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17. Distinctive Features

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Sections

1 Introduction

Distinctive feature theory is an effort to identify the phonetic dimensions that are important for lexical contrasts and phonological patterns in human languages. The set of features and its explanatory role have both expanded over the years, with features being used to define not only the contrasts but the groupings of sounds involved in rules and phonotactic restrictions, as well as the changes involved in rules. Distinctive features have been used to account for a wide range of phonological phenomena, and this chapter overviews the incremental steps by which the feature model has changed, along with some of the evidence for these steps. An important point is that many of the steps involve non-obvious connections, something that is harder to see in hindsight. Recognizing that these steps are not obvious is important in order to see the insights that have been made in the history of distinctive feature theory, and to see that these claims are associated with differing degrees of evidence, despite often being assumed to be correct.

The structure of the chapter is as follows. §2 describes the series of non-obvious claims that led to modern distinctive feature theory, and §3 briefly describes the particular features that have been proposed. §4 reconsiders some of the earlier claims, and §5 looks at some ongoing investigations.

2 Building a model of phonological behavior

Distinctive feature theory began largely as a model for reducing the number of phonological contrasts in a language, and the feature system that was developed for this purpose was gradually embellished in order to provide an account for more and more facts about sound patterns and typology. Trubetzkoy (1939: 66–89) developed the study of oppositions between speech sounds, which grew into the study of distinctive features. After Trubetzkoy's death in 1938, the early years of distinctive feature theory were associated most with Roman Jakobson.

2.1 Reducing contrasts with (mostly) binary features

Jakobson (1942: 235) hypothesized that differences that on their own are not meaningful, such as the differences between phonemes, are very demanding on perception and memory, and he concluded that the number of “primordial and unmotivated values” should be minimized. For example, the eight-vowel inventory of Turkish (/i ɨ y u e a ø o/) involves 28 binary relations, as illustrated in **Figure 17.1**. Jakobson observed that many of these relations are essentially the same, e.g. the difference between /i/ and /y/ is basically parallel to the difference between /e/ and /ø/. Both relate an unrounded vowel and a rounded vowel which are otherwise largely the same. In the figure, solid lines with black circles at the end are used to represent independent contrasts. The contrasts between the eight vowels can be reduced to three orthogonal dimensions (height, backness, and rounding), and any of the 28 binary relations can be represented as differences along one or more of these three dimensions (see **CHAPTER 2**: CONTRAST). In this way, 28 binary oppositions can be captured by three binary distinctive features. The vowel inventory of Turkish is a particularly clean example, because it happens to be "cubic," fully exploiting three features, but any inventory containing pairs of segments that differ from each other along similar phonetic dimensions is reducible in this way to some extent.

The assumption of binarity for these features since the early days of feature theory can be attributed in part to the influence of Information Theory (**Shannon and Weaver 1949**). **Jakobson *et al.* (1952)** argued that Information Theory provides a sequence of binary selections as the most reasonable way to analyze communication, and that language is not merely amenable to such an analysis, but is inherently structured in this way. Some pairs of words, such as *bill/pill* and *bill/dill*, involve a difference of one feature, while pairs like *bill/fell* can be treated as a difference of more than one binary feature (since the difference between /b/ and /f/ can be reduced to two independently motivated dimensions, and the difference between /ɪ/ and /ɛ/ can be reduced to one). **Jakobson *et al.* (1952)** noted that each of the phonetic dimensions related to a distinctive feature is continuous, but features consistently pick out two polar points. Since the dichotomous scale was believed to be the optimal code, they saw no reason why language would be organized according to a more complicated system. Some features, such as [compact/diffuse] (see next section) were considered to be equipollent, having three values (compact, diffuse, or neither), based on the fact that there seem to be three degrees of vowel height along the same dimension (e.g. /i/–/e/–/æ/).

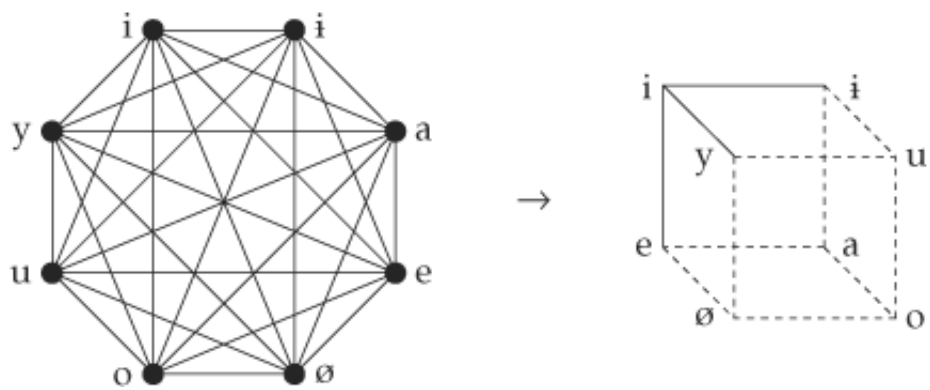

Figure 17.1 Reducing 28 binary relations to 3

The advances up to this point are summarized in (1).

(1) a. Claim: Segmental contrasts can be reduced to a smaller number of featural contrasts.

b. Claim: Features are (mostly) binary.

Miller and Nicely (1955) provided some phonetic evidence in support of the idea that contrast between segments is divided into discrete channels. They showed that the distinctions between different consonants occupy different parts of the speech signal, and can be interfered with through different techniques for signal degradation. Miller and Nicely adopted voicing, nasality, affrication, duration (which could also be called "stridency") and place as features to distinguish /p t k f θ s ʃ b d g v ð z ʒ m n/. The oppositions associated with these features are affected differently by random masking noise, high-pass filtering, and low-pass filtering. The idea is that the information content of a message is distributed among different acoustic channels, and can consequently be selectively and independently degraded. Random masking noise degrades affrication, duration, and place distinctions more than it degrades voicing and nasality. Duration, on the other hand, is more resistant to high-pass filtering. These results are relevant to the design of telephone communication systems, but also supportive of the idea that different phonological contrasts are manifested in different parts of the speech signal. This provides evidence consistent with consolidating phonetic differences as in the Turkish example above in **Figure 17.1**. Although the dimensions investigated by Miller and Nicely are not the same dimension that distinguish the Turkish vowels, oppositions that are treated as parallel in phonological analyses were shown to be degradable in transmission, independent of other oppositions.

2.2 Abstractness, universality, and innateness

The reduction of segmental contrasts to a smaller number of distinctive features can be a purely language-particular endeavor. **Jakobson (1942**: 241) asserted that "[t]he description of a system of values and the classification of its elements can be made only from that system's own perspective, that is, from the perspective of the tasks that the system fulfills." He observed, though, that languages often make use of the same phonetic dimensions for contrasts (**Jakobson 1942**: 239). If two languages use the same phonetic dimension, then a distinctive feature in one language is fundamentally similar to the "same" feature used in the other. Jakobson contrasted this with the difference between similar-sounding phonemes in different languages. Since phonemes are treated as bundles of distinctive feature values, the phonological content of a phoneme depends on the segmental oppositions it is involved in. It was the *features*, then, that could be treated as basic building blocks, comparable across languages.

