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Features in Phonology and Phonetics: The contributions of George N. Clements

Our primary goals in this introduction is to place Nick Clements' contribution to Feature Theory in a historical and contemporary context and introduce some of his unpublished manuscripts as well as new work with colleagues collected in this book.

1 Breaking the phoneme into features

To emphasize to beginning students that linguistics is an empirical science we like to point out that, as in physics, much of our work aims at identifying the ultimate building blocks of our subject. This search takes many different forms. Semanticists look for concepts that qualify as conceptual primitives, while syntacticians look for basic categories below the levels of the traditional parts of speech. Ongoing work often is more likely to lead to further questions than to definite answers. What is the set of primitives in either domain? How are semantic concepts and syntactic categories related? Are the latter autonomous or reducible to the former? Are the primes in either domain universal, present in all languages or, at least, available to all of them? And if so, where do they come from and where do they exist? Do users of languages, or linguists for that matter, construct these categories *de novo*, each time one of them learns or analyzes a language? Or are they part of an innate endowment, anchored in the human genome? While these are undoubtedly the most fundamental questions that can be raised, the field of linguistics is still in a state where none of them has generally accepted answers.

In the early days of phonology, the abstract building blocks of the size of speech sound were called *phonemes*, a term that reflects the claim that these units are the basic building blocks at the phonological level, putting the idea that phonemes are analyzable in smaller ingredients on hold. The recognition of abstract units, of whatever size, entailed questions that are analogous to the questions that we raised earlier concerning syntax and semantics. Importantly, it was now inevitable to ask the question how phonological units (phonemes) relate to phonetic units. Indeed, some see this relation as analogous to that between syntax and semantics. However, it turned out to be far from simple

to correlate each phonological unit with a phonetic event of some sort, since nothing in the articulation or the perception of speech seems to point to a counterpart of discrete phonemes. Notoriously, speech is continuous. Clearly there was and is a mismatch between the basic units of speech (articulatory movements and their acoustic consequences) and phonemes and to this day proponents of the phoneme notion are being suspected of being under the spell of the alphabetic bias of the International Phonetic Alphabet (IPA). But leaving aside for the moment whether phonemes 'exist', and if they do, where, further developments alleviated the mismatch by digging deeper on the phonological side. The early phonologists, notably Nikolai Trubetzkoy, highlighted the fact that classifications of phonological oppositions point to distinctive phonetic properties *below* the level of the phoneme, i.e. the 'features' that were anticipated in the IPA diacritics. Then, Roman Jakobson made the bold proposal that these properties correlate with subunits of the phonemes thus giving proper recognition of phonological features. From the beginning, phonological features were meant to correlate with phonetic properties that are potentially distinctive (or contrastive) in at least one language, although they could function non-distinctively in other languages. A well-known example is '[aspiration]' which is distinctive in Thai and allophonic in English. Jakobson's ideas culminated in Jakobson, Fant and Halle (1952) and Jakobson and Halle (1956) in which a small set of distinctive features was posited. These authors dealt with the duality of speech (production and perception) by providing an articulatory and acoustic definition for each feature. Of these, Jakobson held the latter to be more fundamental because, as he argued, the acoustic aspect of speech is shared by both speaker and hearer. The proposed system found its way in Generative Phonology in Chomsky and Halle (1968)'s The Sound Pattern of English (SPE), where it was decided to put emphasis on the articulatory correlates of their features. The articulatory primacy was also supported by proponents of the so-called *motor theory of speech perception* (Liberman and Mattingly 1985). Thus, 20th century phonology came to be dominated by a view of phonology which acknowledged, at the very least phonemes as well as a universal set of distinctive features. Additionally, various writers or schools made room for higher-order units such as syllables and various kinds of larger stretches. At the same time, we find views that omit the phoneme level and construct larger units, roughly syllable sized, directly from articulatory buildings blocks, a view that we find in modern times in Articulatory Phonology (Browman and Goldstein 1986), as well as other non-segmental phonologies.

2 The internal organization of features

The field of phonology has moved along productively on the assumption that distinctive features are a genuine and minimal part of the phonological vocabulary. Indeed, following the SPE model (and other models that built on Jakobson's insights), much of the field today assumes that phonological representations consist of linear strings of phonemes (although that term was tainted for a while, and for the wrong reasons[1]), each phoneme being an unordered set of features.

In the early 1970's, when Nick Clements had become an active participant in the field, various modifications of this view were proposed, leading to a number of enrichments of the phonological representation 'outside the phoneme' and 'inside the phoneme' (see van der Hulst and Smith 1982 for an early overview of these developments). Firstly, outside the phoneme, it was recognized that some sort of grouping of phonemes ('syllable structure') was needed. Secondly, these syllables, or similar units, themselves needed a grouping into even higher levels such as *feet*. Nick's work mainly focused on what was happening *inside* the phonemes.[2] In 1975, John Goldsmith revived the idea that tones have a tendency to lead a life of their own, an idea that was not unfamiliar to many students of tonal languages, and, theoretically acknowledged in the prosodic school of John Rupert Firth. Goldsmith proposed a transparent notational apparatus to formalize this idea which gave rise to *Autosegmental Phonology*. Clements (1980, 1977) presented a significant extension of the autosegmental theory to the domain of *vowel harmony*, setting a trend to liberate all features from the SPE segmental harness which, then, necessitated recognition of a *skeletal tier* to which all features on their respective tiers refer. Properties and use of the skeletal tier, as the terminal units of syllabic structure, form the subject of Clements and Keyser (1983), an influential study of a wide variety of phonological phenomena.

The mid 1980s witnesses a further development of the world within the phoneme in which Nick played a pivotal role: the idea of feature grouping (see Clements 1985, 1999). The basic idea here is that a segment is not an unordered feature bundle, but displays a hierarchical-geometrical structure in which features are grouped into classes. While such feature classifications were familiar from phonetics and indeed would be implicit in pedagogical explanations

1 Generative phonology rejected the phonemic level *as enforced by biuniquess*. Rejecting this level simply means that a distinction between a morphophonemic and a phonemic level disappears. The resulting level can then be called the phonemic level. Nonetheless, after features had been added to phonology, phonemes were no longer the basic building blocks of phonology.

2 This is not to say that he did not contribute to extra-phonemic domains such as syllable structure (see Clements and Keyser 1983), the related issue of sonority (Clements 2009). Nick also developed a new theory on reduplicative copying (1985).

of the set of features, Nick's work demonstrated that feature grouping had to be acknowledged *in* the phonology. When nasal consonants assimilate to the place properties of following consonants, we do not want to write separate rules for each place adjustment, but rather capture the generalization that nasal copy the place node of the following consonant, no matter which features are dominated by this node. This was a very powerful idea that changed the way that phonological processes were understood and represented.[3] The combination of autosegmental phonology and feature geometry led to a whole new three-dimensional conception of phonological representations in which tiers (rather than features) were hierarchically grouped and phonological operations could effect individual features of feature classes.

Continuously, Nick developed the grouping notion in conjunction with homing in on a set of phonological features and their hierarchical relationships. This work incorporated the notion that some features (like those for the major articulators) are unary, while others are binary; see Clements and Hume (1995). In some cases, Nick proposed new features or feature organization. His work on major class features introduced the feature [approximant] (Clements 1990, 1992, Osu and Clements 2009). Another example can be found in his 1990 study (which is contained in the present volume) of vowel harmony processes involving tongue root, tongue height or aperture which he proposed to unify in a model that would allow multiple tiers for the feature [open].

