Phonological alphabets and the structure of the segment

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1 Introduction

Like every living field, phonology is falling apart. Researchers are becoming increasingly specialized, and some phonologists have come to concentrate on particular subfields which they call their own – tonology, vowel harmony, intonation studies, metrical structure, the interface with morphology, or the internal structure of phonological segments. This concentration on subfields seems to have replaced the more traditional specialisation in terms of languages or language families. In addition, of course, the 1990s saw the advent of Optimality Theory (OT), which all but hid the differences between the various subfields under the blanket of a common notation, by focusing on the issue of *how* to do phonology rather than on what the primitives of phonology are.

This does not mean, however, that these different subfields ceased to exist; as a matter of fact, OT seems to have benefitted certain subfields more than others. Given the centrality of the notion of constraint ranking, OT has proven most successful in domains in which there is some sort of inherent conflict. This may then be one of the reasons why issues concerning the interface between phonology and morphology (such as Prosodic Morphology) or with the interface between phonology and phonetics have been quite successful over the past decade. Considerably less effort has been invested in the study of, for instance, metrical structure, which seems more 'purely' phonological and less influenced by various counterbalancing factors. It is certainly possible to successfully analyze stress phenomena within OT, and various important approaches to these phenomena have appeared, but in many cases there does not seem to be much gain in doing so.

Something similar holds for the study of the internal structure of phonological segments, which is one of the classical topics of phonological investigation. The 1980s witnessed a steady interest in topics such as autosegmental phonology and feature geometry, but it seems fair to say that these have not been in the focus of mainstream OT research until very recently. Part of the reason for this may be that the interest in 'small-scale' phonology now is on those aspects which can be understood in interaction with phonetics. The study of objects like 'the phonological segment' is an enterprise which is to some extent abstract, since the segment cannot be isolated directly within the phonetic signal or described in purely articulatory or acoustic terms. Most authors assume that the constituent parts of segments are abstract as well — for instance, in terms of phonological features.

Another reason why the phonological segment has not received a lot of attention in recent work may be related to the fact that OT is mainly a theory of phonological alternations and linguistic variation, not a theory of phonological representation or linguistic universals. OT itself does not impose any restrictions on possible phonological representations — we can combine OT either with abstract Feature Geometry, or with concrete phonetic specifications, or with both. Neither does OT impose any restrictions on the analyst as to the constraints that must be postulated in analysis. It therefore is not a complete theory of phonology: it should be complemented by a theory of phonological primitives, and of a theory of phonological constraints.

The articles in this volume — consisting of selected papers presented at the first Old-World Conference on Phonology (OCP1), held in Leiden on January 10-12, 2003[1] — show that there are still many interesting questions to be asked on segmental structure, that there is quite a lively debate on many of the issues concerned, and that the field is far from monolithic in its methodological approach: some authors use OT as a tool, but others do not; some refer explicitly to the results of phonetics for phonological explanation, while others prefer a purely abstract, cognitive, approach. Furthermore, the reader will find contributions from neighbouring disciplines such as language typology and historical linguistics. The articles study topical questions within this particular field from various angles: to what extent do we still need a feature geometry, and to what extent is it universal? What is the relevance of evidence from historical linguistics, typology, etc.? How should we represent the 'complexity' of 'complex' segments?

In this introduction, we concentrate on the formal theoretical implications of the contributions made in this volume: in this way we hope to shed light on the nature of the 'complementary' theories to Optimality Theory, i.e. the basic requirements of a theory of phonological representations and univer-

[1] Only a selection of the papers presented at the Conference have been included in this volume. Furthermore, all of the papers were reviewed and revised before they were included in this book.

sals.

On the assumption that it is indeed possible and desirable to construct something like a 'theory of segmental phonology', we must establish what the constituent parts of such a theory are. In syntax, the 1990s saw a strong interest in the so-called 'Minimalist Program' of Chomsky (1995). This program has not been applied to phonology, but part of the 'program' is that the metagrammar of linguistic derivations and representations can be expressed by elements of (i) 'conceptual necessity' on the one hand, and (ii) 'conditions of the interfaces' ('articulatory-perceptual' and 'conceptual-intentional') on the other (Chomsky, 1995, p. 171). This part of the program is kindred in spirit to Occam's Razor; it is a healthy exercise to check the status of every element of the formal apparatus that constitutes our theory. Which objects are part of the phonological universe and which are not? Every article in this book contributes in some way to an answer to this question.

This book consists of three parts. The first part, *Features and feature geometry* is the most general, and deals with some of the general issues we touched upon above. The second and the third part look more closely into two phenomena which warrant further discussion: *Nasality* in the second part, and *Laryngeal features* in the third. We will introduce each of these parts in turn.

2 Features and feature geometry

The first part of this volume is devoted to general issues, and the most general issue of all within the study of segmental structure is perhaps the relation between phonology and phonetics. We propose to look at this issue from the point of view of formal theory-building: the question then is whether the interpretation of the primitives of this theory is purely cognitive, or phonetic. The first two articles in this section deal with the relation between the theories of Feature Geometry and OT; the authors reach conclusions which are diametrically opposed with respect to the question whether such a combination is feasible. The next three articles are concerned with the interpretation of the features themselves, as well as with the issue of temporal ordering within the segment.

