

The challenge from Metaphony for AIU systems: An RCVP account

Abstract: In this article we propose an analysis of metaphony in a unary-feature based system of segment representation. Such systems are traditionally triangular since they typically rely on three core elements or components: A (‘sonority, lowness’), I (‘frontness’) and U (‘roundness’), where the phonetic correspondents can be defined in articulatory or acoustic terms. How do such systems compensate for the absence of a dimension ‘high’, which seemingly makes them unable to characterise the natural class of high vowels, which is crucially referred to in the analysis of metaphony? We propose an account of different types of metaphony specifically couched in the framework of Radical CV Phonology, where an element corresponding to [high] is available as a result of basic principles governing the framework. In this approach an account of metaphony is readily available, which relies on the notion of resolution which has previously been used in analyses of lenition.

Keywords: Metaphony; Radical CV Phonology; triangular feature systems; unary features; [high]; resolution schema

1. Introduction

A common piece of criticism directed at unary-valued feature systems such as Dependency Phonology (Anderson & Ewen 1987) is that they lack a way of characterising high vowels as a natural class and, as a result, also face questions with respect to vowel raising processes, which are commonly part of different instances of metaphony that have been described in the languages of the world. Notwithstanding the many and instructive attempts that have been made in the literature to solve this problem, we accept this criticism: high vowels do indeed act as a natural class for numerous phonological processes, e.g. ones involving assibilation, devoicing, syllabification, and others: this class, and these processes, should be captured in a

straightforward way. We therefore adopt the theory of Radical CV Phonology (RCVP, van der Hulst (2020)), in which polar ('radical') opposition plays a crucial role: elements come in pairs that are polar opposites. This idea is motivated for laryngeal, place as well as manner/major class distinctions in the phonology. Thus, given the fact that a feature [low] (maximal sonority) is uncontroversial, the adoption within this framework of a polar feature that phonetically corresponds to [high] is a logical consequence. This idea preserves the idea of unary features (i.e. elements, instead of binary features) that is argued for in Dependency Phonology but offers a more satisfactory match with the empirical evidence in which high vowels are involved.

In section 2 below, we offer a brief introduction to RCVP (van der Hulst 2020), focusing on the relation between vowel features. Section 3 presents common metaphonic processes (Calabrese 2011), that turn out to be amenable to a principled and unified analysis in the RCVP framework. Section 4 offers a reflection on the empirical and theoretical advantages claimed by the RCVP approach.

2. A short introduction to RCVP

RCVP was developed by van der Hulst in a series of papers culminating in van der Hulst (2020), a comprehensive presentation of the model supported by extensive empirical evidence, especially from segment inventories, natural classes and phonological processes. We refer to this book for further references. The model has some aspects in common with previous and contemporaneous feature frameworks. A number of the principles that lie at the basis of RCVP are presented below:

- (1) a. Segments have internal structure, and consist of unary elements
- b. Polar opposition is fundamental: All minimal phonological contrast involves the presence of one of two opposing elements.¹

¹ The principle of polar opposition is rooted in the cognitive capacity for categorial perception, which

- c. There are only two elements, C and V, which occur in each intrasegmental element group (see (2) below)
- d. Headship plays a role at all phonological (and other linguistic) levels, including segmental, syllabic and higher prosodic structure
- e. The phonetic realisation of an element depends on its position in the hierarchical structure, both intrasegmentally and extrasegmentally (i.e. syllabically)

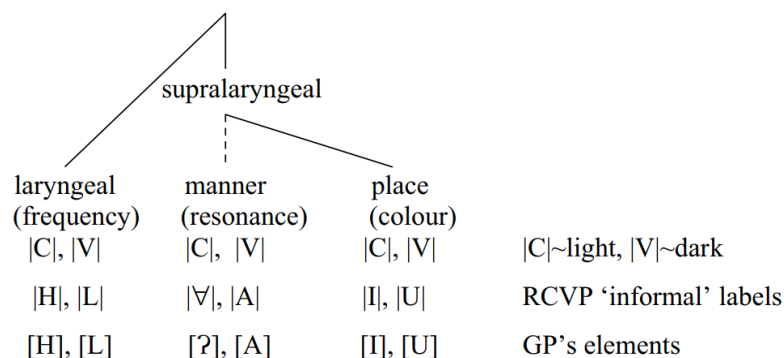
These principles have partial parallels in other frameworks that adopt unary features, such as Dependency Phonology (Anderson & Ewen 1987), Government Phonology (GP) (Kaye, Lowenstamm & Vergnaud 1985, 1990), and Particle Phonology (Schane 1984), but also strokes with metrical phonology (as well as many varieties of morphosyntactic theories) with respect to the concept of headed structure (Lieberman & Prince 1977) and feature organisation into a hierarchy (Clements 1985). RCVP (as well as DP) goes further than most models by assuming that head-dependency relations apply at *all* levels of linguistic structure, including the syllable, morphology, semantics and syntax. See especially Anderson (2011, 2022a, b) in which the consequences of this Structural Analogy Assumption are explored in great detail.

Concretely, the geometry of elements adopted in RCVP is presented in (2):²

fosters a division in two opposite categories in all perceptual dimensions. See van der Hulst (2015) for extensive discussion.

² The model makes a further distinction between a head subclass and a dependent subclass in each of the three classes. Here we refrain from discussing this aspect, which accommodates finer contrastive distinctions in segmental inventories relating to a variety of secondary articulations or other modifications of more basic categories.

(2) The ‘geometry’ of elements in Radical cv Phonology (van der Hulst 2020: 68)



The geometry in (2) expresses the basic division of a segment into three class nodes or gestures, organised by an intervening supralaryngeal node, together with informal labels such as |I A U| which will be familiar from Dependency Phonology (Anderson & Ewen 1987) and the elements recognised in Government Phonology (see e.g. Backley (2011), Bendjaballah, Tifrit & Voeltzel (2021), Scheer & Kula (2018) for overviews and recent discussion of different proposals). We will refrain here from pointing out the many similarities with previous proposals in segment representation: see the references above for details and van der Hulst (2021) for a summary. It is seen in (2) that each class node (i.e. laryngeal, manner, and place) dominates the same two elements (|C| and |V|), which represent the basic polar opposition within each class node: voiced vs. voiceless (or High tone vs. Low tone) for laryngeal, high vs. low (or stop vs. fricative) for manner and front vs. back for place. Recall from (1e) that the phonetic interpretation of the elements C and V is subject to their place in the segmental and syllabic structure, as well as their status as a head or dependent.

Let us focus on the representation of vowels in the RCVP model. Consider a seven-vowel system like that in (3):

(3) i u
 e o
 ε ɔ
 a

Such seven-vowel systems are very common in the languages of the world (Maddieson 1984: 126), and have also played an important role in debates on vowel harmony (van der Hulst 2018), the representation of vowel height (Casali 2018, Clements 1990, Goad 2024, Pulleyblank 2011) and metaphony (see below). Of special interest is the representation of the contrast between the two series of mid vowels (higher-mid and lower-mid) which has typically been expressed either as a height contrast or as a tongue root contrast using features such as [ATR] or [RTR], either as binary or unary features. We will not enter into an in-depth discussion of this issue here, but illustrate the way in which it can be expressed in unary-feature frameworks and how this solution can be used in an account of metaphony. In Dependency Phonology the mid-vowel contrast is represented using the dependency relation, where in the lower-mid series the ‘low’ element A is more prominent. In RCVP, which recognises the extra element \forall , this is slightly different. The RCVP representation of a seven-vowel system such as that in (3) is presented in (4), where the informal labels from (2) are used:

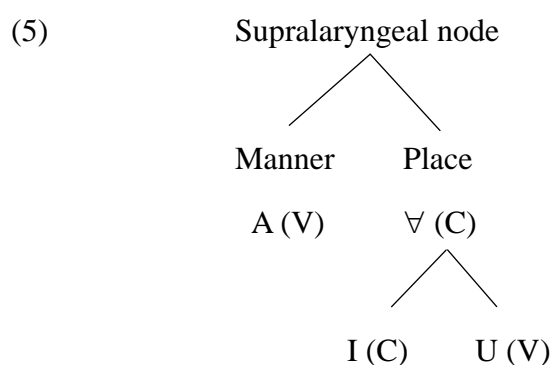
(4) RCVP representations of a canonical seven-vowel system

i	u	e	o	ε	ɔ	a
		A	A	<u>A</u>	<u>A</u>	A
	U		<u>U</u>		U	
I		<u>I</u>		I		
∇	∇	∇	∇	∇	∇	

Underlining of an element in (4) indicates headship, which in this case distinguishes the two pairs of mid vowels: in the lower of these the element A is head, and in the higher of the two the other element (I or U) is head. In this model, the three basic vowels /a i u/ are represented maximally simply, each consisting of just a single element (plus ∇; see below). In this approach, vowel representations are fully interpretable even if they have only one or two elements (*contra* much work in binary feature theory, in which vowels must receive specifications for all features, at least on the phonetic surface). As for natural classes, all rounded vowels have a U element, which is also present in labial consonants, consonants with secondary labialisation, etc. So far, the representations proposed in (4) are compatible with previous approaches in Dependency Phonology. The innovation that RCVP proposes is the ‘upside down’ A element, i.e. ∇, which is included in (4) even though adding this element, which captures a ‘non-low’ articulation, seems redundant at first glance. Let us discuss this proposal in some detail.

An issue which has been discussed in the unary-feature literature is whether there is some kind of organisation to the set of elements, akin to the way binary features are organised in Feature Geometry models (Clements 1985, Sagey 1986 [1990]). The traditional elements A, I and U seem to form two groups: the element A alone refers to vowel height (or sonority—here interpreted as a manner feature) and I and U to place of articulation and rounding (‘colour features’). This insight is expressed in a proposal

where these two groups of elements reside under two different ‘class nodes’ (to use feature geometry terminology). We endorse and develop here a proposal by Ewen & van der Hulst (1985) (cf. also van der Hulst 1989, van Nice 1991), in which I and U (or rather, the basic elements |C| and |V| for which we use these shorthands) are subordinate to a node that characterises the element ∇ (labelled ‘Colour’ below), which itself is a sister of the element A (labelled ‘Sonority’). Both sisters form part of the Place node, itself attached to a higher Supralaryngeal node:



This proposal, which embodies a slight revision or rather a more specific version of the standard RCVP model in (2), explains why the presence of the elements I or U implies the presence of the element ∇ , which is the dominating node to I and U. This was captured by the representations in (4), where the element ∇ is strictly speaking redundant to express the vowel contrasts in this inventory. Its presence is forced as a result the geometry, just like a Place node must be present in a feature-geometrical representation if a specific place feature is present. Finally, as a class node and not a terminal feature, certain differences are expected between the regular elements A, I and U on the one hand, and the element ∇ on the other. Just like a bare Laryngeal, Place or other node in feature geometry, the bare element ∇ (without Colour elements) seems defective without any further specification (see also van der Hulst (2020: 153) for further discussion of this point).

As the geometrical counterpart of the sonority element A in (5), a reasonable phonetic interpretation of ∇ is that it corresponds to vowel height. When this element ∇ occurs by itself (like the other elements can), i.e. lacking I ('frontness') and U (roundness') it represents a high central vowel /i/. When combined with the element A, a reasonable interpretation is that this represents a mid or lower central vowel. Phonological contrasts between high and lower central vowels are attested, e.g. in various dialects and historical stages of Korean. In further support of ∇ , similar proposals have been made in Dependency Phonology, which proposes an element |ə| for the same purpose (Anderson & Ewen 1987: 218). The difference is that the extra element in RCVP is expected as a result of the geometry and the principles of the feature system. The ∇ elements also bears a resemblance to the 'cold vowel' element that was part of the original proposal in Government Phonology (Kaye, Lowenstamm & Vergnaud 1985).

For our purposes in this article, it is important to see that the ∇ element makes it possible to characterise the natural class of non-low vowels: these are the vowels that have the element ∇ . In this way, RCVP is better equipped to deal with processes involving vowel height, and especially raising, than traditional Dependency models. With these preliminaries in mind, we can turn to the analysis of metaphony.

3. The analysis of metaphony in RCVP

We follow van der Hulst (2018) and others in assuming that a basic difference between vowel harmony on the one hand and metaphony on the other is that the former is (typically) unbounded while the latter involves a smaller domain, often a stress domain such as for example the metrical foot. The term umlaut has often been associated with Germanic languages (Hansson & Wiese 2024, Klein 2000, McCormick 1981, 1982), but in fact may be taken to refer to the same kind of phenomenon as metaphony, since it also involves a domain bounded by stress (see

also Ritter & van der Hulst 2024 for discussion). These terms have traditionally been used for different kinds of languages, but such differences in tradition and differences in terminology should not obscure the fact that all of these processes involve inter-vowel dependencies within a stress-bounded domain and raise the same kinds of questions, e.g. in terms of features or elements involved, consonant (and even vowel) transparency, and so on, just like in what is usually called ‘vowel harmony’. All of these vowel-related phenomena are test cases for any theory of segmental structure: in the optimal case, every feature or element posited in such theories should (potentially) correspond to a type of vowel harmony or metaphony. Van der Hulst (2018) offers an extensive typology study and formal analysis of vowel harmony, and argues that RCVP is a close fit to this, identifying palatal, labial, lowering and raising harmony as corresponding to the four basic elements in RCVP, viz. with the basic elements I, U, A and \forall , respectively.³

Let us now turn to a description and analysis (which builds on van der Hulst (2018: § 6.6.2)) of the main types of metaphony described in Calabrese (2011) (see also the important new studies in Torres-Tamarit, Linke & van Oostendorp (2016), Canalis et al. (2024), among others) in an RCVP approach. Calabrese (2011) discusses four aspects of metaphony that call out for a formal analysis. These are listed in (6):

- (6) a. In all cases of metaphony a stressed mid vowel is raised from [e o] to [i u] when followed by a high vowel in the next syllable.
- b. There is dialectal variation in the case of the lower-mid vowels [ɛ ɔ], for which there are three types of dialects:
- bi. In one group of dialects, these vowels raise to higher-mid [e o]

³ Here we sidestep the question of how to relate lowering and raising harmony to the type of harmony identified as ATR (and/or RTR)-harmony; see extensive discussion in van der Hulst (2021).

- bii. In another group of dialects, these vowels diphthongise [je wo]
- biii. Finally, in some dialects, these vowels are unaffected.

To start with the raising case (6a), this can be analysed straightforwardly as a case of deletion of the A-element. Recall the representations in (4), where /e o/ are represented with two elements, and [i u] are represented with one (again ignoring the \forall -element). How should this change, which involves phonetic raising, be interpreted? On the one hand, it could be regarded as a straightforward case of simplification, in which the mid vowels are replaced by the ‘quantal’ vowels [i u] (Stevens 1989). Quantal vowels are more easily audible and therefore have a less ‘diluted’ representation. However, recall that the targets of raising here are stressed vowels; which do not usually simplify spontaneously: it is more usual for *unstressed* vowels to undergo this kind of change, either historically or in synchronic grammars (e.g. as in Brazilian Portuguese (Wetzels 1995) and many other languages). The fact that stressed mid vowels become high before a high vowel seems to indicate an assimilation process is at stake, at least historically (cf. d’Alessandro & van Oostendorp 2016: 356ff.). This is captured by the RCVP interpretation: before metaphony takes place the target vowel and the trigger vowel are different in that the former have, and the latter lack, an A element. After metaphony, the vowels have become more similar in that neither bears an A element: no spreading of any element or feature corresponding to [+high] is necessary. In this way, vowels can also become more similar, i.e. assimilate, by deletion of an element; this is referred to as ‘reduction harmony’ by Harris (1994).

