The Opponent Principle in RcvP: Binarity in a Unary System

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1 Introduction

In this chapter I will review the idea of representing ‘phonological segments’ in terms of *elements*, i.e. unary building blocks which form the ultimate constituents of phonological structure. I will then defend a specific variant of this approach. Presently, unary primes are much less controversial than when the idea was first proposed as an alternative to binary features (cf. Sanders 1972, Anderson and Jones 1974) having been promoted within mainstream generative phonology by a number of prominent researchers (Goldsmith 1985, 1987; Sagey 1986; Clements 1985, 1922; