Contrast in Phonology, 1867–1967: History and Development

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Abstract

This article surveys the history of contrast in phonology from Bell's *Visible Speech* (1867) until Chomsky & Halle's *Sound Pattern of English* (1968). Phonological contrast can be viewed at the segmental and subsegmental (feature) levels. As contrast at the segmental level involves the phoneme, whose later history has been extensively documented, I concentrate on the origins of the concept in the work of Sweet. Subsequently, I focus on subsegmental-level contrast. After a look at its treatment in phonological analyses that operated without an explicit theory of features, I turn to Trubetzkoy, in whose work we find the seeds of later approaches. The article explores the foundations of the main methods of computing contrastive features: minimal differences and hierarchical feature ordering. It concludes with a discussion of contrast in early generative phonology and reviews some of the reasons for its decline at the end of the 1960s.

1. INTRODUCTION

> Ce qui importe dans le mot, ce n'est pas le son lui-même, mais les différences phoniques qui permettent de distinguer ce mot de tous les autres.
>
> *The sound of a word is not in itself important, but the phonetic contrasts which allow us to distinguish that word from any other.*
>
> Saussure [1972 (1916), p. 163], translated by Roy Harris (in Saussure 1986, p. 116)

This article is a brief survey of the history of contrast in phonology from the publication of Bell's *Visible Speech* in 1867, which we can take to mark the beginnings of modern phonology and phonetics, until the appearance of Chomsky & Halle's *Sound Pattern of English* in 1968, after which interest in contrast declined until the end of the century. Contrast in phonology can be viewed at the segmental and subsegmental (feature) levels. Contrast at the segmental level involves the phoneme, whose history has been extensively documented. Therefore, I concentrate mainly on the origins of the concept in the work of Sweet (Section 2); space limitations prevent me from discussing the contributions of the Kazan school of Jan Baudouin de Courtenay and Mikołaj Kruszewski.

Subsequently, this article focuses on the story of contrast at the subsegmental level. Specifically, I look at how it was dealt with in early phonological theory that operated without an explicit theory of features (Section 3). Section 4 is devoted to Trubetzkoy, in whose work on oppositions we find the seeds of later approaches. The next two sections explore the two different methods of computing contrastive features, minimal differences (Section 5) and hierarchical feature ordering (Section 6). Section 7 concludes with a brief discussion of contrast in early generative phonology and reviews some of the reasons for its decline at the end of the 1960s.

2. CONTRAST IN SOUNDS: HENRY SWEET AND THE IDEA OF THE PHONEME

The notion of contrast has been central to phonological thinking since the beginnings of modern phonology in the late nineteenth century. In his *Handbook of Phonetics* (Sweet 1877), Henry Sweet (1845–1912) proposes that a transcription system that attempts to accurately indicate "the endless shades of difference" between every speech sound that can be found in the languages of the world would be too cumbersome and detailed to be of practical use in transcribing the sounds of any one language. For example, the vowels in the English words *bait* and *bet* differ in three ways: The vowel in *bait* is longer and tenser than the vowel in *bet*, and is a diphthong, consisting of a vowel and high off-glide, whereas the vowel in *bet* is a monophthong. An accurate transcription of the vowels would indicate all these distinctions; in the current notation of the International Phonetic Alphabet (IPA), the vowel in *bait* is transcribed [eːj], and the vowel in *bet* is transcribed [ɛ].

These three differences, however, are not independent: Recombining the various properties to create new vowels [eː], [ej], [e], [ɛː], [ɛj], and [ɛːj] would not result in a new word distinct from both *bait* and *bet*, but would be heard as some (perhaps odd-sounding) variant of one of these words. Sweet (1877, p. 104) concludes: "Hence we may lay down as a general rule that only those distinctions of sounds require to be symbolized in any one language which are *independently significant:* if two criteria of significance are inseparably associated, such as quantity and narrowness or wideness [i.e., tenseness or laxness/BED], we only need indicate one of them." That is, for purposes of transcribing English, we need indicate only a single contrast between the vowels in *bait* and *bet*: either tenseness ([e] ~ [ɛ]) or quantity ([eː] ~ [e] or [ɛː] ~ [ɛ]), or the presence of a glide ([ej] ~ [e] or [ɛj] ~ [ɛ]). The predictable differences accompanying the one indicated would be known to native speakers and, for nonnative speakers or for scientific purposes, can be described in a summary statement as a rule.

According to Jones (1967, p. 256), Sweet (1877) was the first to distinguish between two types of phonetic transcription: "Narrow" (now more commonly called phonetic) transcription is universal and aims for a detailed phonetic representation of sounds, and "broad" (now called phonemic) transcription records only the differences in sound that are distinctive in the language being represented. This distinction remains a mainstay of phonological analysis.

Sweet refers to narrow transcription as "scientific," in that it is intended to accurately indicate phonetic detail. There are different degrees to which a transcription can be said to be "narrow," ranging from one that indicates everything that can be measured or observed about the utterance to a transcription that attempts to indicate only those properties of sounds that can be contrastive or the target of a phonological rule in some language, though not necessarily in the language being transcribed. This latter sense appears to be close to the representations proposed by Dufriche-Desgenettes, the inventor of the word "phoneme" (Mugdan 2011), and by Bell's *Visible Speech* (see Section 3.1, below).[1]

Broad, or phonemic, representation is the basis of the concept of the phoneme. Though particular definitions of the phoneme differ, they all have in common the idea that within a language there are only so many contrasting sounds that are considered different from each other in a given context. To continue with Sweet's example, the vowels in English *bait* and *bet* belong to two different phonemes, which we can designate /ej/, as in *bait*, and /e/, as in *bet*. These two sounds must be distinguished because they contrast in the above words as well as in many others. However, we do not need to make any of the other possible distinctions discussed above, for example, /e/ versus /ɛ/ or /ej/ versus /e:j/. Similarly, English distinguishes a high, front, tense, long diphthong [i:j], as in *leap*, from a high, front, lax, short monophthong [ɪ], as in *lip*. These correspond to two phonemes that, following Sweet (1877, p. 110), we can designate /ij/ and /i/.

Because phonemes depend on the contrasts particular to individual languages, phonemic transcription varies from language to language. For example, Sweet (1877, pp. 103–4) observes that short [i] and [ɪ] distinguish words in Danish, unlike in English. We would say that /i/ and /ɪ/ are separate phonemes in Danish. In Icelandic there is a significant contrast between [ij] and [ɪj], suggesting that they must be distinguished in broad transcription, assigned to separate phonemes /ij/ and /ɪj/.