At the same time, Nick also continued to address the fundamental issues that were always 'lurking in the background'. One such issue concerns the question whether all features that are necessary for phonetic interpretation are specified at all levels of representation. Early on in generative phonology much attention was given to the claim that redundant feature values, i.e. values that can be predicted on the basis of other values, can be left unspecified at the lexical level, provided that the predictabilities are encoded in redundancy rules, which at some point before the derivation reaches the surface are filled in. The use of underspecification was criticized in Stanley (1967) as potentially leading to ternarity and therefore traded in for full specification in SPE.[4] In the early 1980s underspecification, if properly constrained so as to avoid ternarity, could be reinstated (Ringen 1977, Kiparsky 1982) and the further-reaching claim was made that more economy could be achieved by designating one value for each feature as 'the default value' which could then also be left unspecified, leading

3 Similar ideas had been or were being explored in Anderson and Jones (1974) and Sagey (1986).

4 Full specification demanded the presence of all redundant values, but not of feature specifications that, in a traditional sense, would be called allophonic.

to what was called 'radical underspecification' (Archangeli 1984). In his more recent work, Nick tackled the problem of under- or non-specification head on, trying to develop a set of explicit criteria for specification of feature values at various levels and going beyond technical issues of redundancy. In his paper on 'representational economy' (Clements 2001), he argues in detail that only those features need to be ever specified that play a role in the expression of phonological generalizations. These would not just be specifications that are distinctive, but also those that are active in one way or another..

While attention for phonemic inventories has always been minimal in generative phonology, Nick also investigated the relationship between features and inventories in his work on feature economy, returning to important findings in the work of André Martinet. In Clements (2009) he develops a set of feature-based principles that account for the major trends in the structure of phoneme inventories:

i. *Feature Bounding*: features place an upper bound on the number of potentially contrastive categories in a language.
ii. *Feature Economy*: features tend to be combined maximally.
iii. *Marked Feature Avoidance*: certain feature values tend to be avoided.
iv. *Robustness*: highly-valued feature contrasts tend to be employed before less highly-valued contrasts.
v. *Phonological Enhancement*: marked features are often introduced to reinforce weak perceptual contrasts.

These 5 principles interact to define broad properties of sound systems, such as symmetry and the tendency of sounds to be dispersed in auditory space. Further phonetically-based principles fine-tune the realization of phonological categories at the phonetic level. It is suggested that these general properties of sound systems may have their explanation in the nature of early language acquisition. In motivating and explaining these principles Nick characteristically made connections between different strands of research in phonology, phonetics and typological studies. He based his findings, as always, on solid empirical grounds, in this case by extensive use of the expanded UPSID database containing 451 phoneme inventories.

Before discussing some more recent avenues in Nick's work, we conclude this section with remarking that his work, while aiming to establish a very precise inventory of features, including their relations and phonetic interpretations, based on broad empirical (and often original) descriptive work, would often reflect, sometimes directly, on some of the broader and foundational issues surrounding the nature of features and feature theory With reference to

the question whether features are innate or learned, Nick sides with the innateness view point. Features for him are primarily cognitive units, i.e. believed to be in the mind of the talker, and not to be transparently reflected in the vocal-tract actions that do causally structure the signal (e.g., Hammarberg 1976; Pierrehumbert 1990; Fowler 1994). In Clements 1993, Nick reflects on the nature of phonological primitives. He held features to be innate, universal and specific to humans, thus not as derived through generalizations based on phonetic similarity and analogy (Blevins 2004, Mielke 2008).

3 Where do features come from?

That the notion of phonological features has gained almost complete acceptance within linguistics does not entail that there was general acceptance of a specific set of features, although the task here seems somewhat more tangible than the task of establishing a set of semantic or syntactic features (which many semanticists and syntacticians have given up on). While no commonly agreed set has been established, it is also still undecided where features come from and where they exist. Are features constructed in the process of language acquisition due to general cognitive principles of categorization (Blevins 2004, Mielke 2008) or is there an innate set of such primes that evolved for the specific purpose of language? While Chomsky and Halle (1968) emphasize the innateness (and thus also universality) of features, even linguists who would take a more 'developmental' view, would generally agree that features are an indispensable tool for phonological analysis, not only by linguists but also by native speakers who seem to cast generalizations in terms of features, which must therefore have some sort of cognitive status, even if not innate. In fact, we could say the same thing for phonemes which, while in doubt for some phonologists, remain indispensable as tools for phonological analysis, both by linguists and native language users; the literature on the 'psychological reality' of phonemes is vast (see Silverman 2006 for a recent critic of the phoneme.). It is interesting that while, for example, speech errors provide good evidence for phoneme-based substitutions, feature-based substitutions are much less clear (Fromkin 1973). We must conclude that generally accepted answers to the issue of which features are needed, their innateness or the nature of phonetic correlates cannot be supplied and while it is clear that discussion is ongoing, Nick's work provides a rich array of potential answers and directions for further research.