While the idea of reduction harmony is a good start to understand the nature of raising metaphony, we will here develop this further by taking into consideration the ‘chain-shift’ aspect of metaphony. This seems appropriate for dialects where higher-mid vowels raise to high, and lower-mid vowels diphthongise (or raise to

high-mid), and low vowels raise to lower-mid. To characterise such chain shifts, the mechanism of *resolution* (first proposed by Anderson & Jones (1974)) is insightful, which elegantly captures the gradualness of phonological processes. In this approach, when an element B is added to an element A (where A and B stand for any elements), B will first be a dependent (non-head) element. When B is added to a segment that already contains B (as non-head), B becomes head (preserving A as a non-head). Thirdly, if B is added to a B-headed segment, it pushes out A completely (this is the ‘reduction stage’). These stages may play out as historical stages or as different parts of a chain process in the phonological grammar. Resolution is described in (7), where underlining again indicates headship:

$$(7) \quad A \quad > \quad \underline{AB} \quad > \quad \underline{AB} \quad > \quad B$$

$$\quad \quad \quad +B \quad \quad \quad +B \quad \quad \quad +B$$

In the present case, the elements involved are A (the ‘low’ element) and \forall (‘non-low’). Mixing these in the way suggested by the resolution schema in (7) has the following effects:

$$(8) \quad \text{Add } \forall \text{ to } A \quad \rightarrow \quad \underline{A}\forall \quad \text{low vowel becomes low mid}$$

$$\quad \text{Add } \forall \text{ to } \underline{A}\forall \quad \rightarrow \quad A\underline{\forall} \quad \text{low mid vowel becomes high mid; headedness flips}$$

$$\quad \text{Add } \forall \text{ to } A\underline{\forall} \quad \rightarrow \quad \forall \quad \text{high mid vowel becomes high; loss of } |A|$$

Thus, all three steps in such a chain involve \forall -attraction, but with different immediate effects: (i) addition of the element itself, as a non-head; (ii) reversal of headship in the combination of elements in favour of \forall ; (iii) deletion of the element with which \forall formed a combination. The procedure is very similar to the Great Vowel Shift in the history of English or increasing sonorisation in lenition processes (see

especially Anderson & Ewen (1987: 175ff.)). The resolution approach provides an explanation for ‘reduction harmony’ (cf. above) by formally recognising the underlying cause as ∇ -attraction. This could further be related to the stress trigger: the element ∇ is naturally attracted to the stressed syllable in the RCVP framework.

In terms of vowels, these changes would have the following effects (van der Hulst 2018: 285):

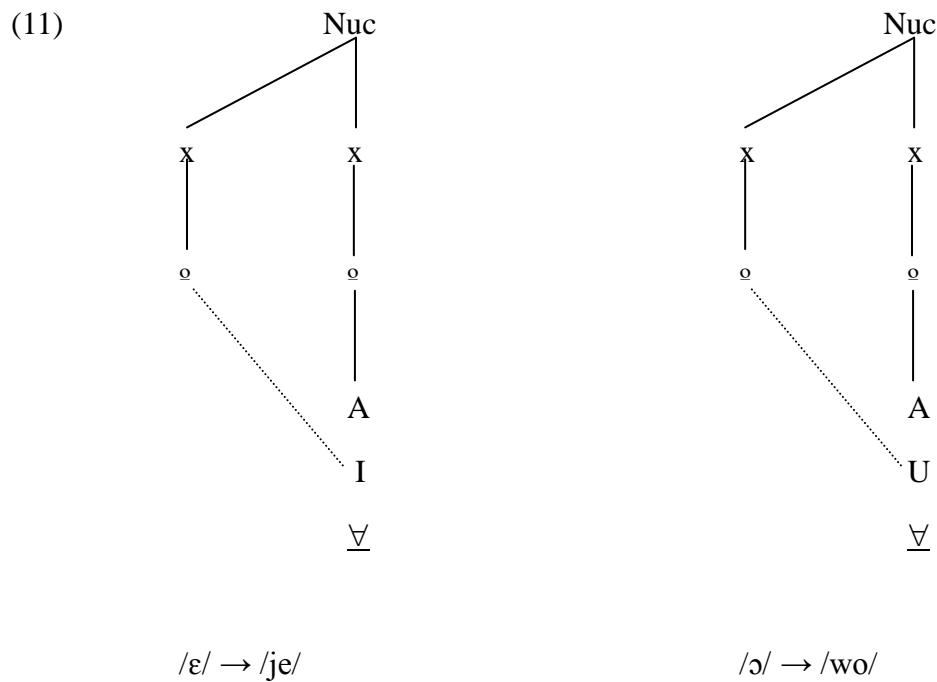
- (9) a. (V V)_{Foot}
 e/o > i/u i/u
 { $\underline{\nabla}$ A} { ∇ }
 { $\underline{\nabla}$ A+ ∇ } (∇) attracting/copying the ∇ -element
 { ∇ } (∇) resolution: loss of |A|
- b. (V V)_{Foot}
 ε/σ > e/o i/u
 { $\underline{A}\nabla$ } { ∇ }
 { $\underline{A}\nabla$ + ∇ } (∇) copying/movement of the ∇ -element
 {A $\underline{\nabla}$ } (∇) resolution: headedness reversal