Because the phonemes of every language must be established on the basis of language-particular contrasts, criteria are required to determine under what circumstances sounds can be said to belong to different phonemes. The criteria for identifying phonemes, though not entirely straightforward, have been much discussed, and I do not review them here; see, for example Krámský (1974), Fischer-Jørgensen (1975), and Dresher (2011).

It is one thing to determine that two sounds are or are not in contrast in a language; it is another matter to determine in what respect two sounds are in contrast. Doing so requires a more complex analysis than simply establishing what the phonemes of a language are. First, one must analyze sounds into smaller constituent units. Second, one must decide which of these constituents are contrastive in particular phonemes. It is to this topic that the rest of this article is devoted.

3. CONTRAST IN SUBPHONEMIC UNITS

Though much literature has been devoted to the definition of the phoneme and to the procedures for identifying phonemes, the same is not the case for contrast in subphonemic units. Explicit

[1]Compare Chomsky & Halle (1968), who propose a level of phonetic transcription that is limited to the distinctions that can be made by a set of universal features. I am grateful to an anonymous reviewer for comments on types of narrow transcription.

discussions of these procedures are rare in the literature, as are accounts of their history. In the tradition of the Prague School (notably the writings of Roman Jakobson and N.S. Trubetzkoy), which was taken up in generative phonology, pioneered by Noam Chomsky and Morris Halle (Chomsky & Halle 1968), phonemes are analyzed into distinctive features. Though explicit theories of distinctive features have their origins in works by the above-named authors, Fromkin & Ladefoged (1981) remind us that the analysis of speech sounds into feature-like properties goes back hundreds of years, and is present in the earliest works of modern phonology.

3.1. Bell and Sweet

A. Melville Bell (1819–1905) was a pioneering phonetician (and the father of Alexander Graham Bell, the inventor of the telephone) who developed an original notation for the sounds of speech that was intended to directly reflect the basic articulatory mechanisms by which they are produced. As Bell writes in *Visible Speech* (Bell 1867, p. 14), his aim was to develop a system that could represent "all *possible* sounds"; in order to achieve this goal, it is necessary "to obtain a knowledge of the exact relation of sounds, and the conditions to which they owed their differences." In other words, Bell aimed to arrive at a set of contrastive universal elements of speech (we could say features) with which all possible speech sounds could be represented and distinguished.

Halle (2002, pp. 3–4) writes that Bell's "capital insight" that speech sounds are composed of features "was obscured and forgotten" when Sweet and others replaced Bell's *Visible Speech* alphabet by that of the IPA, established in Paris in 1886: "As Bell's Visible Speech fell into disuse, the important theoretical insights reflected in this alphabet were also lost" (see Halle 1978 for further discussion of Bell's system and its place in the history of phonology). With respect to our topic, however, Bell's alphabet could be said to be a type of narrow transcription: In aiming to represent all possible contrasts in sounds, his system was not designed to express the language-particular contrasts operative in a language.

Though he chose not to adopt Bell's transcription system, judging it to be impractical for most purposes, Sweet (1877) makes clear that his approach was very much influenced by Bell's, and he adopts a universal descriptive system to describe vowels and consonants. He characterizes simple vowels in the following basic articulatory terms: tongue height (high, mid, or low); tongue backness (front, mixed, or back); tension (wide or narrow); and lip rounding (usually indicated only if round). These descriptive dimensions are intended to be universal, and so would not be modified in a narrow transcription. What about broad transcription, where some of these features are noncontrastive?

In some cases Sweet indicates which specific features he thinks are contrastive. For example, the vowel [ɛ] in *bet* is, in his system, mid-front-wide, whereas the vocalic part of [eːj] in *bait* is mid-front-narrow, as well as long with a [j] off-glide. As these phonetic properties go together, Sweet argues that a broad transcription need not include them all. He proposes (Sweet 1877, pp. 109–10) that in broad transcription [ɛ] should be transcribed 'e,' and [eːj] 'ei' (or, equivalently, 'ej').

Thus, of the three differences in the vowels—width (tenseness), length, and presence of a second element—Sweet chooses the last, ignoring width and quantity. In this case he gives the rationale for his choice. Sweet (1877, p. 110) observes: "The narrowness of all [English] vowels is uncertain," especially /ij/ and /ej/. That is, vowels can vary in the degree to which they are tense or lax without essentially changing the identity of the vowel, as long as other properties do not change. Similarly, he finds that "originally short vowels can be lengthened and yet kept quite distinct from the original longs" (Sweet 1877, p. 18). That is, [bɪt] *bit* can be lengthened to [bɪːt]

without passing into *beat*.[2] Whereas tenseness and length can be altered without changing one vowel phoneme into another one, presumably the same is not the case for the third distinguishing property: Adding a glide to the vowel in *bet*, or removing it from *bait*, could cause the resulting vowel to be perceived as having changed category.

We can conclude that Sweet's analysis posits that the contrastive features of both the vowels in *bet* and *bait* are mid and front, with no contrastive specification for tenseness or quantity. The difference between the two words resides in the addition of a second segment to the vowel in 'bait.' In this case, then, Sweet not only identifies contrasting phonemes but also identifies the contrastive property that distinguishes them, and gives reasons for choosing one of the three phonetic differences as the contrastive one.

However, Sweet does not do the same for most phonemes. Since his main focus is to simplify broad transcription by avoiding superfluous symbols, he does not seek to pinpoint what the contrastive features are in cases where phonemes are represented by simple symbols. For example, Sweet (1877, pp. 41, 48) describes the Standard English *f* and *v* as 'lip-teeth-open' and *p* and *b* as 'lip-stop.' However, *f* and *v* are the only English consonants that are lip-teeth (i.e., labiodental). Should we then treat them as contrastively labiodental and as redundantly open (fricative)? Or should we analyze them, together with *p* and *b*, as simply "labial," ignoring the difference between bilabial and labiodental, and contrast them with *p* and *b* by their manner of occlusion (fricative versus stop)? This question does not arise in Sweet (1877), because *p*, *b*, *f*, and *v* are all transcribed with simple noncomposite symbols that are suitable to broad notation.[3]

3.2. Sapir: Sound Patterns

Edward Sapir (1884–1939) was a pioneer of the phoneme concept in the United States. His work [notably Sapir 1925 and Sapir 1949 (1933)] emphasized the psychological reality of the phoneme as a level of cognitive representation, as well as the distinction between a phonemic approach and a purely phonetic approach to the sounds of language. For Sapir (1925), each phoneme occupies a particular "point" in the "sound pattern" of a language. I have argued (Dresher 2009, pp. 38–42) that the points in the pattern refer to the contrastive properties of phonemes. Though Sapir did not have a formal theory of distinctive features, it is clear from his discussion that he viewed phonemes as decomposable into feature-like units, and assigned a special status to the contrastive units.