2.1 Constraints based on Feature Geometry

In his article 'Optimal geometries' (p. ***), Christian Uffmann argues that OT and Feature Geometry can indeed be combined. In his view, feature geometry can act as a filter on the generator function of OT. This means that constraints on segmental phonology only take into account those representations that are feature-geometrically well-formed. Moreover, constraints may directly inspect the result of autosegmental operations, such as spreading of

a Place node from one segment to one or more other segments, and calculate the number of violations for a particular constraint accordingly.

As far as we can see, the gist of the argument in favour of this proposal is theoretical restrictiveness. The oldest criticism against OT undoubtedly is that it does not provide us with a theory of what constitutes a possible constraint. It thus needs to be complemented with such a theory, which can be understood as a formal language and thus consists of the following two elements:

i. an *alphabet*, i.e. an exhaustive list of symbols which are allowed within a constraint;[2]
ii. a *syntax*, i.e. a set of rules that specify how these symbols can be combined to form well-formed constraints.

By way of illustration, here is the formal language to describe one well-known family of constraints outside the realm of segmental phonology, *Alignment*, where the *syntax* consists of one statement (a rewrite rule, where $\mathscr{C}$ is the symbol for a constraint):

(1) a. *Constraint lexicon* for Alignment constraints
{'$\forall$', '$\exists$', 'left', 'right', 'edge of', 'μ', 'σ', 'Ft', 'ω', 'stem', ...}

b. *Constraint syntax* for Alignment constraints $\mathscr{C}$
$\mathscr{C} \rightarrow$ $\forall$+(left$\vee$right) + edge of + ($\mu \vee \sigma \vee$ Ft $\vee\omega\vee$ stem $\vee\ldots$) + $\exists$ + (left$\vee$right)+ 'edge of' + ($\mu \vee \sigma \vee$Ft$\vee\omega\vee$stem$\vee\ldots$)

The grammaticality of (1b) is connected at least partly to the semantics of the elements in the alphabet: the fact that e.g. 'left$\forall$edge of rightμ' is not a possible constraint is strongly related to the fact that no sensible interpretation can be assigned to this statement (McCarthy & Prince, 1995).

Similarly, Feature Geometry provides us with an alphabet on which constraints can be defined:

(2) a. *Constraint lexicon* for Feature Geometric constraints
{[+voice], [Coronal], [+consonantal], ..., Place, Laryngeal, ..., 'is associated to', 'branches', ...}

b. *Constraint syntax* for Feature Geometric constraints
$\mathscr{C} \rightarrow$ $\forall$(Supralaryngeal$\vee$Laryngeal)+'x: x is associated to the root node'

It also provides us with a semantics — the interpretation of feature tree structures — on which we could build a syntax for constraints on the internal structure of segments. In this way, we constrain the set of constraints.

[2] The term *phonological alphabet* was coined by Calabrese (1988); we extend its use here to refer to all primitives of (segmental) phonology.

It should be noted that there are other ways of arriving at the same effect, and in particular, we could also constrain the theory by deriving our alphabet from phonetics and an appropriate syntax of constraints (which is related to an interpretation – in this case, based on articulatory and perceptual reality).

(3) *Constraint alphabet* for phonetically grounded constraints
{F_0, F_1, . . . , 1, 2, 3, 4, 5,. . . , Hz, ms, . . . , 'should be bigger than', 'should be smaller than' . . . ,}

Even in this case it should be established, however, what the relevant vocabulary items are. This approach does not provide a restrictive theory if everything which is measurable in principle can participate in constraint phrasing. The formalisation and the restrictions are usually left implicit, but essentially every researcher will tacitly assume some restrictions; for instance, an analysis which is based on an alphabet consisting of the features [high], [low], and [open] *as well as* F_1 values within the same constraint set would probably be unacceptable to everybody. A well-known example of a fairly restricted and formalised theory of phonology based in part on a phonetic alphabet is Archangeli & Pulleyblank (1994).

Within an approach such as the one defended by Uffmann, Feature Geometry restricts the notion of what constitutes a possible constraint; at the same time it also gives us a set of possible configurations and results of operations. For instance, while spreading of a Place node could result in a segment acquiring the place feature [Coronal] (and hence an increase or decrease of the number of violations of a constraint involving this feature), spreading of a Laryngeal node by itself could never have this result. It is Uffmann's goal to show that his restricted theory of constraints can analyse various phenomena elegantly. His constraint syntax could be formulated as follows:

(4) *Constraint syntax* for Feature Geometric constraints
$\mathscr{C}\rightarrow$ $\forall$+{segment,Place,Laryngeal, [coronal],[voice]. . . }+x+$\exists$+{μ, segment, Place, Laryngeal, . . . } + y :+x is parsed into y
$\mathscr{C}\rightarrow$ $\forall$+{Foot,segment,Place,Laryngeal, . . . }+x :+x is binary branching
$\mathscr{C}\rightarrow$. . .

In parallel to this, there should be a theory of Gen which uses partly the same alphabet, i.e. which generates structures that can be referred to using terms such as 'segment' and 'Place' and [+voice].

2.2 Phonetically grounded constraints

Moira Yip's article, 'Variability in feature affiliations through violable constraints: The case of [lateral]' (p ***), on the other hand, argues that Feature

Geometry is too rigid to understand the phonological behaviour of certain features, in particular of [lateral]. Her point is that [lateral] behaves ambiguously with respect to the Feature Geometry: in some cases, its behaviour seems to indicate that it depends on [Coronal], but in others that it depends on the Sonorant Voicing node. Feature Geometry predicts that these cannot both be true at the same time; therefore, Yip's data can be seen as evidence that Feature Geometry is falsified if taken as a universally valid tree structure of segments.