We conclude that most of the changes in (6) can be understood in terms of the resolution analysis. However, two questions remain: (i) how is diphthongisation accounted for (6bii)?; (ii) how does RCVP account for dialects that undergo or crucially do *not* undergo (6biii) any of the metaphonic changes? We discuss these issues in turn.

As for diphthongisation, the typical change here is from lower-mid vowels to diphthongs, as in the examples in (10), from Calabrese (2011: 2635), “class III adjectives and nouns”:

(10)	singular	plural	
	'pɛre	'pjeri	'foot'
	'dɛnte	'djenti	'tooth'
	'fɔrte	'fworti	'strong'

Recall from (4) that the vowels /ɛ ɔ/ are represented with two elements each: {A, I} and {A, U}, respectively (plus 'redundant' ∇). The resulting onglides [j] and [w] are the result of linearisation (what Calabrese refers to as 'fission') of the elements I and U, respectively:



Linearisation involves 'parcelling out' available elements across different nuclear positions, resulting, in this case, in diphthongisation. The opposite process, in which different elements merge onto a single position, resulting in monophthongisation, has also been amply attested. An element-based approach accounts for such processes without invoking additional elements. Additionally, remember that an important

principle within the RCVP approach is that elements appear in pairs of polar opposites, which, while combinable, essentially repel each other. Given that this is the case, the appearance of the opposite elements A and \forall as in (11) raises the question whether the presence of opposite elements in the same vowel (which, by the way, undermines perceptual clarity) could be seen as creating intrasegmental ‘tension’ which could be a cause for the ‘extraposition’ of one of the elements in each case, i.e. the linearisation. We hope similar cases could be studied from this perspective which, of course, needs to be developed further. We add that diphthongisation, which resolves this tension, is likely facilitated by the tendency for stress nuclei to be(come) branching; we here assume that branching nuclei are universally right-headed.

The relation between the elements A and \forall also bears on another point. Note the absence of metaphonic processes in which only the vowel /a/ takes part (and being raised to lower-mid / ε / or / ɔ /). Consisting of only an element A, this vowel would repel addition of an \forall element (its direct opposite) most strongly. That is, if a dialect cannot raise (i.e. add \forall) in the mid vowels, it is predicted that it also cannot do this for the vowel /a/. The opposite is not true: if a variety displays raising in /a/, raising in the mid vowels is also expected, other things being equal. As far as we know, this implicational relationship is borne out.

Finally, we are in a position to answer the question *why* metaphony takes place at all and what the difference is between languages with and without metaphony (see (6biii)). Recall that the defining characteristic of metaphony is that it takes place in a domain bounded by stress, i.e. a stress foot. We have attempted to motivate the segmental changes involved in metaphony as \forall -attraction. Increasing preponderance of \forall translates into raising, which in turn means that vowels become less sonorous (i.e. ‘less vocalic’ in a sense), but at the same time, more ‘quantal’ and therefore better audible (i.e. ‘more vocalic’ in a sense). In the RCVP framework, this apparent paradox can be solved by noting the parallel structure of segmental features

(elements; recall (5)) and prosodic structure: the same opposition between A and \forall holds between the stressed ('strong') and unstressed ('weak') part of the foot. The element \forall in this equation is attracted to the strong part (the stressed vowel).

