

## Squibs and replies

### Feature structures and indices\*

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Hayes (1990) proposes the adoption of a new notation for representing hierarchical phonological structure, in response to a notational problem which he calls the DIPHTHONGISATION PARADOX. More generally, he seeks to find a replacement for the current method of depicting feature trees, which is not ideally suited to the clear expression of rules and derivations. While I am in complete agreement with this standpoint and fully support Hayes' assertion that certain ambiguities of interpretation have crept into the graphical conventions currently in widespread use, I nevertheless believe his proposal suffers from a number of problems. Once identified, these problems can be solved with further notational and formal refinements.

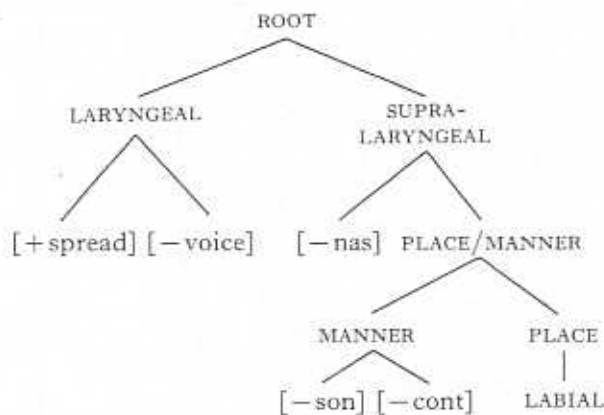
### 1 Overview

Hayes' main argument goes as follows: if a geminate segment is represented as a single feature tree linked to two C slots, then it is not possible to perform alterations that affect only the first 'half' of the geminate, as required for an analysis of Icelandic preaspiration<sup>1</sup> and an impressively broad range of other data he provides. The solution, Hayes argues, lies fundamentally in resolving an ambiguity in a graphical notation of phonology, where lines can indicate both association and category membership (cf. Bird & Klein 1990: 46-48), illustrated in (1) (Hayes' (13)):

- (1) a. Association H  
Lines: |  
a
- b. Category Membership  $\begin{array}{c} \sigma \\ \swarrow \downarrow \searrow \\ t \quad a \quad p \end{array} = [\text{tap}]_r$   
Lines:

In order to resolve this ambiguity, the distinction must be signalled explicitly: two notational devices are required. The first is for category membership or what I will henceforth call DOMINANCE. Hayes represents the feature geometry of (2a) as (2b):

(2) a.



b. ROOT: LARYNGEAL: [-voice]  
 [+spread]  
 SUPRALARYNGEAL: [-nas]  
 PL/MN: MANNER: [-son]  
 [-cont]  
 PLACE: LABIAL

Note that (2b) is essentially the same notation that Gazdar *et al.* (1985: 45) use for syntax trees. Another variant is known as the 'attribute-value matrix' or the 'feature structure' (e.g. Kaplan & Bresnan 1982; Shieber 1986; Scobbie 1991; Broe to appear).

Although feature structures like (2b) look rather different from trees, Hayes stresses that the difference is only superficial and the importance of the new notation to phonology lies in any added convenience that may result from its adoption. However, there is a further advantage to the use of this notation, because it has been given a rigorous mathematical foundation (e.g. Johnson 1988); a similar foundation for the purely graphical notations of phonology is less well-developed (but see Bird 1990 and Coleman & Local to appear for some attempts). Diagrams are often the most apt way to represent information (Larkin & Simon 1987), but their inherent flexibility makes them difficult to formalise.

The second notational device is for association. Hayes proposes to annotate the nodes in these trees with indices, where coindexation represents association (an idea attributed to Halle & Vergnaud 1980). Hayes' reformulation of the No Crossing Constraint ensures that the indices can be given a temporal ordering.

Hayes' two notations are combined as follows. Each member of the skeletal tier is given a single index. This sequence serves as a series of reference points that do not appear to be subject to alteration. A 'percolation convention' causes an index to be copied to the corresponding root node and then downwards through the entire feature tree, as illustrated in (3) (Hayes 1990: 44):

(3) a. *Percolation Co*

When indices  
 assignments at  
 nodes domina:

b. /ō:/ V<sub>1</sub> V<sub>2</sub>  
 R<sub>12</sub>: L:  
 S:

V<sub>1</sub> V<sub>2</sub>  
 → R<sub>12</sub>: L<sub>12</sub>  
 S<sub>12</sub>

As with long vowels, g  
 by two adjacent skelet  
 bear two indices. Cru  
 geminate at all levels o  
 affect only one half of a  
 diphthongisation rule:  
 nodes dominated by  
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## 2 Discussion

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 Indeed, is this distinct  
 indexless node is to b  
 and effectively be 'reli  
 'alignment constraints  
 structural alignment.

(3) a. *Percolation Convention*

When indices are assigned to or removed from a node N, the assignments and deletions are automatically carried over to all nodes dominated by N

b. /ð:/ V<sub>1</sub> V<sub>2</sub>

R<sub>12</sub>: L: [+voice]  
 S: [+nas]  
 PM: M: [+cont]  
           [-cons]  
 P: LB: [+round]  
       D: [-high]  
           [-low]

V<sub>1</sub> V<sub>2</sub>

→ R<sub>12</sub>: L<sub>12</sub>: [+voice]<sub>12</sub>  
       S<sub>12</sub>: [+nas]<sub>12</sub>  
           PM<sub>12</sub>: M<sub>12</sub>: [+cont]<sub>12</sub>  
                       [-cons]<sub>12</sub>  
       P<sub>12</sub>: LB<sub>12</sub>: [+round]<sub>12</sub>  
           D<sub>12</sub>: [-high]<sub>12</sub>  
                       [-low]<sub>12</sub>

MANNER  
 / \  
 PLACE  
 |  
 LABIAL

MANNER: [-son]  
           [-cont]  
 PLACE: LABIAL

Gazdar *et al.* (1985: 45)  
 as the 'attribute-value  
 Bresnan 1982; Shieber

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As with long vowels, geminates are viewed as a single structure dominated by two adjacent skeletal tier elements. All nodes of a geminate therefore bear two indices. Crucially, this gives a handle on the 'two halves' of a geminate at all levels of hierarchy, thereby making it possible for a rule to affect only one half of a geminate. In the case of Icelandic preaspiration the diphthongisation rule simply deletes the 'first' of the two indices from all nodes dominated by (and including) the place/manner node, thus it 'delinks the place/manner autosegment'.

2 Discussion

Three aspects of Hayes' proposal seem problematic. The first concerns the effect of the rule of autosegment delinking described above. If rules are able to remove indices then it is possible, in principle, for a node to lack an index. Is such a node floating, or has it effectively been deleted? Indeed, is this distinction preserved in Hayes' proposal? Suppose that an indexless node is to be interpreted as floating; it may later gain an index and effectively be 'relinked'. Under this view we can think of indices as 'alignment constraints'. An indexless node is unconstrained as to its structural alignment. Those nodes remaining indexless at the end of a

derivation could be construed as phonetically uninterpretable and effectively deleted (cf. stray erasure). The other interpretation of indexless nodes is that they have been deleted. This is the option which Hayes (personal communication) has advocated. His suggestion is as follows (the bracketed part is my addition):

Rules of the form  $i \rightarrow \emptyset$  [where  $i$  is the sole index of a node] are deletion rules (i.e. the node on the target tier indexed  $i$  is deleted, along with the nodes it dominates, owing to percolation). On the other hand, rules of the form  $i \rightarrow i'$ , where  $i'$  represents an index not previously present in the representation, could be taken to be rules of delinking.