The conclusions which Yip draws from this – we should abandon almost all structure in favour of phonetics[3] – are quite strong. In line with recent work (by Gafos, 1996, among others) she proposes that we accept a completely different interpretation of constraints, viz. one which is based on phonetics. This leaves her with an alphabet of constraints which is in some ways simpler than the one proposed by Uffmann (it does not contain vocabulary items such as Place, Laryngeal, and the like), but may be more complex in other ways (e.g. it may need a larger number of constraints). Furthermore, we need an extra device, viz. the universal ranking of constraints, given to us by the phonetics, but still adding to the formal complexity of our machinery.[4]

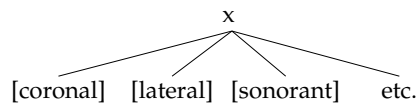
(5) a. *Constraint syntax* for phonetically grounded constraints (Yip-style)
$\mathscr{C} \rightarrow \forall$ + {[coronal],[continuant],[+sonorant], [-sonorant], ...}+ x + $\forall$ + {[coronal],[continuant],[+sonorant], [-sonorant], ...} + y : +
x and y should not co-occur in the same segment
$\mathscr{C} \rightarrow$Segments should be faithful to their underlying specification for {[coronal],[continuant],[+sonorant], [-sonorant], ...}
$\mathscr{C} \rightarrow$...

b. *Ordering statement syntax* for phonetically grounded constraint orderings $\mathscr{R}$ (in the style of Yip)
$\mathscr{R} \rightarrow \mathscr{C}_i\ (\gg \mathscr{C}_n)^*$

Yip's problem might be solved in a different way, for instance by putting to work Jaye Padgett's idea of Feature Classes (Padgett, 2000). This framework inherits many of the properties of Feature Geometry, but it is more

[3]Notice that Yip does not do away with tree structure below the segment altogether. She seems to assume autosegmental spreading, for which at least some rudimentary structure of the following form is necessary:

(1)



This structure (where x is the segmental spine or root node) formally is a tree, albeit a very rudimentary one.

[4]It is not completely clear whether an abstract theory would be able to abandon 'universal' rankings completely, e.g. to be able to deal with sonority effects, as Yip notes. Yet in such a theory it would be very hard to find a motivation – or an interpretation – for such a device.

flexible. Even though Padgett states a prohibition of overlapping class membership, there is nothing inherent to his approach that implies such a prohibition, hence constraints which would allow [lateral] to be a Place feature or a Sonorant Voicing feature, alternatingly or at the same time, are not formally impossible. We would thus slightly enlarge the set of possible constraints, but the change would not be a radical one. As a matter of fact, nothing in Uffmann's system precludes such an interpretation in principle either.[5] Yet Yip argues that "even Feature Classes are unnecessary" (p. ***). If we are willing to accept phonetics as an explanatory force in phonology, this might certainly be true. Scholars such as Uffmann and other contributors to this volume may not opt for this approach, however, so the matter is still open for debate.

2.3 Constraints based on abstract features

Also with respect to the alphabet of phonological constraints, Don Salting's article 'The Geometry of Harmony: Evidence against Targeted Constraints', provides arguments in favour of a geometric approach to vowel harmony using abstract features. His arguments against a phonetically oriented approach (on p. ***) may sound familiar by now: "the theory becomes less constrained, and thus less explanatory" and "these constraints [...] suffer from [a] lack of of explanatory rigor [...]. If one can posit *[+rd,+lo], one can just as easily posit *[-rd,+lo]". Notice that these arguments hold only under the conception that phonetics should be irrelevant in the evaluation of constraints; authors such as Yip do not need to be convinced by them.

Salting goes on to propose an approach to Feature Geometry which is indeed quite abstract; he notes the similarity to Van der Hulst's Radical CV Phonology (van der Hulst, to appear), which might be the theory of segmental structure that is most remote from phonetics of all theories which are presently available: it is based entirely on the concept of binary opposition. Salting's own approach is slightly less radical, and uses the binary feature [±open] (Clements, 1991). The article therefore focuses on the nature of phonological features rather than on the concept of 'geometry'. The geometry is, as a matter of fact, fairly simple in Salting's proposal, partly because the abstract interpretation of the features involved do not necessitate a complex structure. Salting's proposals are more compatible with those of Uffmann than with those of Yip, but only by virtue of the fact that the *interpretation* of the phonological elements he proposes are more similar to the type of interpretations that Uffmann uses.

[5] There is no constraint actively opposing affiliation of a feature to different organizing nodes, since these are assumed not to be generated by Gen (with a few exceptions such as place features that can be linked both to C-place and V-place, as in (Clements & Hume, 1995)). There is a constraint against multiple linking which could probably give us the right effect, if it is placed in an appropriate position in the hierarchy.

2.4 Using different alphabets and constraint sets

Yen-Hwei Lin's article in this volume, 'Piro affricates: Phonological edge effects and phonetic anti-edge effects?' sheds interesting light on the debate on the abstractness of phonological representations, based on a thorough discussion of affricates in Piro. This paper is concerned neither with the geometry of segments (in the sense of the presence or absence of organizing nodes) nor with the specific interpretation of features, but with the phonological implementation of temporal ordering.