A central issue in Nick's recent work concerns the relation distinctive features have to measurable physical properties. Even though most linguists and phoneticians agree that features are defined in terms of concrete physical and auditory

properties, there is little agreement on exactly how they are defined. Historically speaking, as reviewed in section 2, there have been two main approaches to the phonetic implementation of distinctive features, one emphasizing their acoustic/auditory properties and the other their articulatory properties. According to the tradition launched by Jakobson, Fant and Halle (1952), features are defined primarily in acoustic terms, each feature being assigned a unique, invariant acoustic correlate. Features could be extracted by listeners from the speech stream through the detection of these correlates. In this view, the articulatory stage of speech is viewed as the means used to obtain each pair of acoustically contrastive effects: "*we speak to be heard in order to be understood*" (Jakobson, Fant and Halle 1952: 13). This approach has not been abandoned, and some researchers emphasize that "*speech perception is hearing sounds, not tongues*" (Ohala 1996). According to a second tradition initiated by Chomsky and Halle (1968), features are primarily defined in the articulatory domain. This approach is grounded in the *motor theory of speech perception* (Liberman and Mattingly 1985), and underlies some more recent theoretical approaches such as *Articulatory Phonology* (Browman and Goldstein 1986). In this view, objects of speech perception are the intended phonetic gestures of the speaker, viewed as the elementary events of speech production and perception. The emphasis on the articulatory properties of distinctive features provides furthermore a better account for some recurrent phonological processes across languages (such as place assimilation).

Based on phonetic fieldwork and the study of the sounds of a wide variety of languages, Ladefoged (1971), in a criticism of the Jakobsonian and the SPE feature systems, proposed a new system that was meant to account for a variety of phonation and articulation types previously unknown in the phonetic literature. Claiming that neither a purely acoustic/auditory nor a purely articulatory account is self-sufficient, Ladefoged proposed two disjoint feature sets: a set grouping sounds together because of their auditory similarity and a set grouping sounds because of their articulatory similarity. While such an approach may have its appeal, it is unclear whether some of the novel features that Ladefoged proposed (e.g. [click], [tap], and [wide]) satisfy the requirements expected of a feature system: expressing the content and structure of phoneme inventories, delimiting the number of theoretically possible speech sound contrasts within and across languages, and accounting for common phonological patterns found across languages (Clements and Hallé 2010).

K. N. Stevens and his colleagues at The Massachusetts Institute of Technology (MIT) have developed another approach within the framework of *Quantal Theory of speech* (Stevens 1972, 1989, 2003, Stevens and Keyser 2010). The main originality of this approach is the equal status it accords to the acoustic and articulatory dimensions of spoken language, overcoming the tradition competition

between these two apparently incompatible approaches. Features are defined with respect to certain articulatory dimensions within which small shifts in the position of the tongue, lips, or vocal folds do not have major consequences for perception. The central claim is that there are regions in which the relationship between an articulatory configuration and its corresponding acoustic output is not linear:

> "For some types of articulatory parameters, there are ranges of values ... for which the acoustic signal has well-defined attributes, and these ranges are bounded by regions in which the properties of the signal are relatively insensitive to perturbations in the articulation. The acoustic attributes of the signal within one of these plateau-like regions appear to define the acoustic correlates of a phonetic feature. (Stevens 1972: 64)

In this view, these stable regions form the basis for a universal set of distinctive features, each of which corresponds to an articulatory-acoustic coupling within which the auditory system is insensitive to small articulatory movements.[5] Parallel to Quantal Theory, Stevens and colleagues have developed a language-specific process referred to as *enhancement* (see Stevens et al. 1986, Stevens and Keyser 1989, Keyser and Stevens 2006), according to which features in danger of losing their perceptual saliency can be reinforced by additional gestures or redundant features, such as lip rounding in back vowels like [u]. Thus, the surface representation of an utterance includes not only the feature-defining acoustic and articulatory attributes but also an array of articulatory gestures and their acoustic consequences that enhance the perceptual saliency of the defining attributes. The defining acoustic attributes of a feature are a direct consequence of its articulatory definition. These are considered to be language-independent. The enhancing attributes of a feature are additional cues that aid in its identification. These may vary from language to language (Stevens and Keyser 2010).