This proposal could probably be made to work if the following apparent problems are dealt with. First, consider the situation where a node  $x_2$  dominates a node  $y_{23}$ . A rule  $2 \rightarrow \emptyset$  would delete the index from  $x_2$ , thereby deleting the node itself. According to Hayes' definition above, since  $x_2$  dominates  $y_{23}$ ,  $y_{23}$  would also be deleted even though it bears another index. However, as  $y_{23}$  is effectively doubly associated, its deletion would seem to be an undesirable consequence of the deletion of  $x_2$ . Second, it seems necessary to adopt a convention that any rule assigning an index to a node must also remove an existing index just in case the existing index is unique. Therefore, some revision of the above definition appears necessary.

We have now seen two possible solutions to the problem of indexless nodes and delinking *vs.* deletion which arise from Hayes' (1990) proposal. One solution (due to Hayes) is to view indexless nodes as having effectively been deleted, and to adorn floating nodes with unique indices. Another solution – the one I favour – is to view indexless nodes as floating (or delinked) and for delinked nodes to be deleted at the end of a derivation by stray erasure.

These notions of delinking and deletion have further ramifications. If, at some stage in a derivation all of the '2' indices have been removed, then the adjacency of certain nodes (say  $y_1$  and  $y_3$ ) would not be naturally represented. Hayes states (p. 45) that 'indices in rules are meant to be consecutive'. Therefore, a rule such as the one for assimilation (Hayes' (24)) cannot apply, even though  $y_1$  and  $y_3$  are now adjacent. One solution would be to reindex nodes so that an index 3 is changed to 2, a 4 to 3, and so on throughout the entire structure. A more attractive solution, I believe, would involve the use of abstract indices, say  $t_1, t_2, t_3, \dots$ , and an ordering relation  $<$  on these indices. Two nodes could be said to be adjacent just in case there is no other node with an intervening index. (See Bird & Klein 1990: 42 for a more detailed discussion of adjacency.)

The second problematic aspect of Hayes' proposal concerns the representation he proposes for contour segments (p. 60), where 'the two feature values receive the same index, with their temporal ordering determined simply by their ordering within the representation'. Accordingly, Hayes' example (55) for / $\tilde{e}$ / includes a specification for the manner tier as in (4):

(4)  $M_1: [-cont]_1$

This leads to a con- association (p. 43), an (p. 40). Therefore [- which is impossible. 7 lines will autosegmen an instance of Sagey's be rescued from this. interpretation of inde only encodes coarticu option is ruled out by significant' (p. 63). independently of any c and so a contradiction

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The final problem, where (5a) and (5b) 'phonologically distinc

(5) a.  $C_1$

PL/MN<sub>1</sub>: M<sub>1</sub>

PL

b.  $C_1$

PL/MN<sub>1</sub>: M<sub>1</sub>

Hayes' solution involv percolation convention tively distinct outputs may arrange nodes in c formally significant'. significant then the per could not operate, since In short, Hayes has (i) shown how a property (

(4)  $M_1: [-cont]_1 [+cont]_1$ 

This leads to a contradiction. We are told that coindexing encodes association (p. 43), and that associated elements are 'pronounced together' (p. 40). Therefore  $[-cont]_1$  and  $[+cont]_1$  must be pronounced together, which is impossible. The very same mechanism which replaces association lines will autosegmentally 'link' the halves of an affricate.<sup>2</sup> The result is an instance of Sagey's paradox (Sagey 1986: 282ff). Hayes' proposal might be rescued from this contradiction by appealing to a 'context-sensitive' interpretation of indexing. For example, we could say that coindexation only encodes coarticulation across tiers, not within tiers.<sup>3</sup> However, this option is ruled out by the later claim that 'only the indexing is formally significant' (p. 63). This claim requires that indexing is interpreted independently of any other aspects of notation (such as the tier structure), and so a contradiction is inevitable.

The heart of the problem is that Hayes' indices correspond to *atomic* intervals which, by definition, cannot be subdivided. One solution, following Bird & Klein (1990), is to permit the ever-finer subdivision of intervals. Then the manner tier specification could be  $M_1: [-cont]_{1a} [+cont]_{1b}$ , where 1a and 1b are the two halves of 1, just as 1 and 2 are the halves of 12. This provides a natural expression of the adjacency of 1b and 2 and the non-adjacency of 1a and 2.