Like in other languages, affricates in Piro phonetically start with a stop-like ([+continuant]) part, and end with a fricative-like ([-continuant]) part. The question is whether this sequencing is reflected in their phonological representation: arguments for and against such a mirroring have been put forward in the literature, but Lin shows that in Piro we can find arguments in both directions. She therefore proposes that there is a split between a lexical and a postlexical component. Affricates behave as (strident) stops in the lexical component, but as segments with an ordered sequence of [-continuant, +continuant] postlexically.

This corresponds to the postlexical phonology being more 'phonetic' in nature than the phonology, and Lin notes that this type of approach supports the approach of *Stratal OT* (Kiparsky, to appear), in which the grammar consists of more than one Optimality Theoretic module – at least one for the lexical phonology and one for the postlexical phonology. Notice that in the approach advocated by Lin the two modules would not just be differentiated by different rankings of the same constraints: the constraints would also address different phonological objects. Even though Lin leaves open the possibility that there are languages in which affricates behave as strident stops or as complex segments throughout the grammar, both in the lexicon and in the postlexicon, it seems unlikely that there would be languages in which the ordering of events would be reversed and affricates would start out as ordered [-continuant, +continuant] sequences in the lexicon, and turn into strident stops postlexically. This means that the lexical phonology has a constraint system which is based on more abstract representations, whereas the postlexical constraints are more phonetically based. This means that we can formulate the following restrictions on the constraint systems of the two components:

(6) Within the lexical component, segments are not allowed to have both a [+continuant] and a [-continuant] specification. In the postlexical component, segments are allowed to have such a specification.

(6) implies that a constraint such as OCP-AFFR (do not allow two segments with a specification [-cont, +cont] in a row) does not have a sensible interpretation within the lexical phonology: since these segments are not gen-

erated by $\text{Gen}_{lexical}$, no structure will ever violate this constraint. This opens up the possibility that this constraint is not present in the postlexical component at all, i.e. that the constraint grammars for the two components are different. We believe that this is a line of research that will generate further exploration.

2.5 The phonological alphabet of sign language

Within the debate on the abstractness of the phonological alphabet, sign language plays a crucial role. Under the assumption that phonology is an abstract system, there should be no difference between the formal apparatus of sign language phonology and that of spoken language phonology; the two constraint sets should have exactly the same alphabet and syntax (as a matter of fact, they may be the same in all relevant respects). If, on the other hand, phonology is phonetically grounded, the two sets of constraints could be very diverse.

Sign language phonology has been the topic of quite some discussion over the past few years. In the present volume, itis the topic of the article by Els van der Kooij and Harry van der Hulst (p. ***): 'On the internal and external organization of sign language segments: Some modality specific properties'.[6] As the subtitle suggest, the focus of these authors is more on the differences between the phonologies of different modalities than on the similarities. In particular, Van der Kooij and Van der Hulst argue that the sign in sign language corresponds to a phonological segment rather than to the phonological syllable, as other authors have suggested. This implies that in their view most morphemes of sign language (or at least of the Sign Language of the Netherlands) are monosegmental.

These segments may to some extent be different from spoken language segments in the sense that they have some internal ordering: many signs involve a 'movement', e.g. from a relatively low position in front of the body to a relatively high position. This is intuitively very similar of course to the 'movement' in complex segments in spoken language, as noted by Van der Kooij and Van der Hulst, referring to Channon (2002).[7] Interestingly, these authors note that "nothing hinges on making what is essentially a terminological decision. The 'real' proposal is the structure [...], irrespective of how we label or call the nodes." (p. ***) Exactly the same point is made by Yip

[6] Different from the articles just discussed, this paper is not cast in an Optimality Theory framework. This means that the relevant 'grammar' will not be necessarily of OT constraints, but of something else. Yet this grammar will still consist of an alphabet (listing the atoms) and a syntax (listing the ways to formalize sensible statements about the world in terms of the elements of the alphabet).

[7] This similarity disappears altogether if complex segments can be shown not to exist in spoken language, e.g. if affricates are strident stops (cf. Lin, this volume) and prenasalized obstruents are bisegmental (cf. Downing, this volume).

in her article (p. ***): "The terms mora, syllable, and foot, are just labels for levels in the hierarchy, and could equally well be stated in numerical terms. So really all we aresaying is that level n is normally directly parsed into level n+1 [...]". This may be construed as aclaim about phonological alphabets:

(7) Tree structures (relations between nodes) are part of phonological alphabets, but labels of nodes are not.

The statement in (7) is in fact also compatible with all other articles in this volume: no constraint ever seems to rely exclusively on the node label. This is a property that might then be shared between spoken language and sign language. Since tree structures are popular in syntactic and morphological research as well, we may tentatively generalize that these form the core of every alphabet of grammatical constraints.