4. Conclusion

In this article we have confronted RCVP with the diverse facts of metaphony, building on the work by Calabrese (2011) and others. We have seen that the element framework in RCVP, which crucially introduces a new element \forall , can account for raising processes more easily than traditional AIU-approaches such as Dependency Phonology, since vowel height is more easily representable. Adding this element to the tripartite set follows from the 'polar logic' of RCVP, which predicts that the element A has a polar counterpart. In this article, we have suggested a specific proposal for how the element \forall is formally represented such that its presence is geometrically implied by the elements I and U. We then showed how a basic mechanism present in Dependency Phonology, viz. resolution, presents an important clue as to how metaphony could be analysed. Introduction of opposite elements does not imply that RCVP has become equivalent to a binary feature framework: elements are strictly unary, preserving one of the main advantages of models like Dependency Phonology. Rather, it applies the notion of opposition, together with the head-dependency relation, relentlessly throughout segmental (and linguistic) structure in general. In such a conception, metaphony does not involve a single rule or set of rules, but instead is governed by an overarching notion of \forall -attraction, which drives both raising and diphthongisation.

References

Anderson, John M. 2011. *The substance of language. Volume I: The domain of syntax; Volume II: Morphology, paradigms, and periphrases; volume III: Phonology-syntax analogies*. Oxford: Oxford University Press.

- Anderson, John M. 2022a. *A grammar of English: The consequences of a substantive view of linguistic structure. Vol. 1: Categories*. Berlin: De Gruyter Mouton.
- Anderson, John M. 2022b. *A grammar of English: The consequences of a substantive view of linguistic structure. Vol. 2: Structures*. Berlin: De Gruyter Mouton.
- Anderson, John M. & Colin J. Ewen. 1987. *Principles of Dependency Phonology* (Cambridge Studies in Linguistics 47). Cambridge: Cambridge University Press.
- Anderson, John M. & Charles Jones. 1974. Three theses concerning phonological representations. *Journal of Linguistics* 10, 1–26.
- Backley, Phillip. 2011. *An introduction to Element Theory*. Edinburgh: Edinburgh University Press.
- Bendjaballah, Sabrina, Ali Tifrit & Laurence Voeltzel (eds.). 2021. *Perspectives on Element Theory* (Studies in Generative Grammar 143). Berlin and New York: Mouton de Gruyter.
- Calabrese, Andrea. 2011. Metaphony in Romance. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, vol. 5, 2631–61. Malden, MA and Oxford: Wiley-Blackwell.
- Canalis, Stefano, Jes ús Jim énez, Maria-Rosa Lloret & Margaret E. L. Renwick. 2024. Vowel harmony in Romance languages. In Nancy A. Ritter & Harry van der Hulst (eds.), *The Oxford handbook of vowel harmony*, 872–92. Oxford: Oxford University Press.
- Casali, Roderic F. 2018. Markedness and dominance in the ATR harmony system of Diola-Fogny. *Journal of African Languages and Linguistics* 39.2, 201–39.
- Clements, George N. 1985. The geometry of phonological features. *Phonology* 2, 225–52.
- Clements, George N. 1990. The hierarchical representation of vowel height. Ms, Cornell University.
- d’Alessandro, Roberta & Marc van Oostendorp. 2016. Abruzzese metaphony and the