Jakobson *et al.* (1952: 40) reported that they detected only 12 distinctive features (**Table 17.1**) in the languages of the world "which underlie their entire lexical and morphological stock," but left open the possibility of adding more. These features were defined primarily in acoustic terms.

Fundamental source features:		
Vocalic (periodic voice source with non-abrupt onset)	*vs.*	Non-vocalic
Consonantal (acoustic zeros across the spectrum)	*vs.*	Non-consonantal
Envelope features:[a]		
Interrupted (abrupt onset)	*vs.*	Continuant
Checked (abrupt decay)	*vs.*	Unchecked
Strident (irregular waveform)	*vs.*	Mellow
Voiced	*vs.*	Voiceless
Resonance features:		
Compact (predominance of one formant region)	*vs.*	Diffuse
Grave (low end of spectrum dominates)	*vs.*	Acute (high end dominates)
Flat (formants shifted down)	*vs.*	Plain
Sharp (F2 and other formants shifted up)	*vs.*	Plain
Tense (longer and more energetic)	*vs.*	Lax
Nasal	*vs.*	Oral

[a] The term *envelope* in the feature categories refers to the "temporal envelope of sound intensity" (Jakobson *et al.* 1952: 21), i.e. how abruptly the sound starts or ends, and how smooth the intensity remains in between.

Table 17.1 Preliminaries (**Jakobson *et al.* 1952**): Acoustically defined features

The universality of this kind of feature set can be interpreted as a fact about the phonetic dimensions that are available to the human vocal tract and the human auditory system rather than a claim about the features themselves. That is, if humans are physically limited to 12 phonetic dimensions for distinguishing sounds, then language is similarly limited in the range of distinctive features it can involve. The limiting factors are physiology and acoustics, not features. **Jakobson *et al.* (1952**: 31) argued that the feature [flat] (defined acoustically as downwardly shifted formants) could apply to both pharyngealization and labialization, since the two articulatory gestures have similar acoustic effects, since they appear never to be used contrastively in the same language, and since Bantu languages and Uzbek substitute labialized consonants for Arabic pharyngealized consonants in loanwords. This can be treated as an observation about acoustic and perceptual similarity or as the effects of a universal abstract feature. In later approaches, the features themselves were taken to be the basic limiting factor. While this practice of drawing explanations from (potentially innate) features themselves has been attributed to the influence of Chomsky's approach to syntax (e.g. **Chomsky 1957, 1965**), **Halle (1983)** reports that it was present all along:

> Considerations [that languages apparently do not make use of acoustic or articulatory correlates of features alone] were in our minds thirty years ago when Jakobson, Fant and I were working on *Preliminaries to Speech Analysis*, and it was these considerations that led us to draw a sharp distinction between distinctive features, which were abstract phonological entities, and their concrete articulatory and acoustic implementations. Thus, in *Preliminaries* we spoke not of "articulatory features" or of "acoustic features," but of "articulatory" and/or "acoustic correlates" of particular distinctive features. The model we had in mind was, therefore, of the type … where the abstract distinctive features constitute the link between specific articulatory and acoustic properties of speech sounds.

Quantal Theory (**Stevens 1972, 1989**) attributes the phonological oppositions used by languages to the non-linear relationships between articulatory and acoustic parameters (as well as between acoustic and perceptual parameters). For example, a tongue movement from back to front is not linearly related to the acoustic consequences of such a movement. Rather, there are stable regions where the acoustic consequences of tongue movement are small, and an unstable region in between where small movements have big acoustic consequences. Stevens identifies the stable plateau-like regions in articulatory-acoustic mapping with values of universal distinctive features. Quantal relations provide a natural foundation for binary features with acoustic and articulatory correlates that are common to many languages.

The sound pattern of English (*SPE*; **Chomsky and Halle 1968**), which remains one of the most influential works in phonological theory, involved an extension of some of Chomsky's formal universals to the study of phonology. Formal universals were believed to be unlearnable and consequently innate, and the idea of a universal feature set was compatible with the innate primitives of contemporary syntactic theory. **Chomsky and Halle (1968**: 164) claim that distinctive features "must be determined absolutely, within general linguistic theory, and independently of the grammar of any particular language."

Several studies from the 1960s and 1970s looked for evidence of these features in various aspects of linguistic behavior. Although the **Miller and Nicely (1955)** study discussed above indicates the distribution of contrasts across phonetic dimensions, it does not specifically require abstract features. A persistent difficulty with finding empirical evidence for distinctive features is that there is considerable overlap between what features are intended to account for and what can be accounted for more or less directly from acoustics and other independently observable factors.

A dichotic listening study by **Studdert-Kennedy *et al.* (1972)** bears on the question of abstractness.[1] This was a follow-up to a previous study by **Studdert-Kennedy and Shankweiler (1970)**, which found that English-speaking participants more accurately identify different segments heard in both ears simultaneously if the two segments share phonetic features. In other words, segments are easier to recognize when they differ on fewer of the acoustic channels of the type identified by Miller and Nicely. What **Studdert-Kennedy *et al.* (1972)** did in order to address abstractness was to compare stop consonants [p t k b d g] in cases where the following vowels are identical with cases where they are followed by different vowels. The acoustic cues to place of articulation vary by vowel context, but an abstract notion of place of articulation is expected to be stable across vowel contexts. The listeners were no better at identifying stops when the following vowels were identical than when they were different, indicating that identification was facilitated by abstract featural similarity between the segments rather than acoustic similarity alone.

Looking for evidence of features in memory, **Wickelgren (1965, 1966)** tested participants' ability to recall English vowels and consonants, and examined errors for evidence of a feature system used to mediate this process, with the idea that recall errors could take the form of forgetting individual features of sounds, leading to substitution errors involving featurally similar vowels. To show that features are used to store sounds in memory would require showing that a system of distinctive features is superior to phonetic similarity for accounting for errors. **Wickelgren (1965)** examined vowel errors and found that the features of **Chomsky and Halle's (1968)** systematic phonetic level work equally as well as conventional articulatory phonetic descriptions for accounting for errors involving vowels, and that **Chomsky and Halle's (1968)** phonemic level, which would be expected to be more intimately related to memory, does less well, as do the features of **Jakobson *et al.* (1952)**. **Wickelgren (1965)** examined consonant errors and found that **Miller and Nicely's (1955)** features accounted significantly better for the errors than **Halle's (1964)** feature system (using [voicing], [nasality], [vocalic], [consonantal], [continuant], [strident], [grave], [diffuse]), and that Wickelgren's new feature system, based on articulatory descriptions, did better than either.