In the view of Van der Kooij and Van der Hulst there is an essential difference between sign language phonological alphabets and spoken language phonological alphabets: whereas in the latter linearization largely takes place at a level *higher* than the segment, in the former linearization is supposed to take place at a level *lower* than the segment. They relate this to a difference between the two modalities: "We submit, tentatively, that the reversed relation between syllable and segment is a result of the fact that in the visual channel perception is 'instantaneous', which then leaves little room for temporal effects. Conversely, we think that perception in the auditory channel proceeds in a predominantly temporal fashion, making horizontal, co-temporal divisions a secondary effect." The theory presented by Van der Kooij and Van der Hulst, then, is a mixed model: there is an abstract core of linguistic constraints (instantiated by the tree structures), but the contents of the linguistic structures and (presumably) the constraints, are determined also by the modality, i.e. by the requirements of the phonetic interface.

Another interesting finding of Van der Kooij and Van der Hulst is that meaning may be part of the phonological alphabet: some phonological (or phonetic) constraints may need to refer to the meaning of the sign. A pair such as [open]-[closed] has a 'neutral' order ([open, closed]), and whenever this order is reversed ([closed, open]), this seems to be motivated by the meaning. But this in turn means that sign language phonology constraints need to be able to refer to semantic information, something which spoken language phonology is not usually assumed to be capable of (though cf. onomatopoeia, sound symbolism, etc.). Again, this seems to be an indication that the structure of phonological constraints seem to be related to the phonetics after all.[8] Thus, even though Van der Kooij and Van der Hulst start their contribution by stating "that [...] we believe that a consideration of certain conceptual issues regarding a potential common organization of languages

[8]There is one exception, viz. if we dismiss all of these phenomena as being purely phonetic.

in different modalities is [...] important", this does not cover all of their findings. In fact, their contribution is among the more phonetically oriented in this volume.

3 Nasality

Next to general discussions of segmental structure, this volume also contains articles about two types of segmental modification that are of special interest: nasality and laryngeality. Both of these are interesting because they form a well-defined testing ground for issues concerning the phonological alphabet. One article, the one by Botma (p. ***, see also our discussion in section 4.1) covers the interaction between these two dimensions of segmental structure.

3.1 The structure of prenasalised consonants

One longstanding problem in the study of phonological segments is how homorganic nasal-obstruent (NC) sequences should be analysed. Two types of analysis are available in principle: these sequences are monosegmental ('prenasalised obstruents') or they are bisegmental ('clusters'). This topic is important for many reasons, one of them being the question of the internal structure of complex segments. Together with affricates (see the article by Lin on p. *** and our discussion in section 2.4), prenasalised consonants are the most famous examples of such putative complex segments. But while affricates can still be analysed as sequences of [-continuant,+continuant], this is more problematic for nasals. Whereas both [-continuant] and [+continuant] may be active in the phonology, it is very hard to find evidence that this holds for [-nasal] as well.

Based on a wealth of data and detailed analysis, Laura Downing shows in her article 'On the ambiguous segmental status of nasals in homorganic NC sequences' (p. ***) that at least in Bantu languages these items should be analysed as bisegmental clusters. Downing differentiates between three different types of arguments for this reasoning: 'phonetic', 'phonemic' and 'phonological'. Phonetic arguments are those based on measurements — bisegmental units have approximately twice the length of monosegmental units; phonemic arguments are based on matters of complementary distribution — there is a difference between monosegmental and bisegmental units *iff* we can find minimal pairs based on that difference. Downing argues that neither of these classes of arguments can provide us with the definitive answer in this case, and therefore we have to take recourse to phonological arguments, which show that the nasal part of the cluster is in the coda of a separate syllable.

It is an interesting observation that phonetic and phonemic arguments in themselves do not provide us with sufficient evidence to decide between those two analyses, since these arguments presumably are the ones which

are most easily available to the language acquiring child. The fact that subtle phonological argumentation is necessary in order to reach a decision may be seen as an indication that the issue is entirely dependent on the rest of our theory: we can only decide whether or not the first part of the cluster is 'moraic' if we have established independent criteria to decide whether or not a segment is moraic.

In terms of the preceding discussion this means that the difference between monosegmental and bisegmental NC units cannot be expressed in the alphabet of phonetics ({1, 2, 3,. . . , ms, . . . }) or in the alphabet of phonemics ({'differs in meaning from', . . . }). The issue can only be phrased sensibly within a reasonably abstract phonological alphabet (basically again one of tree geometry at the level of the syllable); and here the available evidence points in the direction of a bisegmental analysis for the Bantu languages.

Downing leaves open the question whether there are other languages in which prenasalised consonants do behave as monosegmental also in the phonology. She mentions Fijian, referring to Maddieson & Ladefoged (1993), who found that in this language "NC sequences are not only similar in timing to singleton segments, they also pattern phonologically as unit segments". Yet, importantly, Maddieson & Ladefoged also found that "Fijian has no voiced stops, and NC sequences function as the voiced counterpart of voiceless stops" (p. ***). But this means that we may not need to analyse the Fijian 'prenasalised' segments as phonologically prenasalised at all; the prenasalisation may be the phonetic reflex of phonological voicing. In that case, we might conclude the following:[9]

(8) The phonological alphabet should not provide for the possibility of monosegmental prenasalised segments.

A theory which embraces monovalent [nasal] would be an example of a phonological alphabet satisfying (8), since it would not be able to express prenasalisation. Notice that this would have serious implications for a phonetically grounded view of segmental structure. Since phonetically it is indeed possible to express prenasalisation — since it exists phonetically, and the contrast does not seem particularily difficult to produce or hear —, the burden of proof is on those proposing such a theory – they need to show that (8) is false (or that there is some other reason why this potential contrast is not exploited).