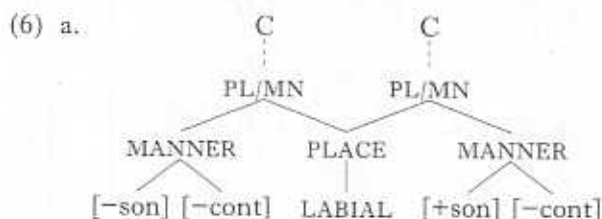
The final problem concerns the 'spurious ambiguity' noted in §9.4, where (5a) and (5b) (simplifying from Hayes' example (59)) are 'phonologically distinct, though phonetically identical':

(5) a. C <sub>1</sub>	C <sub>2</sub>	Output: [bm]
PL/MN <sub>1</sub> : MANNER <sub>1</sub> : [-son] <sub>1</sub>	PL/MN <sub>2</sub> : MANNER <sub>2</sub> : [+son] <sub>2</sub>	
	[-cont] <sub>1</sub>	[-cont] <sub>2</sub>
	PLACE <sub>12</sub> : LABIAL <sub>12</sub>	
b. C <sub>1</sub>	C <sub>2</sub>	Output: [bm]
PL/MN <sub>1</sub> : MANNER <sub>1</sub> : [-son] <sub>1</sub>	PL/MN <sub>2</sub> : MANNER <sub>2</sub> : [+son] <sub>2</sub>	
	[-cont] <sub>1</sub>	[-cont] <sub>2</sub>
		PLACE <sub>12</sub> : LABIAL <sub>12</sub>

Hayes' solution involves revising the definition of dominance and the percolation convention, which apparently has the effect that 'the putatively distinct outputs in [(5)] are notational variants. That is, while we may arrange nodes in outline form for convenience, only the indexing is formally significant'. However, if only the indexing were formally significant then the percolation convention (p. 44, revised on pp. 63-64) could not operate, since it requires access to information about dominance. In short, Hayes has (i) defined a property P (i.e. dominance), then (ii) shown how a property Q (i.e. coindexing) is derived from P, and then (iii)

claimed that P is unnecessary. Crucially, he has failed to show how Q may be derived in the absence of P. Therefore step (iii) is in doubt.

A more attractive solution to this spurious ambiguity problem is to permit  $C_1$  and  $C_2$  to share their place of articulation. Example (6a) illustrates the solution (the dashed lines indicate elided structure). The corresponding feature structure appears in (6b); it uses an index notation discussed by Shieber (1986: 13) and Johnson (1988: 17–18):

b.  $C_1$ 

PL/MN<sub>1</sub>: MANNER<sub>1</sub>: [-son]<sub>1</sub>  
 [-cont]<sub>1</sub>  
 PLACE<sub>1</sub>: LABIAL<sub>12</sub>□

 $C_2$ 

PL/MN<sub>2</sub>: MANNER<sub>2</sub>: [+son]<sub>2</sub>  
 [-cont]<sub>2</sub>  
 PLACE<sub>2</sub>: □

In (6b), both instances of □ are interpreted as referring to the one place node: both  $C_1$  and  $C_2$  effectively share the information that the place of articulation is labial.

In conclusion, Hayes' solution to the diphthongisation paradox relies on clearly distinguishing dominance and association: 'once we separate the two functions, the paradox disappears' (p. 40). However, his percolation convention (21) – loosely: dominance implies association – and his rule (60) – loosely: association implies dominance – leave the reader in doubt that he has actually achieved a clear distinction between dominance and association. I agree with Hayes' diagnosis but not with his solution, which appears to suffer from a number of flaws. I have indicated how these flaws might be dealt with, drawing on insights discussed at greater length in Bird & Klein (1990), Bird (1990) and Bird & Blackburn (1991). My proposals may be summarised as follows: (i) the adoption of abstract indices related by a temporal ordering (for the deletion and delinking problems), (ii) the use of 'ever-finer subdivision', where indices are thought of as temporal intervals which may be partitioned (for the problem with affricates), and (iii) the use of structure-sharing (for the spurious ambiguity problem).