Graham and House (1971) examined the ability of English-speaking girls aged 3–4.5 years to perceive differences between 17 English consonants, and concluded that their results do not support the idea that distinctive features are the perceptual parameters used to categorize segments. They found that segments that differ by only one *SPE* feature are more likely to be confused than segments differing by two or more features, but confusion rates otherwise do not correlate with the number of feature differences, and the two most confusable pairs of segments ([f]/[θ] and [r]/[w]) involve acoustically similar pairs of segments that differ by two and four features, respectively. It is notable that these studies settled on different feature systems for accounting for their observations, even though they were all conducted with English-speaking participants. Nevertheless, the pursuit of a single set of features for all languages was unperturbed.

Infant perception experiments in the 1970s, such as **Eimas *et al.* (1971)**, showed that infants can discriminate phonetic contrasts not present in the ambient language. The ability to discriminate contrasts corresponding to proposed distinctive features was taken as evidence that this ability is part of infants' innate linguistic capabilities, abilities that diminish over time, so that adults often cannot distinguish non-native contrasts. Subsequent studies (see **Aslin and Pisoni 1980** for a review) indicated that differences between infants and adults might not be simply a matter of innate abilities that decline over time. **Kuhl and Miller (1975, 1978)** found that chinchillas can also exhibit categorical perception of synthetic voiced and voiceless labial stop stimuli, and that chinchillas have a perceptual boundary that is very similar to the boundary found for human participants. **Aslin and Pisoni (1980**: 85) argue that the perceptual abilities of chinchillas and infant humans with respect to Voice Onset Time (VOT) point to general properties of the auditory systems of mammals, specifically that detection of the onsets of two stimuli is easiest when they are 20 msecs apart. **Holt *et al.* (2004)** also found a discontinuity at 20 msecs in the perception of non-speech stimuli. Many of the results reported by Aslin and Pisoni support an "attunement theory" of the acquisition of the perception of contrasts, wherein infants initially can distinguish many acoustic differences and learn to focus on the distinctions that are linguistically important. **Werker and Tees (1984)** showed that adult participants can still distinguish non-native contrasts under the right conditions, supporting the idea that the differences between infant and adult speech perception are a matter of attention, not sensory-neural capabilities. **Best *et al.* (1988)** argue that the loss of sensitivity to non-native contrasts can be attributed to learning native categories, and that non-native sounds that are not similar to native categories (such as clicks for English speakers) continue to be discriminable on the basis of acoustic differences.

Another area that has been examined for evidence of features underlying speech production is speech production errors. Errors that are understandable as feature substitution or exchange but unexpected from other perspectives would provide evidence for features in processing. A recurring problem is that many errors that can be analyzed in terms of features can be analyzed in other ways as well. **Fromkin (1973, 1988)** cites specific examples such as the substitution of *me*[n]*aphor* for *metaphor*, which appears to involve the wrong value of the feature [nasal], but reports that many errors are ambiguous between feature-based and segment-based substitutions. Since any feature-based error can also be analyzed as a segment-based error, the real issue with finding evidence for features in speech errors is finding that feature-based errors occur more than would be expected if segments were atomic. **Shattuck-Hufnagel and Klatt (1979)** report that most phonetic speech errors involve manipulating segments rather than features, and that in their analysis of their MIT error corpus and **Goldstein's (1977)** UCLA corpus, fewer than a dozen out of 2,989 substitution errors appear to involve feature exchange. More recent studies have indicated that subsegmental speech errors are better handled in terms of sub-featural units or gestures (**Mowrey and MacKay 1990**; **Frisch and Wright 2002**; **Pouplier and Hardcastle 2005**; **Goldstein *et al.* 2007**). For the use of gestures as phonological primitives (instead of or along with features), see the *Phonetica* special issue on Articulatory Phonology, especially the target article by **Browman and Goldstein (1992)** and the commentary by **Clements (1992)**.

If the set of distinctive features places a limit on possible contrasts (a concept **Clements 2009** refers to as *Feature Bounding*), a prediction is that there will be phonetically plausible contrasts that are unattested due to the lack of any feature to distinguish the two segments. **Odden (2005)** observes that retroflex stops in Hindi and Telugu are phonetically distinct (Hindi has apical retroflexes while Telugu has sub-apical retroflexes; see X-ray tracings in **Ladefoged and Maddieson 1996**), but the two types of retroflexes are not known to contrast in any language. This is retroactively predicted by a feature theory that explicitly lacks a feature to contrast these two places of articulation, although an alternative account is that the phonetic difference between the two sounds is too small, or that the two sounds are rare enough that their co-occurrence is not likely in the first place.

In addition to ruling out unattested contrasts, the feature set needs to be rich enough to handle any contrast that does occur. The apparent absence of a contrast in any language between apical and sub-apical retroflex consonants straightforwardly provides support for a feature theory that predicts the impossibility of this contrast (if it is shown that the co-occurrence of these segments would be expected otherwise). Other cases are less clear. For example, both *Preliminaries* features and the later *Sound pattern of English* feature system predict three vowel heights. It has been possible to maintain this claim in the face of apparent evidence of languages with more vowel heights (and counter-proposals such as **Schane 1984** and **Clements and Hume 1995**, which allow more vowel heights), by making use of features like [Advanced Tongue Root]/[tense] to account for additional apparent height differences.

(2) Claim: Different languages make use of the same features, drawn from a universal feature set (whose universality may be due to Universal Grammar).

The interpretation of features as universal allowed them to form the basis of an increasingly elaborate model of phonological behavior.

While **Jakobson *et al.* (1952)** focused on identifying the distinctive features used for contrasting sounds, these features have since been put to other uses in describing phonological phenomena. For example, it was discovered that the features used to define lexical contrasts could also be used to formulate phonological rules. **Halle (1959**: 65) describes the assimilation pattern in Russian in (3) in terms of features as follows: "Before acute compact (palatal) consonants, strident acute noncompact (dental) consonants become compact (palatal)" (see **CHAPTER 71**: PALATALIZATION AND **CHAPTER 121**: SLAVIC PALATALIZATION).

(3) *Russian sibilant assimilation* (Halle 1959: 65)

/bez-'ʧestʲij-o/	bʲiʃ'ʧʲesʲtʲijə	'dishonor'
/bez-'ʒalostʲn-o/	bʲiʒ'ʒaəsnə	'pitiless'
/s-'ʃum-om/	'ʃʃumәm	'with noise'

This rule can be formulated in the *SPE* rule format (using *Preliminaries* features) as in (4).

(4)
$$\begin{bmatrix}\text{consonantal}\\ \text{strident}\\ \text{acute}\\ \text{non-compact}\end{bmatrix} \rightarrow [\text{compact}] \quad / \; \_\_ \begin{bmatrix}\text{consonantal}\\ \text{acute}\\ \text{compact}\end{bmatrix}$$

Here the feature [compact] is being used not simply to distinguish sounds from each other, but for two additional purposes. First, along with other features, it is being used to define the classes of sounds involved in a sound pattern, namely the class of sounds that become palatal in the context of the rule, and the class of sounds that trigger this change. Second, the feature [compact] is being used to define the change described by the rule. As a member of the set of distinctive features, [compact] can define contrasts, classes, and changes. These multiple functions mean that multiple types of evidence can be used to motivate a feature. Since there are often multiple ways to define the same class or the same segmental contrast, spreading of a single property is taken as particularly strong evidence for the existence of a feature.