3.2 The structure of the velar nasal

The article by Gregory D.S. Anderson, 'Areal and phonotactic distribution of /ŋ/ does not present a phonological theory, but it can be used to test existing

[9]Notice that this is of course a theory, and could be falsified, viz. by a language in which it can be shown that there are monosegmental nasalised segments.

theories, given the broad range of facts it covers.

For instance, Anderson points out that there is a well-known theory about English (and other Germanic languages) relating the fact that /ŋ/ cannot occur at the beginning of a syllable (*ŋa) to the fact that this segment is historically and/or underlyingly a cluster /ng/, and nasal+obstruent clusters do not occur at the beginning of a syllable (coincidentally, this is an assumption on which Downing bases much of her argument). Anderson shows that there are languages for which there is no basis for assuming a historical cluster, while they still satisfy the same requirement. This in turn means that the ban on */ŋ/ in English is not necessarily related to the history of the language. Apparently, our constraint system needs to be able to ban this segment in this position independently.

Another interesting observation is that in some languages this restriction against initial velar nasals concerns only the first position of the word. This gives us various indications about the phonological alphabet. In the first place it shows, once again, that we need to be able to refer to (prosodic) structure. It also shows that we need so-called 'positional markedness' of some form: our linguistic constraints need to be able to refer to the markedness of initial positions in the word separately. As a matter of fact, this shows that we need a parameterized constraint of some form:

(9) $\mathscr{C} \rightarrow *[_{\alpha}$ŋ, where $\alpha \in \{\sigma, \omega, \dots\}$

The fact that constraint schemes seem to be used by almost every contributor to this volume — as well as by virtually all other work in phonology — is an indication that the constraint set is not random, but has some internal structure (this does not tell us of course whether the source of this structure is functional of cognitive). We may therefore posit the following generalisation:

(10) The rules of constraint syntax may contain variables.

There are at least two types of variables: (i) those which refer to features or equivalents {[coronals], [voice], ...}, (ii) those that refer to organizing nodes {segment, σ, F, ω, ...} and, depending on one's assumptions, also {Place, Laryngeal, ...}.

On the other hand, at least the set of feature sets does not seem to be completely randomly organized. This is another conclusion we can draw from Anderson's article: it seems unlikely that it would be possible to gather similar material about restrictions on, for instance, coronal nasals or velar obstruents. There is something special about velar nasals and phonological theory should be able to express what this is. We are not aware of any theory that can give a satisfactory account of all of these data (cf. van der Torre, 2003, for a theory that may come close).

3.3 Morphosyntactic features in phonology

Siri Tuttle's article 'Cryptosonorant phonology in Galice Athabaskan' (p. ***) describes the behaviour of two segments in one specific language. This article deals with the intricate relations between voicing, sonorancy and nasality, and in this sense it belongs to the next part of this volume (on laryngeal features) almost as much as to the one on nasality. The article also touches on another important topic: the way in which morphology and segmental phonology interact.

Tuttle argues that a class of 'phonetically obstruent' segments can best be analysed as being 'phonologically sonorant'. The phonological theory which Tuttle uses is the Sonorant Voicing theory of Rice (1993), among others. Within this theory, there are two possible phonological representations of voicing: a feature [voice] and an organizing Sonorant Voicing (SV) node. The former is typical for voiced obstruents, the latter for sonorants. Sonorant features such as [nasal] dock onto the SV node, and this explains, among other things, why only sonorants are targets for nasal spreading in some languages.

Adherents of an abstract view of phonology could argue that this is an argument in favour of their approach, since it is unclear phonetically why [d] should behave as a sonorant. Their opponents could point out that the phonetic sources for Galice are not very clear, and, furthermore, that SV theory does not really *explain* why some obstruents behave like sonorants, whereas others do not. SV Theory merely provides us with a sufficiently rich phonological alphabet and constraint syntax to describe this state of affairs. But richness can also be seen as a lack of restrictiveness, and therefore does not necessarily count as a virtue (for theories). In any case, it is interesting that there are several examples of phonetic obstruents which behave as phonological sonorants, but as far as we are aware there are no examples of phonetic sonorants which behave phonetically as obstruents; and these would be excluded in SV Theory.

Another interesting property of Tuttle's proposal is that it draws a connection between morphological and phonological features. In the first place, she assumes that the class of ALIGNMENT-constraints should refer both to phonological features and to morphological features. This means that the constraint grammars for phonology and for morphology share at least one rule (the one in (1b)). Furthermore, she shows that morphological and phonological constraints can refer to the same object. She shows how a feature [nasal] can move to an initial position in the word due to phonological alignment of the nasal feature, while at the same time it has to be linked to its original (vocalic) position due to morphological alignment (which basically says that every phonological feature which is part of the specification of a given morpheme should occur in the slot that is assigned to that morpheme in the template).

In order for this proposal to work, morphological and phonological features need to be linked in some way (as is illustrated in Tuttle's example (21), p. ***). We can do this in many ways, but the following may be one of them:

(11) Every element in the phonological alphabet can have an index denoting the morphological affiliation of the element involved.