Sapir's general approach is well illustrated by the four languages he constructs in his 1925 paper, drawn from actual languages he was familiar with. Languages C and D have different sounds but isomorphic pattern alignments. For example, language C has the vowels shown in list 1*a*, and language D has the vowels in list 1*b* (I have updated the symbols to current IPA practice). Sapir suggests that each vowel in language C occupies the same point in the pattern as the vowel directly under it in language D.

Vowels in languages C and D (Sapir 1925)

(1a) Language C: a aː ɛ ɛː i u

(1b) Language D: æ æː e eː i y

[2]English vowels are in fact systematically longer before voiced consonants than before voiceless consonants; thus, the vowel in *bid* is longer than the vowel in *bit*, and the vowel in *bead* is longer than the one in *beat*. Nevertheless, these length differences are noncontrastive and do not change the identity of the vowel phonemes.

[3]How to represent the similar contrast between *p*, *b* and *f*, *v* in Standard French became an issue more than 50 years later, as discussed in Sections 4, 5.1, and 6.1.

High		Nonhigh			
		Short		Long	
Unrounded	Rounded	Nonlow	Low	Nonlow	Low
i/i	u/y	ɛ/e	a/æ	ɛː/eː	a/æː

Figure 1

Possible contrastive specifications for the vowels in list 1.

The isomorphic alignments can be understood as indicating that corresponding phonemes have the same contrastive values. Sapir did not specify what these might be; the chart in **Figure 1** represents one possible set of specifications. In each cell, the first sound is from language C, the second from language D. The differences between them do not involve contrastive properties.

Languages A and B illustrate the converse situation. They have the same sounds, but these sounds occupy different points in the pattern; that is, different contrastive positions. Both languages have the phonetic vowels shown in list 2.

Phonetic vowels in languages A and B (Sapir 1925)

(2) a aː ɛ ɛː e eː i iː u uː o oː ɔ ɔː

The phonemes of language A are listed in **Figure 2*a***; positional allophones are given in parentheses. Instead of the 14 different vowels in the above inventory, there are only 3 short and 3 corresponding long vowel phonemes. The vowels of language B fall into a very different set of contrastive phonemes, as shown in **Figure 2*b***: There are seven vowel phonemes, and length is not a contrastive property. The labels in **Figure 2** are my own.

Sapir's (1925) discussion lacks an articulated set of features, as well as principles for identifying contrastive features. Nevertheless, it is clear that he had a conception of phonemes as being characterizable in terms of contrastive feature-like units.

a The vowel phonemes of language A

		Front/ unrounded		Back/ rounded
Nonlow	**Short**	i (e)		u (o)
	Long	iː (eː)		uː (oː)
Low	**Short**		a (ɛ, ɔ)	
	Long		aː (ɛː, ɔː)	

b The vowel phonemes of language B

	Front/ unrounded		Back/ rounded
High	i (iː, j)		u (uː, w)
Mid	e (eː)		o (oː)
Low	ɛː (ɛː)	a (aː)	ɔ (ɔː)

Figure 2

Contrastive specifications of the vowels of languages A and B.

3.3. Twaddell: Phonemes and Minimum Phonological Differences

W.F. Twaddell (1906–1982) was an American linguist who was an exponent of the approach to linguistics associated with Leonard Bloomfield. His 1935 paper (Twaddell 1935) is set apart from other American structuralist publications in the first half of the twentieth century in its analysis of phonemes into contrastive feature-like units. Twaddell proposes to define phonemes in terms of minimal contrasts based on the following partial list of basic articulatory differences.

A set of articulatory components (partial list)

(3) 1 bilabial; 2 aspirated; 3 voiceless; 4 exploded stop; 5 alveolar; 6 palatovelar; 7 voiced; 8 unaspirated; 9 unexploded stop; 10 labiodental; 11 interdental; 12 dental-alveolar; 13 alveolar-palatal; 14 fricative; 15 slit narrowing; 16 groove narrowing.

Twaddell's first step in identifying phonemes is to isolate units that participate in minimal contrasts in particular contexts and to characterize them in terms of these articulatory differences, such as the series in **Figure 3*a***. Within each class, the differences must be distinguished from the similarities. The common terms in each class—4 in class I, 3–14 in class II, and 8–9 in class III—can be omitted, because they do not contribute to differentiating the members of each class. Each series defines a set of microphonemes.

Twaddell observes that the microphonemes of class II have no similarities with those of the other classes, but the microphonemes of class I and class III, characterized by the differences among terms in each series, are similarly ordered (**Figure 3*b***). We observe further that terms 2 (aspirated) and 8 (unaspirated) in class I are correlated with terms 3 (voiceless) and 7 (voiced), respectively. In other words, in initial position voiceless stops are predictably aspirated and voiced stops are predictably unaspirated. Therefore, we can omit the predictable aspiration terms, and line up the microphonemes in classes I and III, as in **Figure 3*c***.

Twaddell (1935, p. 48) writes that "[t]he sum of all similarly ordered terms (microphonemes) of similar minimum phonological differences among forms is called a MACRO-PHONEME." The common terms of classes I and III show that initial and final stops can be combined: Initial [p^h] is part of the same macrophoneme /p/ as final [$p^\neg$], and similarly for /t/, /k/, /b/, and so on.

a Contrasts in terms of articulatory differences: microphonemes

Class I		**Class II**		**Class III**	
pill	1-2-3-4	**f**in	10-3-14-15	na**p**	1-8-3-9
till	5-2-3-4	**th**in	11-3-14-15	gna**t**	5-8-3-9
kill	6-2-3-4	**s**in	12-3-14-16	kna**ck**	6-8-3-9
bill	1-8-7-4	**sh**in	13-3-14-16	na**b**	1-8-7-9

b Aligning classes I and III

Class I		**Class III**	
pill	(1-3)–(2)	na**p**	(1-3)
till	(5-3)–(2)	gna**t**	(5-3)
kill	(6-3)–(2)	kna**ck**	(6-3)
bill	(1-7)–(8)	na**b**	(1-7)

c Identifying macrophonemes

Macrophonemes I–III
pill...(1-3)...na**p**
till...(5-3)...gna**t**
kill...(6-3)...kna**ck**
bill...(1-7)...na**b**

Figure 3

Identifying micro- and macrophonemes in terms of minimal contrasts (Twaddell 1935).

However, the same does not hold for stops following /s/. As shown in list 4, a contrast between voiceless and voiced stops is lacking in this position. Therefore, the three-member list of differences in class IV cannot be aligned with the four-member lists of classes I and III. According to Twaddell (1935, p. 49), "There appears to be no alternative to considering the stops of 'spill, spare, spin', etc. as corresponding to a different phoneme from the stops of 'pill, pare, nap, lip, tapper, slapper', etc." This is because the former are contrastively bilabial and stop, but not contrastively voiceless, whereas the latter are contrastively bilabial, stop, and voiceless.