- [A] eater. In Francesc Torres-Tamarit, Kathrin Linke & Marc van Oostendorp (eds.), *Approaches to metaphony in the languages of Italy* (Phonology and Phonetics 20), 349–68. Berlin and New York: Mouton de Gruyter.
- Ewen, Colin J. & Harry van der Hulst. 1985. Single-valued features and the nonlinear analysis of vowel harmony. In Hans Bennis & Frits Beukema (eds.), *Linguistics in the Netherlands 1985*, 39–48. Dordrecht: Foris.
- Goad, Heather. 2024. Height harmony. In Nancy A. Ritter & Harry van der Hulst (eds.), *The Oxford handbook of vowel harmony*. Oxford: Oxford University Press.
- Hansson, Gunnar Ólafur & Richard Wiese. 2024. Umlaut in Germanic languages. In Nancy A. Ritter & Harry van der Hulst (eds.), *The Oxford handbook of vowel harmony*, 864–71. Oxford: Oxford University Press.
- Harris, John. 1994. Monovalency and opacity: Chicheŵa height harmony. *UCL Working Papers in Linguistics* 6, 509–47.
- Kaye, Jonathan, Jean Lowenstamm & Jean-Roger Vergnaud. 1985. The internal structure of phonological elements: A theory of charm and government. *Phonology Yearbook* 2, 305–28.
- Kaye, Jonathan, Jean Lowenstamm & Jean-Roger Vergnaud. 1990. Constituent structure and government in phonology. *Phonology* 7.2, 193–231.
- Klein, Thomas B. 2000. *Umlaut in Optimality Theory: A comparative analysis of German and Chamorro* (Linguistische Arbeiten 416). Tübingen: Niemeyer.
- Liberman, Mark & Alan Prince. 1977. On stress and linguistic rhythm. *Linguistic Inquiry* 8.2, 249–336.
- Maddieson, Ian. 1984. *Patterns of sounds*. Cambridge: Cambridge University Press.
- McCormick, Susan M. 1981. A metrical analysis of umlaut. *Cornell Working Papers in Linguistics* 2, 127–37.
- McCormick, Susan M. 1982. *Vowel harmony and umlaut: Implications for a typology of accent*. PhD dissertation, Cornell University.

- Pulleyblank, Douglas. 2011. Vowel height. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, vol. 1, 491–518. Malden, MA and Oxford: Wiley-Blackwell.
- Ritter, Nancy A. & Harry van der Hulst. 2024. Themes in vowel harmony. In Nancy A. Ritter & Harry van der Hulst (eds.), *The Oxford handbook of vowel harmony*, 3–16. Oxford: Oxford University Press.
- Sagey, Elizabeth C. 1986 [1990]. *The representation of features and relations in non-linear phonology*. PhD dissertation, Massachusetts Institute of Technology. Published 1990, New York: Garland.
- Schane, Sanford A. 1984. The fundamentals of Particle Phonology. *Phonology Yearbook* 1, 129–55.
- Scheer, Tobias & Nancy C. Kula. 2018. Government Phonology: Element Theory, conceptual issues and introduction. In S. J. Hannahs & Anna R. K. Bosch (eds.), *The Routledge handbook of phonological theory* (Routledge Handbooks in Linguistics), 226–61. London: Routledge.
- Stevens, Kenneth N. 1989. On the quantal nature of speech. *Journal of Phonetics* 17.1, 3–45.
- Torres-Tamarit, Francesc, Kathrin Linke & Marc van Oostendorp (eds.). 2016. *Approaches to metaphony in the languages of Italy* (Phonology and Phonetics 20). Berlin and New York: De Gruyter Mouton.
- van der Hulst, Harry. 1989. Atoms of segmental structure: Components, gestures and dependency. *Phonology* 6.2, 253–84.
- van der Hulst, Harry. 2015. The opponent principle in RcvP: Binariness in a unary system. In Eric Raimy & Charles Cairns (eds.), *The segment in phonetics and phonology*, 149–79. London: Wiley-Blackwell.
- van der Hulst, Harry. 2018. *Asymmetries in vowel harmony: A representational account* (Oxford Linguistics). Oxford: Oxford University Press.
- van der Hulst, Harry. 2020. *Principles of Radical CV Phonology* (Edinburgh Studies

- in *Theoretical Linguistics* 4). Edinburgh: Edinburgh University Press.
- van der Hulst, Harry. 2021. A guide to Radical CV Phonology, with special reference to tongue root and tongue body harmony. In Sabrina Bendjaballah, Ali Tifrit & Laurence Voeltzel (eds.), *Perspectives on Element Theory* (Studies in Generative Grammar 143), 111–56. Berlin and New York: Mouton de Gruyter.
- van Nice, Kathy. 1991. Hierarchical particle phonology. In John van Lit, René H. Mulder & Rint P. E. Sybesma (eds.), *Proceedings of LCJL 2*, 233–44. Leiden: Holland Institute of Generative Linguistics.
- Wetzels, W. Leo. 1995. Mid-vowel alternations in the Brazilian Portuguese verb. *Phonology* 12.2, 281–304.