The set of possible changes is identified with the set of possible contrasts, and the set of classes that are predicted to be involved in rules (or later, constraints) are defined as those classes of segments that share one or more feature values, to the exclusion of all other sounds in the inventory. Using the same features that define contrasts to describe classes of sounds involved in rules or to describe changes involved in rules is not a necessary step, and it interacts with the earlier claim that there is a particular feature set available to all languages.

(5) a. Claim: The distinctive features that define segmental contrasts also define changes in alternations.

b. Claim: The same features also define classes of sounds that may be involved in alternations.

Halle (1972: 62) summarizes the goals of feature theory as follows:

> I take it that a study of the speech sounds of a given language must account for, among others, the following three sets of facts: it must yield insights into the articulatory aspects of the sounds; it must concern itself with the acoustic and psycho-acoustic character of the sounds, and, finally, it must allow us to make sense of various regularities that can be observed in the behavior of different speech sounds and sets of speech sounds, regularities that have traditionally been referred to as phonological or morphophonological. The task of the student of speech sounds then is to discover a theory that will do justice to these different aspects of speech.

A further development of feature theory that was motivated in part by the account of alterations involve the number of values possessed by features. For example, **Sagey (1986)** argued that place features are privative (have only one value). This claim helps account for the observation that the negative values of these features do not seem to be involved in sound patterns. Dependency Phonology and Element Theory (**Harris 1994**; **Harris and Lindsey 1995**) take this further. See also **CHAPTER 7**: FEATURE SPECIFICATION AND UNDERSPECIFICATION.

2.4 Characterizing functional subgroupings of features

2.4 Characterizing functional subgroupings of features

A further development of the feature model was the hierarchical organization of features, in a way that is consistent both with the interdependence of their phonetic correlates and with the way they are grouped together in phonological patterns. In motivating constituency among distinctive features, **Clements (1985**: 229) observed that at least four articulatory parameters show considerable independence from each other: (a) laryngeal configuration, (b) degree of nasal cavity stricture, (c) degree and type of oral cavity stricture, (d) pairing of an active and a passive articulator:

> For example, one can maintain a certain oral tract configuration constant, say the one appropriate for producing the vowel [a], while varying the type of laryngeal configuration, or the position of the velum. Or one can hold the laryngeal configuration constant while varying the internal geometry of the oral tract.

However, within each category, it is difficult or impossible to vary one gesture while maintaining another. Clements observes that with the exception of laryngeal, which seems to be completely independent, there is limited mutual dependence between these parameters. Clements emphasizes that the justification for a model of feature organization must come from observed sound patterns rather than physiology, even if there is an apparent physiological basis to the organization. This move to features organized hierarchically was accompanied by a move to autosegmental rules, in which assimilation is treated as an association between a set of features forming a constituent in the hierarchy and the representation of a segment undergoing assimilation. Since there are assimilatory patterns that spread only laryngeal features, these features are grouped together as a constituent in the hierarchy, and such patterns are formalized as spreading of the laryngeal node, which dominates these features. Spreading of place features independently of other features is handled similarly. After the addition of feature organization to the model, **McCarthy (1994**: 191) describes four criteria that feature theory must now meet:

> An adequate theory of phonological distinctive features must meet four criteria: (a) it must have a relatively consistent and direct relation to the phonetic properties of speech sounds; (b) it must be able to describe all and only the distinctions made by the sound systems of any of the world's languages; (c) it must be able to characterize all and only the natural classes of sounds that recur in the phonological phenomena of different languages; and (d) it must correctly characterize the sub-groupings of features by recurrent phonological phenomena. The third criterion is the most important one and probably the hardest to achieve.

Other aspects of feature behavior have been dealt with using feature organization. Spreading is limited to nodes in the hierarchy that have their own tiers, which includes potentially all features, and any class nodes that dominate functionally related subgroupings of features. It has been noted that some features (namely [consonantal] and [sonorant]) appear never to spread. **McCarthy (1988)** proposes that these features are bundled inside the root node and do not have their own tiers, so that the feature organization itself prevents them from ever spreading. Since feature theory seeks to isolate the phonetic parameters that are involved in language, features that do not spread risk being dropped from the feature set, as was proposed for [consonantal] (**Hume and Odden 1996**; see also **CHAPTER 13**: THE STRICTURE FEATURES). The independent explanation for different behavior of different features allows the claim of identity between features involved in contrast, changes, and natural class definitions to be maintained.

(6) a. Claim: The features in the universal feature set are organized hierarchically in a way that is consistent with their grouping by sound patterns.

b. Claim: Features that do not spread are located in the root node of the feature hierarchy.

See **CHAPTER 27**: THE ORGANIZATION OF FEATURES and **Padgett's (2002)** Feature Class Theory for an approach to multi-feature spreading that does not involve a feature hierarchy.

2.5 Feature economy

Clements (2003, 2009) has recently revived interest in the concept of feature economy (**de Groot 1931**; **Hockett 1955**; **Martinet 1955, 1968**), the idea that languages tend to favor the exploitation of a small number of phonological contrasts rather than add new ones. The study of feature economy seeks to account for the nature of segment inventories, but since the account of inventories is mediated by a universal feature set, it also supports the idea that there is a universal feature set. **Clements (2003)** shows that segments occur more frequently in inventories that contain other segments that require the same features (based on the UPSID database; **Maddieson and Precoda 1990**). For example, /v/ is more frequent in inventories with at least one other labial consonant or voiced obstruent.

As with many other feature-based accounts of cross-linguistic regularities, alternative explanations exist. **Blevins (2004, 2005)** argues that the tendency for segments to occur in series (e.g. a series of voiced stops) can be explained as an emergent property, making an additional feature economy explanation unnecessary. **Blevins (2004**: 281–285), referring in particular to work by Lindblom (e.g. **Lindblom 1986**; **Liljencrants and Lindblom 1972**), asserts that tendencies for inventories to be symmetrical are rooted in gestural efficiency and perceptual distance. **Mackie (2007)** reports that natural language inventories (using P-base; **Mielke 2008**) are more economical than comparable randomly generated inventories. However, Mackie and Mielke (forthcoming) show that **de Boer's (2001)** synthesized vowel inventories are just as economical as comparable natural inventories, even though they were generated using phonetic pressures and no features. **De Boer (2001)** simulated the emergence of vowel systems with a model in which computer agents played listening games with each other by "speaking" vowels back and forth. Each of the agents created its own vowel inventory by assigning areas of its acoustic vowel space to the incoming acoustic information. The resulting vowel inventories look similar to those of natural languages. The presence of feature economy in inventories generated without features was taken by Mackie and Mielke (forthcoming) to suggest that feature economy effects may be independent of features themselves, consistent with Blevins's account of feature economy effects.