Series of stops following /s/ (class IV)

(4) s**p**ill, s**t**ill, s**k**ill, *s**b**ill

Twaddell's procedure is presented only with partial examples, and has some significant problems. The main shortcomings are that it is not clear how to apply the procedure to a full set of sounds of a language and that the macrophonemes it arrives at are not inclusive enough to amount to the "phonemes" recognized by most phonologists of Twaddell's time and after. The procedure is very sensitive to accidental gaps: For example, the [p^h] in *pig* {*pig–*tig–*kig–big*} cannot be aligned with the [p^h] in *pill* {*pill–till–kill–bill*}. It follows that these [p^h] are not part of the same macrophoneme, an apparently undesirable result that Twaddell (1935, pp. 50–51) attempts to remedy.

Twaddell's (1935, p. 49) procedure is, in his own words, "complicated and forbidding," and was not taken up by other phonologists, or even by Twaddell himself, for example, in his celebrated phonemic solution to the problem of Old High German umlaut (Twaddell 1938). Nevertheless, the important insight that the phoneme is a "negative, relational, differential abstraction" in the sense of Saussure [1972 (1916)], which must be built out of smaller constituents, was being acted on in different terms by linguists of the Prague School. I turn to their work in the following section.

4. TRUBETZKOY: A THEORY OF CONTRASTIVE FEATURES

> [A] phonemic system presupposes a system of oppositions. . . . But *opposition* is not exclusively a phonological concept, it is a logical one, and the role it plays in phonology is strongly reminiscent of its role in psychology.
>
> Trubetzkoy [2001 (1936), p. 15]

The phonologist who did the most to establish subphonemic contrastive features as an organizing principle of phonology was Prince N.S. Trubetzkoy (1890–1938). Halle (2002, p. 4) credits Trubetzkoy, together with Jakobson, with rediscovering Bell's idea that "features [are] not properties of the sounds; rather they [are] the (interchangeable) parts of which the sounds are composed."

At the heart of Trubetzkoy's theory in the *Grundzüge der Phonologie* (Trubetzkoy 1939) is the notion of an "opposition," which is a relation between a pair of phonemes. Every phoneme of a language enters into an opposition with every other phoneme. Oppositions can be classified in a number of ways. One is in terms of their basis of comparison, those properties that the opposition members share. In a bilateral opposition, the shared properties are unique to those two members; in a multilateral opposition, the shared properties are not limited to the two opposition members. For example, in a language where /m/ and /n/ are the only nasals, and [nasal] is a contrastive feature, the opposition *m* ~ *n* is bilateral, because they are the only [+nasal] phonemes. If a language has

a Place of articulation is contrastive, not occlusion

	Bilabial	Labio dental	Apical	Alveolar	Pre palatal	Dorso velar
Voiceless	p	f	t	s	ʃ	k
Voiced	b	v	d	z	ʒ	g

b Occlusion is contrastive, not minor place of articulation

		Labial	Apical/ alveolar	Prepalatal/ dorsovelar
Stop	**Voiceless**	p	t	k
	Voiced	b	d	g
Fricative	**Voiceless**	f	s	ʃ
	Voiced	v	z	ʒ

Figure 4

Standard French obstruent phonemes: two contrastive solutions.

three nasal phonemes, say /m, n, ŋ/, then the *m* ~ *n* opposition is multilateral if the only property they share is [+nasal], because [+nasal] is not exclusive to this pair but is also shared by /ŋ/.[4]

One of Trubetzkoy's key insights is that the determination of contrastive features in an inventory is not self-evident, but must be established by the analyst on the basis of the patterning of the phonological system (the "system of oppositions"). For example, Standard French has the consonantal phonemes shown in list 5. Trubetzkoy observes that stops and fricatives never occur at the same place of articulation. It follows that either place of articulation, as in **Figure 4*a***, or occlusion, as in **Figure 4*b***, could be taken to be contrastive.

Standard French consonantal phonemes

(5) /p, b, t, d, k, g, f, v, s, z, ʃ, ʒ, m, n, ɲ, l, r, j/

No purely logical scheme can choose between the alternatives in **Figure 4**, for both are properly contrastive. Trubetzkoy (1969, p. 126) prefers the analysis in **Figure 4*a*** because the contrast between stops and fricatives does not occur "in its pure form"; it is always accompanied by a difference in place of articulation. As discussed below, both analyses were subsequently taken up by other phonologists.

The phonologically distinctive properties of a phoneme make up its phonemic content, namely "those properties which are common to all variants of a phoneme and which distinguish it from all other phonemes of the same language, especially from those that are most closely related" (Trubetzkoy 1969, p. 66). According to Trubetzkoy, phonemic content is closely tied up with the system of oppositions: "The definition of the content of a phoneme depends on what position this phoneme takes in the given phonemic system, that is, in final analysis, with which other phonemes it is in opposition. . . . Each phoneme has a definable phonemic content only because the system of distinctive oppositions shows a definite order or structure" (Trubetzkoy 1969, pp. 67–68).

[4]The opposition *m* ~ *n* could still be bilateral if these phonemes share another feature, say [−compact], that is not shared by ŋ, for they would be the only phonemes specified [+nasal, −compact].

These remarks suggest that the phonemic content of a phoneme, that is, the set of its distinctive (contrastive) properties, ought to derive from its position in the system of distinctive oppositions. Therefore, we need a way to determine a phoneme's position in the system of oppositions before we have determined its distinctive properties.

For all of his achievements, Trubetzkoy's account of contrastive relations in the *Grundzüge* is crucially incomplete, for it admits of ambiguity as to how contrastive features are determined.[5] Trubetzkoy does not set out an explicit procedure for computing contrastive features. An analysis of the examples he presents suggests that he employed two different (and incompatible) procedures.

4.1. Standard French Consonants: Contrastive Features via Minimal Differences

Though Trubetzkoy (1969, p. 68) at first states that "only the phonologically distinctive properties are to be considered" when evaluating the properties that members of an opposition share, he allows that "some nondistinctive properties may be taken into consideration if, on the basis of these properties, the members of the opposition in question are placed in opposition with other phonemes of the same system." Trubetzkoy gives an example from French (Trubetzkoy 1969, p. 69): "[T]he opposition *d–n* (as in French) is to be considered bilateral because its members are the only voiced dental occlusives. Yet neither voicing nor occlusion is distinctive for *n*, as neither voiceless nor spirantal *n* occur as independent phonemes."[6]

Trubetzkoy here understands a feature to be distinctive in a phoneme only if there is another phoneme in the language that is identical with respect to all its properties (contrastive as well as noncontrastive) except for that feature. Applying this criterion to French *n* in list 5, we observe the contrasts in procedure 6. On this account, the only contrastive feature that /n/ shares with /d/ is [+dental], and this feature is shared also with /t/; thus, the opposition *d* ~ *n* is multilateral unless we include the noncontrastive features [+voiced] and [+occlusive], in which case /d/ and /n/ are the only voiced dental occlusives, turning *d* ~ *n* into a bilateral opposition. I refer to this procedure for computing contrastive features as the Minimal Difference (MD) method.

