the contrastive hierarchy of Classical Manchu is thus as in (25).

(25) Constraint set for the Classical Manchu contrastive hierarchy

IO-IDENT [low] >> *[coronal, +low] >> IO-IDENT [coronal] >> *[labial, –low] >>IO-IDENT [labial] >> *[ATR, +coronal], *[ATR, +labial] >> IO-IDENT [ATR] >> *[F]

A sample tableau illustrating the operation of this constraint set is given in (26).[5]

[5] Abbreviations used in the tableau are as follows: ID = IO-IDENT; lo = low; cr = coronal; lb = labial; at = ATR. Square brackets are omitted from feature specifications.

(26) Sample tableau: Classical Manchu contrastive specifications

| Input /–lo +cr –lb +at/ | ID lo | *cr +lo | ID cr | *lb –lo | ID lb | *at +cr | *at +lb | ID at | *F |
|---|---|---|---|---|---|---|---|---|---|
| a. –lo +cr –lb +at | | | | *! | | * | | | |
| b. +lo +cr | *! | * | | | * | | | * | |
| c. –lo –cr +at | | | *! | | * | | | | |
| d. –lo +cr +at | | | | | * | *! | | | |
| e. –lo +cr +hi | | | | | * | | | * | *! |
| f. ☞ –lo +cr | | | | | * | | | * | |

In this example we suppose that the input is the feature combination /–low, +coronal, –labial +ATR/. This is an impossible combination, according to the contrastive system of Manchu, and candidate (a), which faithfully preserves this set of features, cannot surface, because it violates the constraint *[labial, –low]. Candidate (b) is an example of a candidate that violates IO-IDENT [low]; since this is the highest-ranking constraint, all such candidates are eliminated. Candidate (c) violates IO-IDENT [coronal], and thus loses to candidates who observe this constraint. Candidate (d) maintains the underlying values of [low], [coronal], and [ATR], fatally violating *[ATR, +coronal]. Candidate (e) includes the non-contrastive feature [high], violating *[F].[6] The winning candidate is (f): though it violates the faithfulness constraints for [labial] and [ATR], maintaining them would result in worse violations. As we have seen, a segment that is [–low, +coronal] has no other contrastive specifications, and this is the result we have obtained.

A general procedure for converting a contrastive hierarchy to an OT constraint hierarchy is given in (27).

(27) Converting a contrastive hierarchy to an OT constraint hierarchy

a. Go to the next contrastive feature in the list, $F_i$. If there are no more contrastive features, go to (e).
b. In the next stratum of constraints, place any co-occurrence constraints of the form *[$F_i$, Φ], where Φ consists of features ordered higher than $F_i$.
c. In the next stratum, place the constraint IO-IDENT [$F_i$].
d. Go to (a).
e. In the next constraint stratum, place the constraint *[F], and end.

[6] Technically, every candidate violates *[F] once for every feature it bears. Where these are contrastive features that must be preserved in the output, these violations play no role in the evaluation, because they are overridden by the higher-ranked faithfulness constraints. To simplify the tableau, I indicate violations only of (redundant) features that have no higher-ranking faithfulness constraint.

Every contrastive hierarchy can be converted into a constraint hierarchy by the above procedure. But the converse does not hold: not every constraint hierarchy can be converted into a contrastive hierarchy. Limiting constraint hierarchies to those that conform to a well-formed contrastive hierarchy captures the relation between contrast and phonological activity and constrains the class of possible grammars.

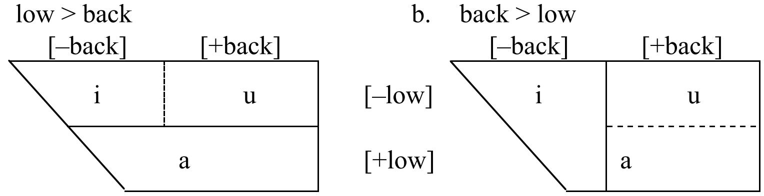
## 4. Some implications of the contrastive hierarchy for acquisition

I would like to briefly sketch some implications of the contrastive hierarchy for the acquisition of phonological systems.

First, acquiring phonological contrasts is not the same as acquiring phonetic contrasts. The surface phonetics do not determine the phonological specifications of a segment. Many three-vowel systems, for example, have vowels that approximate [i], [a], [u] on the surface. Though their surface manifestations may be similar, the phonological specifications of these vowels can differ considerably from one language to another. We have seen in (16) that the same two contrastive features can yield different phonological systems depending on which has wider scope. Further systems become available with a different choice of contrastive features. In (28) the features [low] and [back] are highest in the contrastive hierarchy, rather than [high] and [labial, as in (16).

(28) More contrasts in three-vowel systems

a. low > back　　　　b. back > low




The dispersion phenomena discussed by Flemming (1995) operate at the phonetic level to enhance phonological contrasts (Stevens, Keyser and Kawasaki 1986, Rose 1993, Rice 2002). For example, /u/ in (16a) is specified [+high, +labial], /u/ in (16b) is specified only as [+labial], and /u/ in both examples in (28) is [–low, +back]. In phonological terms these are distinct objects, but due to considerations of markedness and phonetic contrast these vowels may all surface as something close to [u].[7] Hence, a variety of phonologically different three-vowel systems can all end up as [i, a, u].

Second, contrast acquisition requires learners to take into account phonological processes, and not just the local phonetics of individual segments (Dresher and van der Hulst 1995). This is demonstrated most clearly by languages in which a phonological contrast is neutralized in all or most contexts.