3 Proposed features

As the model of the role of features in phonology has expanded, changes have been proposed for the features contained in the universal feature set. *SPE* proposed a revision of the **Jakobson *et al.* (1952)** feature system and, as **Chomsky and Halle (1968**: 303–304) state, many of the changes look more dramatic than they really are, mostly because acoustically inspired feature names have been replaced with articulatorily inspired ones.[3] For example, despite all the apparent changes, the rule stated in (4) above can be transparently converted into *SPE* features as in (7):

(7) $$\begin{bmatrix}\text{+consonantal}\\\text{+strident}\\\text{+coronal}\\\text{+anterior}\end{bmatrix} \rightarrow [\text{–anterior}] \;\; / \; \_\_ \begin{bmatrix}\text{+consonantal}\\\text{+coronal}\\\text{–anterior}\end{bmatrix}$$

This section gives a non-exhaustive account of proposed changes to the universal feature set from the 1960s to the 1990s, divided into major class features, manner features, laryngeal features, and other features (including place and height).

3.1 Major class features

Jakobson *et al.*'s (1952) Fundamental Source Features [consonantal/non-consonantal] and [vocalic/non-vocalic] were basically responsible for the distinction between consonants and vowels, with middle ground for glides, which were [non-vocalic, non-consonantal]. **Chomsky and Halle (1968**: 302–303) kept these as [consonantal] and [vocalic], changing the definitions from acoustic to articulatory without changing much in the way of segments they apply to. In both cases, phonetic definitions were chosen to match the traditional understandings of consonants and vowels. **Clements and Hume (1995)** later advocated rebranding [consonantal] as its opposite [vocoid]. **Chomsky and Halle (1968**: 302) also added the feature [sonorant], and later entertained the idea of dropping [vocalic] in favor of [syllabic] (**1968**: 353–355). The difference between these two is that [+vocalic] includes both syllabic and non-syllabic liquids and excludes nasals, while [+syllabic] includes syllabic liquids and nasals, but excludes their non-syllabic counterparts. The motivation for making this change is accounting for truncation phenomena occurring before foreign words in French, whereby vowels truncate before vowels, while consonants truncate before consonants (including liquids and glides), so there is no elision in *le yogi* and no liaison in *les yogis*, as in (8). When the following word is part of the native vocabulary, glides pattern with vowels.

(8) *Elision in French native and foreign words* (Chomsky and Halle 1968: 353)

a. Native vocabulary: Glides pattern with vowels
le garçon
l'oiseau
l'enfant

b. Foreign vocabulary: Glides pattern with consonants
le yogi
**l'yogi*

The feature [syllabic] is needed to capture the distinction between the classes involved in truncation before foreign words

(**Chomsky and Halle 1968**: 355):

> This example is, thus, of the greatest importance for our feature framework. If, as it now appears to us, [(9)] is indeed the correct formulation of the phonetic facts just discussed, and if, moreover, this example is shown to be more than an isolated instance, the feature framework will have to be revised along the lines [of replacing [vocalic] with [syllabic]].

(9) $\begin{bmatrix}-\alpha\text{syll}\\ \alpha\text{cons}\end{bmatrix} \rightarrow \varnothing \;/\; \_\_\# \begin{bmatrix}-\alpha\text{syll}\\ +\text{foreign}\end{bmatrix}$

History has shown that this example is indeed more than an isolated instance, and that the distinction between vowels and consonants is referred to by rules. [syllabic] is not typically necessary to contrast the segments in inventories, because [vocalic] does basically the same work, but the issue is capturing classes of sounds that pattern together. More recently, the feature [syllabic] has been mostly abandoned as a segmental feature, because its work (distinguishing segments that are or are not syllable nuclei) is done by prosodic structures (see e.g. **Anderson 1981**). But there are two important points here. First, the distinction made by the feature [syllabic] turned out to be supported by cross-linguistic evidence, showing that the initial proposal was on the right track. Second, though, the feature [vocalic] is automatically jettisoned as a consequence. The problem is that subsequent work in phonology has shown a need for this distinction too, but a common practice in feature theory is to accompany the introduction of a feature with the elimination of a feature.

(10) Claim: If feature X is in the universal feature set, then the similar feature Y is not.

In the name of the pursuit of a small set of universal features, features are quickly dispatched in the face of an often small number of examples in favor of an alternative, as though two alternative formulations of similar contrasts are incompatible. This is a potential problem with the guiding assumption that the set of distinctive features is small, since it is not obvious that two features with very similar phonetic definitions should be mutually exclusive. This is discussed further below with respect to competing definitions for the feature [continuant]. (See also CHAPTER 13: THE STRICTURE FEATURES.)

3.2 Manner features

The *Preliminaries* features [interrupted/continuant], [strident/mellow], and [nasal/ oral] were adopted without incident into the *SPE* system as [continuant], [strident], and [nasal]. [nasal] received a more direct articulatory (as opposed to acoustic) definition, and [continuant] received a more tentative articulatory definition. [strident] was used to distinguish labio-dental from bilabial fricatives. In the many languages that have bilabial stops and labio-dental fricatives, there is no need for a feature to distinguish the two places of articulation, but in languages like Ewe (**Ladefoged 1964**), where fricatives occur contrastively at both places as in (11), some feature must distinguish them. Since there is a difference in noisiness between the two types of fricatives, [strident] can do the job without adding a new feature (see CHAPTER 22: CONSONANTAL PLACE OF ARTICULATION).

(11) *Ewe bilabial–labio-dental contrast* (Ladefoged 1964)

éɸá	'he polished'	éfá	'he was cold'
ɛ̀βɛ̀	'the Ewe language'	ɛ̀vɛ̀	'two'

Jakobson *et al.* (1952) similarly used [strident/mellow] to distinguish uvulars (strident) from velars (mellow). This kind of re-use of features motivated for another purpose obviates the need to add a new feature for an uncommon contrast, but also makes the claim that the contrast between the disparate pairs of [±strident] sounds is the same in an important way, and makes the prediction that these sounds would pattern together in sound patterns. This is another consequence of the guiding assumption of a small universal feature set. There is a difference between observing that oppositions such as /i/-/e/ and /u/-/o/ involve parallel phonetic differences and observing that oppositions such as /x/-/χ/ and /θ/-/s/ can be squeezed into the same dimension. This reductionist approach to contrasts makes a prediction that the classes defined by these feature values might be involved in sound patterns, etc. If not, then it is vacuous to say that two phonetically distinct contrasts involve the "same" feature.

SPE also employs the feature [lateral] to distinguish laterals from other sounds (see CHAPTER 31: LATERAL CONSONANTS). [delayed primary release] is used to distinguish affricates from stops, which for **Jakobson *et al.* (1952)** was done by [strident/mellow], and which later was done by [strident] among other features (see CHAPTER 16: AFFRICATES). This feature and [delayed release of secondary closure] were also used to distinguish release types in different clicks. Chomsky and Halle also describe a feature [suction] for distinguishing clicks from other sounds (see CHAPTER 18: THE REPRESENTATION OF CLICKS).