Procedure for arriving at Trubetzkoy's specifications for French /n/

(6a) *n* is distinguished from *m* and *ɲ* by [dental] (or another place feature).

(6b) *n* is distinguished from *d* by [nasal].

(6c) The above two features suffice to distinguish *n* from every other phoneme as well, regardless of any other distinctions that may exist. That is, no other phoneme is both [+dental] and [+nasal].

4.2. Polabian Vowels: Contrast via a Feature Hierarchy

There are places in the *Grundzüge* where Trubetzkoy adopts a different method. In his discussion of the Polabian vowel system, Trubetzkoy (1969, pp. 102–3) remarks 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. His rationale for this analysis is that in Polabian, the

[5] See Dresher (2007; 2009, pp. 42–59), on which this section is based. Some of the inconsistencies and ambiguities in the posthumous *Grundzüge* may be due to Trubetzkoy's tragic early death.

[6] Martinet (1946, p. 27) considers this resort to nondistinctive features to be an error on Trubetzkoy's part, though he follows Trubetzkoy here in his approach to identifying contrastive features; see Section 5.1, below.

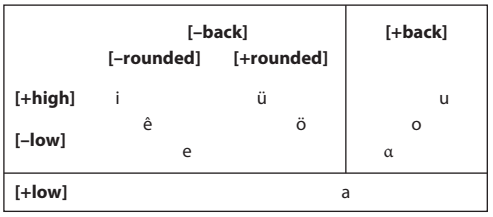

Figure 5

Polabian vowel system: [back] > [rounded] (Trubetzkoy 1939).

front vowels act as a class with respect to palatalization in consonants. He observes, as further evidence, that the oppositions between back and front vowels are constant but that those between front rounded and unrounded vowels of the same height are neutralizable after *v* and *j* to the unrounded vowels *i* and *ê*. His analysis suggests that the features are ordered into the partial hierarchy [back] > [rounded]; the notation "[F1] > [F2]" indicates that feature [F1] is ordered before feature [F2]. Under this analysis, the vowel system is as in **Figure 5**.[7]

If we used the same MD reasoning as for French /n/, we would conclude that [−back] is not distinctive for Polabian /i/ and /ê/, because there are no [+back] unrounded phonemes /ɯ/ and /ɤ/. But then we could not group /i, ê/ with / ü, ö/ as [−back] vowels. Rather, Trubetzkoy's account of the contrastive features of Polabian /i, ê/ requires a different procedure; for ease of exposition, let us limit procedure 7 to the high vowels /i, ü, u/. I refer to this procedure as the Feature Ordering (FO) method.

Procedure for arriving at Trubetzkoy's specifications for Polabian high vowels

(7a) First, divide the vowels by [back] into [–back] (/i, ü/) and [+back] (/u/) sets. /u/ is now distinguished from the others and needs no further features.

(7b) Then, divide the [–back] vowels into [–rounded] (/i/) and [+rounded] (/ü/) sets. Now all the high vowels have been distinguished from each other.

It is possible to adduce many more examples from the *Grundzüge* where feature ordering, though not referred to explicitly, allows us to capture Trubetzkoy's analysis in a systematic way (see Dresher 2007, 2009 for examples). Moreover, the above procedure meets the requirement that the phonemic content of a phoneme—that is, the set of its distinctive (contrastive) properties—follows from its position in the system of distinctive oppositions. In this procedure, "the system of distinctive oppositions shows a definite order or structure." The order in question is the order of the features, which gives structure to the inventory.

4.3. Two Methods for Computing Contrastive Features

The above two subsections dealt with two different methods put forward by Trubetzkoy (1939) for assigning contrastive features to phonemes: the MD method, based on finding features that uniquely distinguish phonemes from each other, and the FO method, based on successively

[7]The vowels in **Figure 5** are as presented by Trubetzkoy. According to Polański (1993), the Polabian nonnasal, nonreduced monophthongs are the high vowels /i, ü, u/; closed *é* /è/; the mid vowels /e, ö, o/; and the low vowel /a/ and its rounded counterpart /å/.

dividing the inventory by ordered features. These methods follow different principles and give different results, and both have continued to be used by phonologists until today. In the following sections, I trace the history of these approaches.

5. CONTRASTIVE FEATURES VIA MINIMAL DIFFERENCE

First, I describe the MD approach. Generalizing Trubetzkoy's statement about why neither voicing nor occlusion is distinctive for *n*, we can formulate the key idea of this approach as in definition 8.

Contrastive features via MD

(8) A feature [α F] is contrastive for a phoneme P if and only if there is another phoneme Q that has the same specifications as P except that it is [$-\alpha$ F].

Definition 8 continues to govern many contrastive analyses in the literature, though not always expressed in the same way.[8] It has a certain common-sense appeal in that it is undoubtedly true that if a feature represents the sole difference between two phonemes, then it must be contrastive for those phonemes. Thus, definition 8 can be said to be a sufficient condition for a feature to be contrastive for a phoneme. Problems arise, however, when phonemes are distinguished from each other by more than one feature—a common situation, particularly if one pays attention to all the ways that two phonemes may phonetically differ. MD is flawed on logical and empirical grounds (Archangeli 1988; Dresher 2002, 2003, 2009; Hall 2011a); also see the argument by Halle (1959), discussed below in Section 6.3.

5.1. Martinet

André Martinet (1908–1999) applied a systemic view of phonological contrast to synchronic and diachronic phonology that was influenced by the Prague School. He employed MD to arrive at the contrastive specifications of the phonemes of Franco-Provençal of Hauteville (Martinet 1956) and of Standard French (Martinet 1964). Martinet (1964, p. 64) begins his analysis of the French consonants in a manner reminiscent of Twaddell (1935), by listing all the consonants that appear before *-ouche*, though he loosens the criterion by also including consonants that may appear in that context, even though there is no current French word with that sequence. Having established what the contrasting phonemes are, he groups them in sets and assigns them contrastive features, as in **Figure 6**.