A final comment about the ultimate purpose of these proposals is in order. Hayes is not alone in his frequent use of the term 'formal' (and the related terms 'formalise' and 'formalism'). However, far from being a well-defined notion as might be expected, the word is an enigma (cf. Pullum 1989). Hayes' theory is 'formalised' simply by formulating a notation (pp. 43–44). I contend that the more substantive notion of

'formal' as it appears in a grammar would only be a descriptive language. (To be sure, there are many such as convenience, complexity, syntax and a formal se and not also as a suffix. Once this FORMAL ADEQ a grammar that uses fe exist software systems mechanically grind ou based linguistic theori are crucial, I believe, theory is to be determ

## NOTES

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[2] I am grateful to Bru argument.

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'formal' as it appears in logic should also be adopted in phonology. A grammar would only be called formal once it was expressed in a descriptive language having both a formal syntax and a formal semantics. (To be sure, there are other properties we would like a grammar to have, such as convenience, clarity and economy. The requirement for a formal syntax and a formal semantics is proposed only as a necessary condition and not also as a sufficient condition for the acceptability of a grammar.) Once this FORMAL ADEQUACY has been achieved, the empirical adequacy of a grammar that uses feature structures can be tested automatically. There exist software systems such as PATR-II (Shieber *et al.* 1983) which can mechanically grind out the empirical consequences of feature-structure based linguistic theories. The above formal refinements to Hayes' theory are crucial, I believe, if the coverage of a large grammar couched in his theory is to be determined.

## NOTES

- \* This squib has benefited from criticisms and suggestions from Bruce Hayes, Ewan Klein, Bob Ladd, Jim Scobbie and two anonymous reviewers.
- [1] Note that Hayes' analysis of Icelandic preaspiration (along with those of Clements 1985, Sagey 1986 and others) is based on an assumption that a lengthening rule exists which feeds the preaspiration rule for forms like /opna/ → /oppna/ → [ɔhpna]. However, Árnason (1986: 13) claims that the evidence for such a rule is unclear. Furthermore he argues that stress data is most naturally accounted for if the aspiration forms part of the syllable nucleus (as a voiceless vowel). I suspect, therefore, that an adequate account of this data will be less straightforward than Hayes' rule (34) suggests.
- [2] I am grateful to Bruce Hayes for suggesting this sentence as a paraphrase of my argument.
- [3] Note that the use of consecutive indices to encode adjacency would need revision for the edge effects claimed for affricates (Sagey 1986: 93ff) to be expressed.

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38: 17-18):

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## *Diacritic extrametricality: a reply to Hammond*

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### 0 Introduction

Although primary word stress in Polish and Macedonian is on the antepenult in both languages, Hammond (1976) suggests that the extrametricality of the antepenult in Polish and the antepenult in Macedonian can be analysed in a unified way. Hammond's analysis is based on the framework of Chomsky & Vergnaud (1987) and (1987, forthcoming) and accounts for the extrametricality of the antepenult in both languages. Hammond's analysis is conceptually more elegant than the analysis of extrametricality in Macedonian which is based on the framework of Hammond (1976) and (1987, forthcoming) and accounts for the extrametricality of the antepenult in both languages.

In this reply to Hammond, I argue that the 'advantages' of Hammond's analysis are made against unified extrametricality. Evidence from Polish and Macedonian is used to show that Hammond's analysis is not unified. I then contrast Hammond's analysis with a unified analysis of extrametricality in both languages. The unified analysis is essentially identical to the analysis of extrametricality in Hammond's analysis. The unified analysis is conceptually more elegant than Hammond's analysis in that it accounts for the extrametricality of the antepenult in both languages. The unified analysis is also more elegant than Hammond's analysis in that it accounts for the extrametricality of the antepenult in both languages.