3.3 Laryngeal features

Two of the envelope features of **Jakobson *et al.* (1952)** involve larynx activity. These are [voiced/unvoiced], which in *SPE* features was succeeded by the very similar [voice], and [checked/unchecked], for ejectives and glottalized consonants, which was replaced by *SPE's* [glottal (tertiary) closure] and [movement of glottal closure]. **Chomsky and Halle (1968)** also introduced [heightened subglottal pressure] for aspirated sounds and trills. The *SPE* system of laryngeal features was quickly replaced by **Halle and Stevens (1971)**, who proposed [constricted glottis], [spread glottis], [slack vocal cords], and [stiff vocal cords] in place of [voice] and all other laryngeal features. **Avery and Idsardi (2001)** later proposed the additional features [raised larynx] and [lowered larynx].

Voicing in obstruents and voicing in sonorants are physically different, as discussed in **Chomsky and Halle (1968)** in defining the feature [sonorant] (see CHAPTER 8: SONORANTS). Other features have been proposed in order to capture the different phonological behavior that seems to relate to the differences in voicing. **Rice and Avery (1989)** and **Rice (1992)** proposed [sonorant voice] in order to be able to treat voiced obstruents as a natural class to the exclusion of sonorants, as many sound patterns do, and **Bradshaw (1999)** proposes the feature [L/voice], whose phonetic correlates are low tone in vowels and voicing in consonants, similar to **Halle and Stevens's (1971)** [stiff vocal folds] analysis.

3.4 Place, height, and other features

As **Chomsky and Halle (1968**: 303–304) point out, the resonance features of **Jakobson *et al.* (1952)** were renamed and redefined in articulatory terms in **Chomsky and Halle (1968)**, but the basic ideas are largely unchanged. The [grave/acute] opposition became the feature [coronal] in consonants, where [−coronal] is essentially [grave] recast in articulatory terms. **Chomsky and Halle (1968**: 306) note that palatal consonants were grouped with alveolars, etc. as [acute] but in their system are grouped with labials, velars, etc. as [−coronal], although in later versions of feature theory, palatals were again treated as coronals, and [grave] vowels became [+back] (see CHAPTER 71: PALATALIZATION).

Similarly, [compact/diffuse] was replaced by the feature [anterior] in consonants. The value [+anterior] in consonants (e.g. for labials and alveolars) corresponds to [diffuse]. In vowels, [compact/diffuse] was replaced by two features [high] and [low]. [compact/diffuse] was already an equipollent opposition with three possibilities ([compact], [diffuse], and neither), and these were replaced by [+high], [+low], [−high, −low], respectively, with [+high, +low] ruled out as a physical impossibility (see CHAPTER 21: VOWEL HEIGHT).

Feature proposals have differed in the extent to which they use the same features for consonant place (CHAPTER 22: CONSONANTAL PLACE OF ARTICULATION) and vowel place (CHAPTER 19: VOWEL PLACE). **Jakobson *et al.* (1952)** explicitly used the same features for consonants and vowels. **Chomsky and Halle (1968)** used the feature [coronal] for consonant place but continued using vowel place features for secondary articulation and for minor place distinctions. **Clements and Hume (1995)** used [Labial], [Coronal], and [Dorsal], traditionally associated with consonants, for all aspects of consonant and vowel place of articulation, in order to capture interactions between consonants and vowels.

The feature [sharp] was used by **Jakobson *et al.* (1952)** for palatalized consonants (i.e. consonants with F2 and possibly other formants shifted up), and this was replaced by [+high, −back] in *SPE*. Velarization and pharyngealization were similarly handled in *SPE*, using superimposed vowel features ([+high, +back] for velars and velarization and [+low, +back] for pharyngeals and pharyngealization), which were previously handled by the acoustically defined feature [flat]. The feature [round] was used for rounding in vowels, and for labialization in consonants, another of the articulatory correlates of [flat]. **McCarthy (1991)** proposes the feature [guttural] for uvulars, pharyngeals, and laryngeals.

The *Preliminaries* feature [tense/lax] was replaced by the *SPE* feature [tense]. Chomsky and Halle also introduced the feature [covered] for what was later described as the Advanced Tongue Root (ATR) distinction in West African languages. **Halle and Stevens (1969)** propose the feature [Advanced Tongue Root] as a replacement for both [tense] and [covered].

Flemming (1995: 6) proposes features with clear acoustic correlates but non-straightforward articulatory correlates to capture natural classes that are not expressible using strictly articulatorily-defined features. These include features with correlates such as high F2, low F2, low F3, intensity, formant structure, low noise frequency, low noise intensity, and diffuse spectrum. An example is the patterning together of labial and retroflex consonants to condition rounding or retroflexion of front vowels in Wembawemba and Wergaia (**Hercus 1969**), discussed by **Flemming (1995**: 70–76). Labiality and retroflexion are articulatorily distinct but share the acoustic correlate of low F3. See also CHAPTER 98: SPEECH PERCEPTION AND PHONOLOGY.

4 One model or many?

Feature theory has assembled observations about sound patterns that are not obviously related into a single model where a single set of phonetically defined features provide an account of possible contrasts and possible sound patterns. The precise set of features that belong in such a model remains controversial (see the various feature chapters referred to in the previous section). The "non-obvious claims" itemized above have been supported primarily by phonological evidence, i.e. cross-linguistic generalizations and particular sound patterns that are largely consistent with them. It is generally conceded that there are "crazy" sound patterns that are beyond the scope of feature theory (see e.g. **Bach and Harms 1972**; **Ladefoged and Everett 1996**; and discussion in **Clements 1985**: 246).

An example of a "crazy" class occurs in Kolami (**Emeneau 1961**: 46–50). The suffix /-(u)l/ is a plural marker for a variety of nouns, and the allomorphy is phonologically conditioned. The [−l] allomorph is conditioned by /ʈ ɖ n̪ i iː e eː a aː/, while the [−ul] allomorph is conditioned by /pt̪ k d̪ g s v z m ŋ j/. Even if one allomorph is treated as basic and the other derived, there is no way to characterize a derived class in terms of traditional distinctive features, or to describe it in terms of shared phonetic properties. The most straightforward reason for the unnaturalness of this class is the fact that the dental nasal patterns with the retroflex stops and not with the dental stops.