Martinet's analysis follows Trubetzkoy's in preferring to make place of articulation the main contrast, rather than occlusion, which plays no role here. That Martinet utilizes minimal differences in assigning the features in **Figure 6** is evident from the fact that /b, d, j/ are designated nonnasal but /g/ and /p, t, k/ are not. This is because /b, d, j/ have nasal counterparts /m, n, ɲ/, which otherwise have identical specifications. But there is no /ŋ/; thus, /g/ (and a fortiori /k/) is not contrastively nonnasal.

Apart from unvoiced ~ voiced and nonnasal ~ nasal, none of the other features has a negative counterpart. This would follow if we regard all the other features (including lateral, hiss, and hush) as being values of a single multivalued place feature. If we somewhat anachronistically treat the

[8] Examples of MD can be found in Clements (1988), Campos Astorkiza (2007), and Nevins (2010). More complex versions that try to address MD's shortcomings are given by van den Broecke (1976), who nevertheless does not advocate it, and Calabrese (2005).

Feature	Consonants	Feature	Consonants
'unvoiced'	/p, f, t, s, ʃ, k/	'voiced'	/b, v, d, z, ʒ, g/
'nonnasal'	/b, d, j/	'nasal'	/m, n, ɲ/
'lateral'	/l/	'uvular'	/r/
'bilabial'	/p, b, m/	'labiodental'	/f, v/
'apical'	/t, d, n/		
'hiss'	/s, z/	'hush'	/ʃ, ʒ/
'palatal'	/j, ɲ/	'dorsovelar'	/k, g/

Figure 6

Contrastive sets of French consonants (Martinet 1964).

two paired features as two values of the features [voiced] and [nasal], then we can plot the feature specifications in **Figure 6** as in **Figure 7**. The pattern of blanks (zero specifications) in the triads /p, b, m/ and /t, d, n/ is characteristic of MD underspecification.

5.2. Jakobson and Halle

Together with Trubetzkoy, Roman Jakobson (1896–1982) was a pioneer of the notion that contrastive features are essential to an understanding of phonological structure. Trubetzkoy's notion of "phonemic content" is foreshadowed in Jakobson's [1962 (1931)] account of the "phonemic make-up" of phonemes as consisting of their contrastive features (see Dresher 2009, pp. 3–4). Jakobson [1972 (1931)] argued that an understanding of oppositions is crucial not just to synchronic phonology but also to diachrony.

Whether Jakobson had a specific procedure for identifying contrastive features is not clear in his earlier writings. Though he later was a proponent of FO, he occasionally appears to have employed MD, though he is not explicit about how he obtains contrastive feature values.

An example is his article on the phonemes of Serbo-Croatian (Jakobson 1949). His specifications for voicing and nasality for /p, b, m/, /t, d, n/, and /k, g/ are exactly the same as in Martinet's analysis of French (**Figure 7**), suggesting a similar approach. Similarly, Halle (1954) appears to resort to this method in some parts of his analysis of literary Standard German, contrary to his prevailing practice (for fuller discussion, see Dresher 2009, pp. 82–89).

	/p/	/b/	/m/
[voiced]	–	+	
[nasal]		–	+
[place]	bi	bi	bi

	/f/	/v/
[voiced]	–	+
[nasal]		
[place]	l-d	l-d

	/t/	/d/	/n/
[voiced]	–	+	
[nasal]		–	+
[place]	ap	ap	ap

	/s/	/z/
[voiced]	–	+
[nasal]		
[place]	hi	hi

	/ʃ/	/ʒ/
[voiced]	–	+
[nasal]		
[place]	hu	hu

	/j/	/ɲ/
[voiced]		
[nasal]	–	+
[place]	pa	pa

	/k/	/g/
[voiced]	–	+
[nasal]		
[place]	d-v	d-v

	/l/	/r/
[voiced]		
[nasal]		
[place]	la	uv

Figure 7

The specifications of **Figure 6** in a chart.

	p	b	m	f	v	t	d	n	s	z	ʃ	ʒ	ɲ	k	g	l	r
Vocality	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	±	±
Nasality	–	–	+	–	–	–	–	+	–	–	–	–	+	–	–		
Saturation	–	–	–	–	–	–	–	–	–	–	+	+	+	+	+		
Gravity	+	+	+	+	+	–	–	–	–	–							
Tensity	+	–		+	–	+	–		+	–	+	–		+	–		
Continuousness	–	–		+	+	–	–		+	+	+	+		–	–	+	–

Figure 8

The specifications of Standard French consonants (Jakobson & Lotz 1949).

6. CONTRASTIVE FEATURES VIA FEATURE ORDERING

Despite occasional detours, Jakobson, together with Morris Halle, was the main advocate of a hierarchical FO approach to contrast. A hierarchical approach may be implicit in Jakobson's famous *Kindersprache* [Jakobson 1968 (1941)], which views the child's developing inventory as beginning with the most basic and maximal contrasts (consonant versus vowel) that then successively split into narrower and less universal contrasts.[9] Throughout the 1950s, Jakobson and Halle, sometimes with other colleagues, advanced this approach to contrastive specification. Notable publications include Jakobson et al. [1976 (1952)], Cherry et al. (1953), and Jakobson & Halle (1956), culminating in Halle (1959). Before these, a clear hierarchical approach was evident in a 1949 article on Standard French by Jakobson and János (John) Lotz (1913–1973) (Jakobson & Lotz 1949).

6.1. Jakobson and Lotz

Jakobson & Lotz's (1949) analysis takes a different tack from Martinet in two ways. First, and most noticeably, Jakobson and Lotz adopt the analysis in **Figure 4*b*** that Trubetzkoy rejected; that is, they treat French contrasts as based on occlusion and ignore differences in minor place. Second, they adopt a hierarchical FO approach to contrastive feature specification, developing the other approach to contrast implicit in Trubetzkoy's *Grundzüge*.

Jakobson & Lotz (1949) do not explicitly discuss their method for computing what the contrastive features of French are. They present a transcription that indicates the feature specifications of every phoneme in a particular French sentence, specifying each phoneme as positive (+), negative (–), intermediate between positive and negative (±), or blank for each feature (/ɲ/ and /g/ do not occur in the transcribed sentence, but their feature values are inferred from the discussion and diagrams in the rest of the article).

The pattern of blanks gives clear evidence that the features were computed hierarchically, by successively dividing the inventory by features in a particular order until every phoneme had been distinguished. The authors' analysis presupposes that the features apply in the order in which they are listed in **Figure 8**. Each feature applies in turn to each branch of the tree in which it is contrastive, as shown in **Figure 9**.

The analysis proceeds as a decision tree. The first decision pertains to [vocality] (**Figure 9*a***). Phonemes are classified as [–vocality] (consonants); [+vocality] (vowels and glides); or a third intermediate value, [±vocality], for liquids. The second decision involves [nasality], which is

[9]Jahr (2011) traces this idea back to a review by Sommerfelt (1929), to whom Jakobson dedicates his book. This idea is developed further in FO terms by Jakobson & Halle (1956).