Because it places phonology on solid, testable phonetic grounds, Quantal Theory is one of the recent models which has best succeeded in integrating phonetics and phonology. It has also inspired related approaches, such as the theory of distinctive regions and modes (Carré and Mrayati 1990). However, Quantal Theory has not been submitted to a complete, rigorous empirical testing. Clements, together with some of his colleagues and students, proposed to undertake such testing within the project *"Phonetic bases of distinctive features: quantal*

5 Another explanation for why languages heavily favor certain articulatory and acoustic pairings in constructing their phoneme systems while avoiding others is that preferred contrasts maximize acoustic distinctiveness while minimizing articulatory effort (Liljencrants and Lindblom 1972).

theory" funded by the French Ministère délégué de la Recherche under the ACI-Prosodie program (2004–2007).

Quantal theory has raised a certain number of controversies (see the special issue of *Journal of Phonetics* 17 (1989)). A first criticism concerns its inability to explain the fact that certain sounds and sound inventories are much more frequent across languages than others. Other criticisms have borne more particularly on the nature of the fit between Quantal Theory and the facts which it is supposed to explain. The project coordinated by Nick was most particularly interested in the following questions:

- What is the exact acoustic and articulatory definition of each feature?
- Can these definitions be confirmed at the perceptual level?
- Can a quantal definition be given to each feature?
- Is quantal theory as valid for vowel features as for consonant features?
- Are both values of binary features (such as nasal/oral) quantal?
- To what degree do acoustic correlates vary according to phonological context, style, speaker, or language?
- Do acoustic correlates vary according to the class of sounds in question (for example, stops *vs*. fricatives, obstruents *vs*. sonorants, or consonants *vs*. vowels)?

The study of these and similar questions form the main subjects of Nick's recent contributions. Clements proposed and edited, with P. Hallé, a special issue of *Journal of Phonetics* 38 (1), published in 2010. The papers collected in this issue emanated, for the most part, from a conference organized by Nick on the theme *"Phonetic Bases of Distinctive Features"* held at the Carré des Sciences, Ministère Délégué de la Recherche, Paris, on July 3, 2006. The volume provided an up-to-date overview of the phonetic bases of distinctive feature theory and highlighted the considerable evolution of the theory since the early work of the 1950s and 1960s, due to the development of new theoretical models on the one hand and to empirical studies that have developed our understanding of the diversity of cues that may be associated with any given feature on the other. The contributions to this issue dealt with various aspects, including biological bases of universal feature definitions, feature theory and variation, and features in lexical access.

Clements also edited with R. Ridouane a book on "*Where features come from: phonological primitives in the brain, the mouth, and the ear*", published in 2011. Most of the papers collected in this volume grew out of the conference *"Where Do Features Come From?"* held at Sorbonne University, Paris, October 4–5, 2007, co-organized by Clements and Ridouane. Following on the issues dealt with in the special issue of Journal of Phonetics 38(1), papers in this volume explored how

distinctive speech categories originate and how they are cognitively organized and phonetically implemented. In addition, it explored the role features play in language acquisition and how they emerge in language development.

4 Summary of themes

In addition to the purely scientific goals of the project "*Phonetic bases of distinctive features: quantal theory*", one of Nick's objectives was to create a 'features research group' with the specific aim of providing a thorough description for some of the most common features. Two studies from this research group have been published in a volume following a conference at the University of Chicago's Paris Center in June of 2009, organized in tribute to Nick's contributions to the field of phonology. The first study entitled "*Do we need tone features?*" (Clements, Michaud and Patin 2011) was concerned with whether tone is different from other phonological features and concluded that tonal features may well be motivated in our studies of tonal system, but the type of motivation is different in kind from that which is familiar from the study of other aspects of phonology. The other study entitled "*Language-independent bases of distinctive features*" (Ridouane, Clements and Khatiwada 2011) provided a language-independent phonetic definition of the feature [spread glottis], and showed that an articulatory definition of this feature in terms of a single common glottal configuration or gesture would be insufficient to account for the full range of speech sounds characterized by this feature; an acoustic definition is also necessary.