(12) *Kolami plural /-(u)l/ allomorphy* (Emeneau 1961: 46–50)

a. [-l] after /ʈ ɖ n̪ i iː e eː a aː/

singular	*plural*	
d̪uʈ	d̪uʈl	'hips'
eɖ	eɖl	'bullock'
toːren̪	toːren̪l	'younger brothers'
sir	siɖl	'female buffalo'
kaje	kajel	'fish'
biː-am	biːl	'rice'
kala	kalal	'dreams'

b. [-ul] after /p t̪ k d̪ g s v z m ŋ j/

singular	*plural*	
roːp	roːpul	'plant'
ket̪	ket̪ul	'winnowing fans'
maːk	maːkul	'tree'
mood̪	mood̪ul	'particular man . . .'
d̪eg	d̪egul	'heaps, masses'
kis	kisul	'fires'
aːv	aːvul	'fathoms'
gaːz	gaːzul	'bangle'
d̪em	d̪emul	'draws on a pipe'
nenjeŋ	nenjeŋul	'meat'
poj	pojul	'hearth'

An alternative to a universal feature set as an explanatory force in phonology is that inventories and sound patterns are limited by phonetic and historical factors (factors often invoked to explain "crazy" phenomena), and the appearance of a single feature set responsible for disparate phonological phenomena may be due to the role of phonetics in all of these phenomena. This is consistent with **Blevins's (2004)** approach to sound patterns in general and **Mielke's (2008)** approach to feature effects. A move away from a small feature set is also seen in some approaches to Optimality Theory, such as **Flemming (1995)**, **Kirchner (1997)**, and **Boersma (1998)**.

4.1 Segmental contrasts

The idea that features play a limiting role in determining possible contrasts in inventories has for the most part not been accompanied by a null hypothesis about what segmental contrasts would be like in the absence of features. **Mielke (2008)** argues that the record of sound patterns does not support the literal interpretation of a restricted universal set of features. The main criticism is that the similarity between sound patterns in unrelated languages can be accounted for in terms of shared historical and phonetic factors.

An example of this type of argument is final devoicing, which is documented in a wide range of unrelated languages (see CHAPTER 69: FINAL DEVOICING AND FINAL LARYNGEAL NEUTRALIZATION). **Blevins (2006**: 136–140) describes the sources of these final devoicing patterns in detail. To summarize briefly, the phonetic sources of phrase-final devoicing include the use of laryngeal spreading and closing gestures to mark phrase boundaries in many languages, phrase-final lengthening, and difficulty perceiving phrase-final consonant release. Further, since children are typically exposed to a high number of single-word utterances, there is a tendency for them to generalize phrase-final phenomena to the word-final context. Since final voicing does not have the same phonetic sources, it is not widely observed. Mielke (forthcoming) shows that uses of the feature [voice] to characterize sound patterns are dominated by a small number of phonetically motivated patterns that are mostly assimilatory. As long as there are phonetic and historical explanations for the recurrence of certain sound patterns, feature theory can be interpreted as a model of these historical and phonetic effects (and this is how it is interpreted by many linguists), but the nature of sound patterns does not support features as a primary source of explanation or the restrictive nature of a small universal feature set.

If features are not universal as a part of Universal Grammar, then there is no need to explain how they could have emerged in the human genome over a short period of time, or why signed and spoken languages appear to have completely different features (or how signed language features could have developed in the human genome at all). See CHAPTER 9: HANDSHAPE IN SIGN LANGUAGE PHONOLOGY, CHAPTER 10: THE OTHER HAND IN SIGN LANGUAGE PHONOLOGY and CHAPTER 24: THE PHONOLOGY OF MOVEMENT IN SIGN LANGUAGE on features in sign language phonology. There is, however, a need to show how features are learned, and this is a topic of ongoing research (**Lin 2005**; **Lin and Mielke 2008**; **Mielke 2010**).

Also, if features are not innate, then there are consequences for other arguably universal primitives, such as constraints in Optimality Theory (**Prince and Smolensky 1993**). Many of these constraints refer to features, so if the features are not innate, the constraints referring to them cannot be innate either. Some approaches to Optimality Theory, such as **Hayes (1999)**, involve universal constraints that are induced from phonetics. Features referred to by these constraints would need to be either innate or similarly induced from available data. See CHAPTER 86: MORPHEME STRUCTURE CONSTRAINTS and CHAPTER 63: MARKEDNESS AND FAITHFULNESS CONSTRAINTS.

Crucial evidence for features as the basis of segmental contrasts would be contrasts that appear to be ruled out by features but not by phonetics, such as (perhaps) the unattested apical retroflex *vs.* sub-apical retroflex contrast. However, it remains to be shown whether the cross-linguistic frequency distribution of both types of retroflex is such that they would be expected to co-occur in the same language anyway.

On the other hand, proposed features predict a wide range of unattested contrasts, and overdetermine the representation options for many attested ones. As discussed above, it has been possible to maintain the claim that there are only three vowel heights by making use of auxiliary "height" features like [ATR]. This is possible in part because it is difficult to falsify without articulatory imaging. While there is X-ray evidence for English to support the use of [ATR] to distinguish, e.g. [i] from [I], the fact that the tongue root is not directly visible makes it possible, in the absence of direct evidence, to deal with additional height differences using features like [ATR], which cannot readily be verified or refuted, giving the feature a "wild card" role in the theory and making it harder to falsify the claim in (2) that there is a universal feature set. The increased availability of articulatory imaging such as ultrasound has made it easier to investigate these claims (see e.g. **Gick 2002**; **Gick *et al.* 2006**).

4.2 Defining natural classes

The concept "natural class" has traditionally been defined in terms of both features and patterning, as in (13).

(13) *Natural class: Traditional two-part definition* (**Mielke 2008**: 12–13)

a. A group of sounds in an inventory that share one or more distinctive features, to the exclusion of all other sounds in the inventory.

b. A group of sounds in an inventory that may participate in an alternation or static distributional restriction, to the exclusion of all other sounds in the inventory.

This definition includes the aforementioned non-obvious claim of a connection between features used to define segmental contrasts and classes involved in sound patterns. The idea that the features used to define contrasts are involved in determining which classes of sounds are involved in rules has been a component of many approaches to feature theory, and the different parts of the definition are often assumed to be interchangeable, as though the claims in (13) have been reinterpreted as an assumption. **Ladefoged (2005)** argues that the features needed to define contrasts predict far more classes than are ever actually involved in sound patterns, and **Mielke (2008)** shows that many classes involved in sound patterns cannot be described using the features that have been proposed (e.g. in the previous section), suggesting that the components of the definition should be treated separately, as follows.

A phonologically active class (14a) is a group of sounds that are involved in a sound pattern, something that can be assessed without recourse to a theory of features. A phonetically natural class (14b) is a group of sounds that share phonetic properties, which requires a notion of phonetic properties but not a feature theory that includes or excludes particular candidate features.

(14) a. *Phonologically active class: Feature theory-independent definition*
A group of sounds in an inventory that do at least one of the following, to the exclusion of all other sounds in the inventory:
- undergo a phonological process;
- trigger a phonological process; or
- are crucially referred to by a static distributional restriction.

b. *Phonetically natural class*
A group of sounds in an inventory that share one or more phonetic properties, to the exclusion of all other sounds in the inventory.

The last definition requires reference to a feature theory:

(15) *Natural class: Feature theory-dependent definition*

A group of sounds in an inventory that share one or more distinctive features within a particular feature theory, to the exclusion of all other sounds in the inventory.