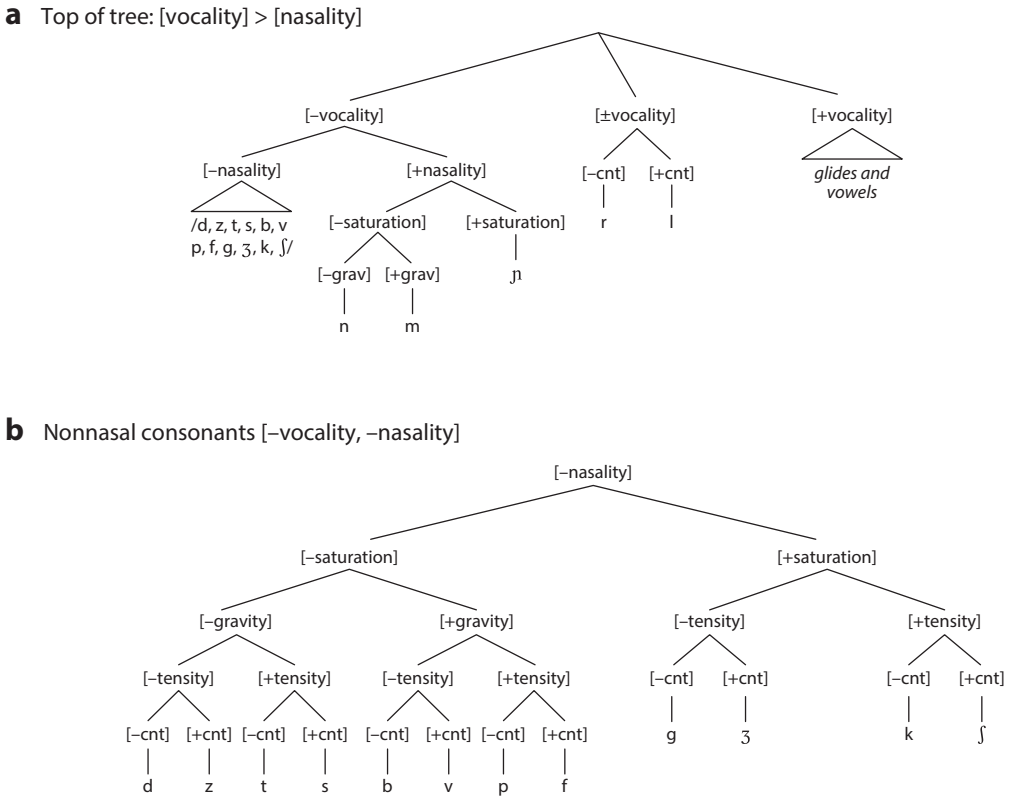

Figure 9

Feature tree for Standard French consonants (Jakobson & Lotz 1949).

contrastive in the consonants (and vowels) but not in the liquids. If a feature is not contrastive in a branch of the tree, it is not assigned to that branch. There are only two liquids, /r/ and /l/, and only the last feature, [continuousness], distinguishes them; therefore, the other features do not apply to the liquids, and [±vocality] is divided by [continuousness]. The nasal consonants are further distinguished from one another by [saturation] and [gravity]. The liquids and nasals are now completely distinguished and receive no further specifications.

The tree continues with the expansion of contrasts in the nonnasal consonants, under [−vocality, −nasality] in **Figure 9*b***. The next choice is [saturation]: These phonemes are either unsaturated (front coronals and labials) or saturated (postalveolars and velars). If we choose [−saturation], then the next feature is [gravity]: Coronals are [−gravity], and labials are [+gravity]. The final choices are [tensity] (which in this group functions as [voicelessness]) and [continuousness] in each branch. In the [+saturation] branch, there are no contrasts with respect to [gravity], so the next features that apply are [tensity] and then [continuousness].

The hierarchical FO approach to contrastive feature specification is made more explicit by Jakobson et al. [1976 (1952)], who compare it to answering a series of yes/no questions (the intermediate value is excluded). These authors attach a particular importance to the feature tree, or "dichotomous scale": "The dichotomous scale is the pivotal principle of the linguistic structure. The code imposes it upon the sound" [Jakobson et al. 1976 (1952), p. 9].

6.2. Principles Governing Feature Ordering

In a hierarchical approach to feature specification, it is necessary to put the features into an order. The ordering is crucial to the analysis because different orders yield different trees and, hence, different contrastive specifications. For example, if we were to reverse the order of the top two features in **Figure 9**, so that [nasality] precedes [vocality], then /r/ and /l/ would be specified as [−nasality], rather than having no specification for [nasality]. Therefore, it is important to develop principles that govern what the ordering should be. Dresher (2015) identifies three principles that have been appealed to at various times, as shown in principles 9*a–c*. These principles do not always conflict, but in many cases they lead to different solutions.

Principles used to determine the ordering of features in a hierarchy

(9a) Activity: to identify the contrastive features that are relevant to the phonological computation.

(9b) Minimality: to minimize redundancy in phonological representations and to maximize the amount of information conveyed by each feature.

(9c) Universality: to express universal tendencies in the nature of phonological inventories and the order of acquisition of feature contrasts.

Principle 9*a*, Activity, has its roots in the earlier work reviewed above, where distinctive features were identified on the basis of the role they played in phonological patterning. For example, Jakobson & Lotz (1949) give empirical arguments for their choice of feature specifications for Standard French, based on the adaptation of foreign sounds and language-internal alternations. To support the feature [saturated], they observe (Jakobson & Lotz 1949, p. 153)

> the difference between velar and palatal is irrelevant in French phonemics . . . . These contextual variations do not hinder French speakers from rendering the English velar *ŋ* through the French palatal *ɲ* . . . or the German 'ich-Laut' through *ʃ*. The advanced articulation of *k g* before *j* or *i*, as well as the existence of *ŋ* instead of *ɲ* before *w* . . . illustrates the unity of the saturated consonants in French.

It is thus Activity (principle 9*a*) that stands as the rationale for their feature order.