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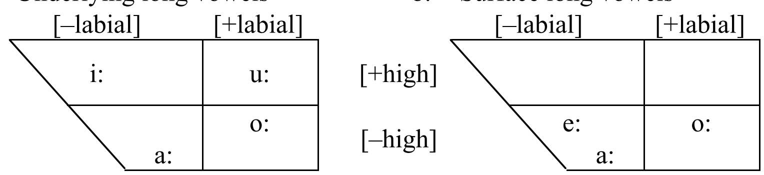
[7] There may, of course, be considerable variation in the surface realizations of these vowels, depending on the language, as well as allophonic variation which may reflect to some extent the basic phonological specifications.

Consider the well-known case of Yowlumne (formerly Yawelmani, Kuroda 1967, Archangeli 1984), where underlying long high vowels do not surface. Instead, they lower: /i:/ lowers to [e:], and /u:/ lowers to [o:], merging with [o:] from /o:/. The only way to distinguish [o:] (or [o], if shortened) derived from /u:/ from [o:] (or [o]) derived from /o:/ is by attending to the effects of the vowel on neighbouring segments.[8]

(29) Yowlumne long vowels

a. Underlying long vowels  b. Surface long vowels




Other examples in this class are /u/ ~ /ʊ/ in Classical Manchu (Zhang 1996), which merge to [u] everywhere except after back consonants, and /i/ ~ /ɛ/ in Nez Perce (Hall and Hall 1980), which are uniformly realized as [i].

Third, a contrast-driven theory of phonological representations can account for several types of variation in child language. Within a language, the relatively underspecified nature of the developing system predicts greater variability in child language, as shown by Rice and Avery (1995) and Rice (1996a, b). Across languages, differences in the contrastive hierarchy itself are reflected in different paths of segmental elaboration (Dresher 1998a).

The last point concerns positional effects of contrast. Up to now we have been considering contrasts as being established over the whole language. It is also possible that contrastive sets may be limited by position.

Dyck (1995) proposes that unstressed suffix vowels in Spanish and Italian dialects form a distinct set for purposes of setting up contrastive representations. She observes the following generalization:

(30) Dyck's generalization about Spanish and Italian metaphony triggers

Unstressed suffix vowels in Spanish and Italian dialects can trigger metaphony (i.e., cause raising) only if they contrast with a mid vowel in the same place.

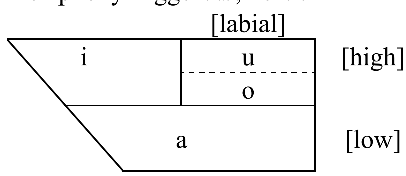
Dyck (1995) explains this generalization as follows:

a. To cause metaphony a vowel must have the phonological feature [high].
b. Features are assigned in the order [low] > [labial] > [high].
c. Thus, a vowel is assigned the feature [high] only if there is a contrasting mid vowel in the same place.

[8] The lowering of /i:/ to [e:] cannot be accounted for only by the contrastive features [high] and [labial], which do not distinguish between [e:] and [a:]. Therefore, Yowlumne appears to be a language in which a redundant feature plays a role in the phonology. For discussion and possible solutions see Hall (2002) and D'Arcy (2003).

For example, in (31) /u/ can potentially trigger metaphony, because it bears the phonological feature [high]; however, /i/ is not contrastively [high], and therefore cannot trigger metaphony.

(31) Potential metaphony trigger /u/, not /i/




It is crucial to this account that the contrasting set consist only of the unstressed suffix vowels. For in all dialects, stressed high vowels are in contrast with mid vowels in the same place, since all dialects have at least the stressed vowels /i e a o u/. Therefore, Dyck's generalization (30) applies only if one regards the desinential vowels as a separate set for purposes of establishing contrastive specifications.[9]

Despite such examples, the interconnection of segments in adult languages – the fact that an underlying phoneme may appear in a variety of positions due to the existence of alternations – constrains the degree to which contrast may be limited by position. In child language, however, the lexicon is not as integrated, and it is possible that learners may initially treat positionally delimited contrastive sets separately. It appears that child language indeed displays positional effects in assessing contrast (Waterson 1987, Fikkert 1994, Levelt 1994).[10]

For example, in child Dutch (Fikkert 1994, Levelt 1994) onset and coda consonants appear to make up distinct sets, with a different order of development and different defaults and contrasts. These effects are a further manifestation of the relative nature of phonological contrast, and the importance of establishing the proper scope of a contrast.

## 5. Conclusion

Following Jakobson, I have argued that the contrastive hierarchy really is a pivotal principle of phonological structure. Of particular relevance here, I have tried to show that the same mechanism that is useful in characterizing developing phonological systems also distinguishes between contrastive and redundant features in adult phonology.

The contrastive hierarchy appears to allow a certain amount of cross-language variation: the ordering of the features may vary, presumably within limits, as well as

[9] Frigeni (2003) argues along the same lines that desinential vowels form a distinct contrast domain in Campidanian Sardinian. Whereas Dyck (1995) assumes that the same feature hierarchy applies in all vowel domains, albeit with different effects, Frigeni proposes that the different domains are also characterized by different feature hierarchies.

[10] Fikkert and Freitas (2003) argue that children's representations of unstressed vowels in European Portuguese are not adult-like, because the children are unaware of allomorphic relationships that could allow them to discover that stressed and unstressed vowels are underlyingly specified in the same way.

the designated phonetic defaults. How, then, do learners know how to order the features of the contrastive hierarchy? What do they do in the face of apparently conflicting evidence? If we can answer these questions we will be well on the way to an explanatory theory of Universal Grammar in the domain of phonology.

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