The reason for breaking the definition down in this way is that natural classes and phonologically active classes are implicitly treated as the same thing in many approaches to phonology. It is worthwhile to seriously ask whether these definitions all refer to the same thing. The identification of natural classes with phonologically active classes is an explicit working assumption in some approaches, e.g. **Halle (2002)**, who argues that the position that phonologically active classes are featurally natural has led to improvements in analyses of phonological phenomena. **Mielke (2008)** collected a database of phonologically active classes in the world's languages based on grammars of 549 languages and conducted feature analyses on the 6,077 resulting phonologically active classes involved in alternations, using *Preliminaries* (**Jakobson *et al.* 1952**), *SPE* (**Chomsky and Halle 1968**), and Unified Feature Theory (**Clements and Hume 1995**) features. **Chomsky and Halle (1968)** does the best, but still leaves a residue of about 29 percent of the unnatural classes, which is not easily handled using feature proposals subsequent to *SPE* (e.g. the Kolami example above and hundreds of others).

The way in which natural classes are traditionally defined (conjunction of distinctive feature values, yielding the intersection of the classes defined by each feature value individually) is also non-obvious. This technique has allowed many phonologically active classes that are not defined by a single feature to be represented, providing support for the idea that features used for contrast are also accounting for phonologically active classes, but it also massively overpredicts the range of phonologically active classes. It is not obvious that phonologically active classes defined by more than one feature are less atomic than classes defined by one feature. For instance, the class defined by [+voice, −sonorant] (voiced obstruents) is more frequently active than the class defined by [+voice] alone, and the class of glides (which requires reference to syllabicity and something like [−consonantal] or [+vocoid]) is more frequently active than the class defined by [−consonantal]/[+vocoid] alone. The fortunate fact that these active classes can be defined in terms of features needed to define contrasts has made it unnecessary to propose features for them, but their reasons for being involved in sound patterns may have more to do with the phonetic properties of the sounds involved in a way that is not directly related to the features used to describe them.

If there is a mismatch between phonologically active classes and the features used for lexical contrast, an alternative is a separate model predicting classes that are likely to be involved in sound patterns, perhaps in terms of common sound changes affecting more than one segment (**Blevins 2004**; **Mielke 2008**, forthcoming). The phonetic parameters defining these classes would not necessarily correspond directly to the parameters needed to contrast segments from one another. The class of voiced obstruents can be defined atomically in terms of non-spontaneous voicing – consistent with feature analyses by **Rice and Avery (1989)** and **Rice (1992)** that use the feature [sonorant voice], distinct from [voice] – which is relevant for many of the sound patterns this class is active in; moreover, the class of glides is frequently involved in sound changes resulting in vocalization/devocalization alternations.

Flemming (2005) argues for another type of phonologically active class that is a consequence of constraint interaction. In this view, classes of sounds that pattern together can do so as a result of separate constraints, each targeting a different featurally natural class. The resulting (apparent) phonologically active class is not necessarily featurally natural, since it is determined by constraint interaction, not directly by features. See also **Yip (2004, 2005)** for a constraint-based approach to the cross-linguistic variability of laterals.

Mielke (2005) argues that examining a large sample of phonologically active classes shows that they range quite continuously from phonetically natural to phonetically unnatural, and that there does not appear to be evidence for a distinct cut-off between natural and unnatural classes. In cases where phonetic correlates are less clear, phonological patterning is also less clear, indicating that it is the phonetic properties in which features are grounded that are important, and features themselves do not make more specific predictions about sound patterns. For example, the feature [continuant] appears to be categorical for segments such as stops and fricatives, which strongly display its phonetic correlates, but laterals – whose specification has been controversial and whose phonetic cues are ambiguous – pattern with continuants about as often as with non-continuants. See CHAPTER 31: LATERAL CONSONANTS for more on this issue.

4.3 Defining alternations

If the features needed for defining the change in alternations do not match the features needed for other purposes, they could be accounted for by a model of likely alternations. For example, it is known that not all features appear to spread. This observation was addressed within feature geometry by placing non-spreading features such as [consonantal] and [sonorant] in the root node. If assimilation is the result of phonologized co-articulation (Baudouin de Courtenay 1972 [1895]; Ohala 1993; Blevins 2004), then an account of co-articulation and its phonologization could possibly account more directly for sound patterns interpreted as feature spreading. Mielke (forthcoming) surveys the behavior of classes defined by various features, and concludes that the phonological behavior of particular features can be attributed to the phonologization of phonetic effects. Features that are frequently spread in assimilatory patterns are features whose phonetic correlates are believed to be easily co-articulated. Features that rarely or never spread seem to be those that are not easily involved in co-articulation without involving the correlates of other features. Feature values that are frequently involved in dissimilation ([−voice] and [−nasal]) are the opposite values of the feature values that assimilate most frequently, consistent with Ohala's (1981) claim that dissimilation is the result of mistakenly undone assimilation (see CHAPTER 60: DISSIMILATION). As such, dissimilation is dependent on the phonologized co-articulation of an opposite value.

5 New types of experimental evidence

Regardless of whether features are needed to account for the typology of contrasts and sound patterns, behavioral studies such as Studdert-Kennedy *et al.* (1972) indicated that features are involved in representations used in language processing. More recently, advances in brain imaging technology have opened new lines of research into the mental organization of phonology, building on earlier behavioral research (see CHAPTER 96: EXPERIMENTAL APPROACHES IN THEORETICAL PHONOLOGY). Two big questions here are whether brain activity provides evidence for abstract features in adults, and the separate issue of whether this organization is a consequence of language exposure or a consequence of innate aspects of the language faculty.

In a magneto-encephalography (MEG) study, Phillips *et al.* (2000) report evidence for the feature [voice] in the left-hemisphere auditory cortex of adult English-speaking participants. This is similar to Studdert-Kennedy *et al.*'s (1972) dichotic listening experiment. Since acoustic similarity is similarly controlled for, an abstract feature can be motivated over acoustic similarity. Acoustically distinct but featurally identical stimuli were treated as identical in the auditory cortex. Other MEG studies report evidence of abstract vowel features (Obleser *et al.* 2004) and featural underspecification in the mental lexicon (Eulitz and Lahiri 2004). Dehaene-Lambertz and Pena (2001) report electrophysiological evidence that newborns distinguish [pa] and [ta] in a way that they do not distinguish repetition of the same syllable produced by different speakers. Studies with infants have the potential to address more directly the questions about whether these abstract representations are rooted in innate features or in exposure to language data.

These are a few examples of types of evidence that were not available in the early years of distinctive feature theory. New techniques for studying phonetics and phonology – such as brain and vocal tract imaging, new behavioral methodologies and computer modeling, and electronic databases of inventories, sound patterns, and sound changes – stand to improve our understanding of sound patterns and our understanding of how features are involved in accounting for them.

Notes

1 Dichotic listening studies involve playing different stimuli in each ear of the participant.

3 Often the distinction between acoustic and articulatory is an issue of terminology, but see Kingston (2007) for a discussion of this issue.

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