A selection of additional papers written by members of the 'features research group' is included in this collection. They deal with the following distinctive features: [ATR], [nasal], [pharyngeal], [strident], and [tense]. A protocol was established by Nick to homogenize the contributions on each feature. Specifically, authors were asked to first provide a brief bibliography of the main sources on the feature as well as a historical overview of the feature (who first proposed it, its status within the current models, critics, etc.). Then a more developed presentation of the linguistic use of the feature is provided, specifying both lexical and phonological functions of the feature. The rest of the contribution is devoted to the phonetic implementation of the feature. Depending on the feature, the authors provide its articulatory, acoustic and auditory definitions, its temporal alignment in different segments it defines, whether the definition provided is quantal or not, and the way the feature may enhance or be enhanced by additional cues. A basic assumption in these studies is that a segment can be said to bear a feature [F] at the phonetic level only if it satisfies both its articulatory and acoustic definitions. In other words, for a feature [F] to be recovered from

a speech event, not only must its articulatory condition be met, but its acoustic definition must be satisfied, or failing that its enhancing attributes must be present.

This volume includes in addition two previously unpublished manuscripts. *"The hierarchical representation of vowel height"*, written in the early 90's, is concerned with how vowel height could be formally characterized in phonological representations. More specifically, it questions how the phonological nature of vowel height is expressed in feature terms, and how these features are formally organized within an autosegmental approach. In this extremely thorough contribution Nick proposed an account in terms of an 'aperture' theory of vowel height, in which different vowel categories were distinguished in terms of a single, hierarchically subdivided feature category [open], used to implement height distinctions. We decided to include this manuscript in this volume because it proposes a model that directly addresses problems that were and still are inherent in models of vowel height, and because it offers well-motivated solutions. For instance, by characterizing vowel height in terms of a single phonological feature, it directly accounts for the fact that vowel height maps into a unitary phonetic parameter, with well-defined acoustic and articulatory correlates. We believe that by publishing this manuscript in this volume, this work will receive the attention it deserves.

The second manuscript entitled *"Aspiration as a Root-level Feature in Nepali"*, co-authored with Rajesh Khatiwada, examines cooccurrence restrictions on aspirated consonants in Nepali. Similar to other Indo-Aryan languages, such as Hindi, Nepali has as many as four series of stops: voiceless unaspirated, voiced unaspirated, voiceless aspirated, and voiced aspirated. Based on an exhaustive search of the 26,073 entries in Turner's Comparative and Etymological Dictionary of the Nepali Language (1931), the study reveals that only a small number of noncompound words contain two aspirates, and that the vast majority of these are either reduplications or loanwords. When these sectors of the lexicon are excluded, the number of diaspirate roots is vanishingly small. The cooccurrence constraints on aspirates are not predictable from the individual frequencies of the phonemes concerned, since the number of observed C^hVC^h sequences is significantly less than what would be predicted on a statistical basis. These facts support the view that aspiration takes the root as its domain in Nepali, though its location within the root is unpredictable and must be lexically specified. The distribution of aspiration in Nepali is compared to that of Sanskrit and examined within the typological framework of MacEachern (1999).

5 Conclusion

In this brief introduction we have not been able to do full justice to the enormous amount of work that Nick Clements produced on the subject of phonological features (let alone on the many other subjects he worked and wrote on), nor have we documented his influence of phonological theory in general and the work that many others have done and continue to do on phonological features. Nonetheless, we hope that the preceding sections have touched upon some general aspects of his work, especially work that he was engaged in until just before his untimely death. His vast body of published work as well as the work that is collected in this volume will speak for themselves. Nick was always and will continue to be a positive force in phonology.

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