4 Laryngeal features

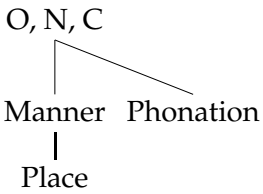
Laryngeal contrasts can in principle be produced on all phonological segments, but they play the most prominent role on consonants. The way in which laryngeal modifications influence the patterning of segments is the topic of the last three contributions to this book; they all argue in favour of a three-way distinction in the laryngeal dimension and thus seem to converge on one view, in spite of differences in the labelling of these three elements of the alphabet, and their interpretation.

4.1 Typological restrictions on phonetic possibilities

The article by Bert Botma, 'On the phonological interpretation of aspirated nasals' (p. ***), investigates how the behaviour of aspirated nasals in a variety of languages can inform us about the phonology of laryngeality. In a survey based on the UPSID Database (Maddieson, 1984; Ladefoged & Maddieson, 1996), Botma shows that languages allow for at most a threefold laryngeal contrast on nasals. A fourfold phonetic contrast – voiced, voiceless (apirated), laryngealised or breathy voice – is possible, and this phonetic space is indeed explored (every possibility is used in some language), but every language uses at most three out of those four possibilities, and furthermore all languages with nasal consonants have *voiced* nasals. Botma argues that phonological theory has to be structured in such a way that it can account for these restrictions and he proposes a model to do this, combining insights of Element Theory (Harris & Lindsey, 1995) and Dependency Phonology (Anderson & Ewen, 1987).

In line with some other work (see, for instance the article by Van der Kooij and Van der Hulst in this volume) Botma proposes a structure for (sub)syllabic constituents which is quite similar to what other people have proposed for segmental structure:

(12)



(12) looks like a segment, except for the label of its root node, which is one of the subsyllabic nodes O(nset). N(ucleus) or C(oda). The feature geometry in its strictest sense is minimal (it involves Manner dominating Place, a standard assumption in Feature Geometry (see for instance McCarthy, 1988)). This conforms to the observations by Yip and by Van der Kooij and Van der Hulst in this volume, viz. that the labels of phonological trees might be irrelevant.

Botma's main concern is with the structure of the constituent elements of the segment. In line with Element Theory and Dependency Phonology, he argues that these are not binary features, but unary elements. He suggests that there are three possible laryngeal ('phonation') elements, H, L and ʔ, which represent aspiration, voicing and glottalisation, respectively. Phonological glottalisation may be interpreted as either laryngealisation or breathy voice; this is the reason why these two interpretations cannot contrast phonologically in a language.

The type of approach which is put forward by Botma aims at reducing the number of elements in the phonological alphabet. One way of achieving this is by interpreting these elements differently if they appear somewhere else in the segmental hierarchy, which therefore attains crucial status. In particular, the elements H, L and ʔ are also used to describe Manner (while other elements function to describe Place). That is, the research program that he adheres to can be summarised as follows:

(13) Keep the number of primitives in the phonological alphabet as small as possible.

The ultimate conclusion of this program might be that there are only one or two phonological primitives. This will then imply more complicated structures which are built out of those primitives (if we have 60 primitives to describe 60 distinctions, our structures can consist of 1 primitive each; if we have 2 primitives, we need to combine them in various ways to get the required number of distinctions). Botma seems to be able to keep these in reasonable balance: the structures are sufficiently simple and the number of primitives is sufficiently small.

It should be noted also that 'as small as possible' is a relative notion. Some scholars who propose a much larger phonological alphabet might include many elements for which they see independent phonetic justification. In that case, they could argue that these elements do not really enlarge the alphabet of their theory, because their ambitions are to build one system for both phonetics and phonology; more abstract views of phonology then need a phonological *and* a phonetic alphabet which would be bigger, if unified.

Furthermore, Botma adduces interesting evidence for this type of approach: since sonorant Manner and voicing Phonation are both represented by the element L, we can establish a direct relation between the two, and fur-

thermore he speculates about similar direct relations if we represent 'nasality' as an L element as well, and both High tone and aspiration as an H element.

Notice that the system does not abstract away from the (acoustic and perceptual) phonetics, as H, L and ʔ are assumed to have at least some very general phonetic interpretation, and their phonological behaviour can therefore probably be understood at least in part by this very general phonetics.

4.2 Phonetics and economy of phonological alphabets

Hyunsoon Kim's article, 'The three-way laryngeal contrast in Korean' provides us with new data on a phenomenon which has been discussed extensively in previous literature, viz. the representation of laryngeal contrasts in the Korean obstruent system, where we find 'lenis', 'aspirated' and 'fortis' segments in a three-way contrast. Kim draws a distinction between two types of theory, which mainly differ in their representation of fortis consonants. While both theories agree that lenis segments are unmarked — do not have a laryngeal feature or only have unmarked values for those features —, one theory states that fortis consonants are bisegmental, whereas the other theory has it that fortis segments have a marked feature specification ([+tense]).

Kim shows that the latter theory is more successful in describing her phonetic, instrumental data. In some ways, her analysis is reminiscent of what Botma proposes for the laryngeal modifications of nasals, and one could wonder whether the same three elements that he proposes, H, L and ʔ, could be put to use. However, Kim argues that her data also show that *binary* features are necessary, for instance that we need a binary feature [±tense] in order to describe the facts she discusses.

The relevance of Kim's findings for 'purely' phonological research can only be established once we have established a satisfactory notion of 'economy' for phonological alphabets. Every theorist wants her theory to be as parsimonious as possible. In terms of our preceding discussion, this means that the alphabet should not contain any superfluous elements, and the constraint syntax should also be as short as possible.