Jakobson et al. [1976 (1952)] and Cherry et al. (1953) manifest a shift toward a greater emphasis on Minimality (principle 9*b*) in choosing feature orders. The latter consider some properties of phonemic structure in terms of mathematical concepts relevant to the then-emerging field of statistical communication theory (Shannon & Weaver 1949). This trend continues in Jakobson & Halle (1956). These authors give an analysis of Standard French similar to that of Jakobson & Lotz (1949), and though they still pay attention to activity, their main justification is based on Minimality. In reply to Chao (1954), who asked if the dichotomous scale is a principle imposed by the analyst or inherent in the structure of language, Jakobson & Halle (1956, pp. 45–46) argue that theirs is "the unique solution" on the grounds that it is optimal in terms of the number of binary decisions that have to be made. They argue that the six French voiceless consonants /p, f, t, s, ʃ, k/ can be distinguished from one another by only three binary decisions in their analysis (essentially the same as in **Figures 8** and **9**, with "saturation" renamed "diffuse"): compact/diffuse, grave/acute, and continuous/discontinuous. For example, /p/ ∼ /f/ are distinguished by [continuousness], parallel to /t/ ∼ /s/ and /k/ ∼ /ʃ/; both /f/ ∼ /s/ and /p/ ∼ /t/ are distinguished by [gravity]; and /k/ ∼ /t/ and /ʃ/ ∼ /s/ display the same compact/diffuse opposition, labeled [saturation] in **Figures 8** and **9**.

Jakobson & Halle (1956) compare this analysis with one that takes the point of articulation to be distinctive. In an analysis such as that of Martinet, given above in **Figures 6** and **7** (they do not explicitly refer to Martinet or to any other analysis), every opposition involving the six voiceless consonants requires a different contrast, amounting to 15 different decisions rather than 3. For example, /p/ ~ /f/ opposes bilabial to labiodental; /t/ ~ /s/ opposes apical (or dental) to hiss (or alveolar); and /k/ ~ /ʃ/ opposes dorsovelar to hush (postalveolar).

Following Jakobson [1968 (1941)], Jakobson & Halle (1956, pp. 37–41) argue that the dichotomous scale plays an important role in language acquisition. They suggest that distinctive features are necessarily binary because of the way they are acquired, through a series of "binary fissions." They propose that the order of these contrastive splits is partially fixed, thereby appealing to Universality (principle 9*c*); a universal order, if it could be empirically established, would constrain the possible feature orders and support the connection drawn by Jakobson [1968 (1941)] between synchronic phonological universals and the order of development of child language.[10]

6.3. Feature Hierarchies in Early Generative Phonology

A major early work in the developing framework of generative phonology is Halle's (1959) *Sound Pattern of Russian*. This book features a novel argument that phonological features must be ordered into a hierarchy. Halle proposes that for phonemes to be properly distinct, they must satisfy the following Distinctness Condition, and that the only way to ensure that they do so is to determine that the features can be displayed as a branching tree.

The Distinctness Condition (Halle 1959, p. 32)

(10) Segment type {A} will be said to be different from segment type {B}, if and only if at least one feature which is phonemic in both, has a different value in {A} than in {B}; i.e., plus in the former and minus in the latter, or vice versa.

It is clear that the specifications in **Figure 7**, derived by MD, do not all meet the Distinctness Condition. In the triad /p, b, m/, /p/ ~ /b/ are distinguished by [voiced], and /b/ ~ /m/ are distinguished by [nasal], but for /p/ ~ /m/, there is no feature that is positive in one and negative in the other (and similarly for /t/ ~ /n/). No feature hierarchy yields the representations in **Figure 7**: Ordering [voiced] > [nasal] would result in /m/ being specified [−voiced] in addition to [+nasal], and ordering [nasal] > [voiced] would result in /p/ being specified [−nasal] in addition to [−voiced].

The specifications derived by FO in **Figure 8**, on the contrary, do all meet the Distinctness Condition [the third, intermediate value, no longer permitted in Halle (1959), is nevertheless distinct from both the positive and negative values]. Ordering binary features into a hierarchy guarantees that every pair of phonemes will be distinguished by at least one feature for which one is specified positive and the other negative.

Though Halle (1959) does not mention any other method for computing underspecified representations, the Distinctness Condition serves as an argument against arriving at contrastive specifications by means of the MD method, employed by Martinet and others. This approach to contrast is featured prominently in Harms (1968), the first textbook in generative phonology. Harms (1968, pp. 15–21) presents a number of examples of contrastive specifications and provides

[10]Later researchers have argued that the development of child language allows for much more variation than Jakobson hypothesized; see, for example, Menn & Vihman (2011). Nevertheless, the notion of a contrastive hierarchy continued to be fruitfully applied to describe developing child phonological inventories; examples include Pye et al. (1987), Ingram (1988, 1989), Levelt (1989), Dinnsen et al. (1990), Dinnsen (1992, 1996), and Fikkert (1994).

exercises in which students are asked to check whether various classificatory feature representations in the literature meet the Distinctness Condition (what he calls "strict binarity") by seeing whether they can be represented as binary branching trees. Interestingly, all three examples containing underspecified feature matrices, from Ferguson & Chowdhury (1960) (Bengali), Hohepa (1967) (Maori), and Warotamasikkhadit (1967) (Thai), fail to meet the Distinctness Condition; moreover, they do not appear to have been produced in accord with either MD or FO, or any other consistent method that I can discern. This finding suggests that consistent principles of contrastive specification were not widely known or commonly followed in the 1960s.

7. THE DECLINE OF CONTRAST IN GENERATIVE PHONOLOGY

Harms's attempt to correct this state of affairs, however, came at a time when the theory of generative phonology was turning against the notion that grammars should give special status to language-particular contrastive features. First, the attacks on the structuralist taxonomic phoneme by Halle (1959) and Chomsky (1964), and their advocacy of a rule component that mediates between underlying (lexical) and surface (phonetic) representations with no distinguished intermediate level, left little room for making significant distinctions between contrastive and noncontrastive features (see Dresher 2005, 2009). Second, the notion of underspecification, and with it the branching feature tree, was attacked by a number of writers, notably Stanley (1967). Third, Kiparsky (1965), expanding on earlier demonstrations that purely contrastive accounts of phonemic systems make even closely related dialects incommensurable (Moulton 1960), argued that analyses that classify phonemes only in terms of the number of contrasts they enter into, rather than by the rules they undergo, make impossible a coherent account of a series of Armenian sound changes.

As a result of these various anticontrast currents (see Anderson 1985, pp. 10–13), the influential *Sound Pattern of English* by Chomsky & Halle (1968) posited that phonological rules operate on fully specified feature matrices, and make no distinction between contrastive and noncontrastive features. Consequently, interest in contrast and principles of contrastive specification fell out of the mainstream of phonological theory for the rest of the twentieth century.[11]

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[11] Contrastive hierarchies occurred sporadically in Cairns (1988) and Boersma (1998) and were revived by Clements (2001, 2003, 2009) and independently at the University of Toronto (Dresher et al. 1994; **http://homes.chass.utoronto.ca/~contrast/**). See Dresher (2009, p. 163f) for references and a detailed review. For recent applications and developments of this approach, see Hall (2011b), Mackenzie (2011, 2013), Ko (2012), Spahr (2014), and Oxford (2015).

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