If we now assume that Kim's facts and the more purely phonological processes of Neutralisation etc. have to be described within the same theory, the conclusion must be that unary features are unwanted, and so is a description of fortis consonants in terms of length, since the alternative descriptions are necessary independently.

Unfortunately, measures of theoretical economy are never as simple as this. For instance, we can not rule out in principle the possibility that we need an analysis of Korean fortis stops along the lines of Lin (this volume): one in which their representation in the phonology is slightly different in than it is in the phonetics. While this will necessarily make the phonological alphabet more voluminous, it may simplify the set of necessary constraints.

We then have to find an overall evaluation measure for alphabet and constraint syntax, but there is no *a priori* way to establish this. We simply do not have an objective, purely theoretical way to determine which grammar would be the simplest.

However this may be, Kim's facts show that those proposing a bisegmental and/or a bivalent feature analysis of Korean consonants need to reconsider their arguments. They will have to prove that their preferred theory would still be able to account for these facts in a satisfactory way, or otherwise recognize that they need to change their phonological alphabet.

4.3 Diachronic tests of phonological theories

Patrick Honeybone's article, 'Diachronic evidence in segmental phonology: the case of obstruent laryngeal specifications' also discusses the relevance of a three-way distinction for phonological theory. The languages which Honeybone discusses, mainly German and English, merely display a binary contrast between two types of voicing. Within a ternary theory, this raises the question which two out of three possible values are selected.

Honeybone's article is the only one in this volume which is mainly concerned with markedness: given a pair of phonemes which are written as <b> and <p>, which should count as the most marked? Logically speaking there are two possibilities, and both seem to be explored in natural languages. In some languages — for instance Romance languages such as Spanish and French — it can be demonstrated that /b/ is the marked segment in the pair: the marked feature is [(+)voice], and in a unary feature account we could say that /p/ does not have any laryngeal feature at all. Based on diachronic data, Honeybone shows that in Germanic languages such as German and English, it is more appropriate to assume that /p/ is the marked segment: the marked feature is [(+)aspirated], and /b/ does not have any laryngeal specifications.

Honeybone draws his arguments from diachronic evidence. He shows that both in German and in English at some point the 'voiced' and 'voiceless' sets became conflated, and that the new system was interpreted as 'voiced'. Under the assumption that the result of a sound change will be a less marked structure, this means that the 'voiced' (i.e. unaspirated) segments are unmarked.

It is important that the two groups of languages are also distinguishable in terms of phonetics: French /p/ is closer to English /b/ than to English /p/. The transcription of IPA symbols within dashes is therefore rather confusing: it is distinct from the phonetic observations, but it also does not conform to the phonological reality. /p/ and /b/ are not part of the phonological alphabet, while [aspirated] and [voiced] are.[10]

[10]Honeybone draws attention to the fact that there are different possible labels for these features, and that Botma and Kim make different choices among these. These differences may

The fact that the phonetics and the phonological behaviour converge is interesting, and it could lead us to suppose that the phonetics will be a cue for the language learning child to acquire the phonology. It does not necessarily mean, however, that phonetic information should be part of the phonological alphabet.

5 Conclusion

One of the demands on phonological theory is that it should describe those aspects of sound structure which are universal. In order to be able to do this, we need to know what the formal language of phonology is, and which statements can be made in that language.

Together, the articles in this volume contribute to an answer to these questions in the domain of segmental phonology. For instance, it seems clear that we need some form of arboreal structure, even though not everybody agrees on the question whether such structure also extends to the level below the segment. A general trend in the articles in this volume is to relocate the complexity of 'complex' segments to a higher level, so that prenasalised consonants are bisegmental and laryngeal modifications occur at the level of subsyllabic constituents. At the same time, we have seen that several authors declare the actual labeling of trees irrelevant, which blurs the distinction between subsegmental and suprasegmental structure even further. Within our theoretical vocabulary we need both tree structures and features (or elements); the argumentation about the precise nature of the tree structures and the elements will have to be detailed and subtle. We have also seen that many authors crucially use variables in the formulation of constraint: if a constraint can refer to one node, similar constraints should be able to refer to other nodes.

Since a debate about the 'abstractness' of phonology seems to be inherent to the discussion of segmental structure, it is interesting that none of the contributions in this volume abstract away completely from the phonetics, as some work advocates (Hale & Reiss, 2000). On the other hand, no author seems to take a purely phonetic point of view either. We believe that this reflects a common understanding in the field (which does not mean that extreme positions are not worth considering). We have also seen that some authors need to refer to entities which are outside the phonology (or the phonetics) proper, such as morphological structure, and even lexical semantics. The precise form of the phonological alphabet certainly has not been established yet.

be connected to differences in phonetic interpretation and as such be responsible for different phonological behaviour; but formally it does not make a real difference what the labels of features or elements are (just as it does not make a difference whether we label a certain prosodic node as σ, as $\overline{\overline{\mathrm{N}}}$ or as X).

An interesting development within the phonology of the past decades is that considerable attention is being paid to evidence from neighbouring disciplines, such as experimental psycholinguistics, diachronic linguistics, language acquisition, etc. Theoretical phonology has clearly profited from the confrontation from these data, but it has its own (theoretical) agenda as well. This volume shows that the field is still very lively and full of promising developments.

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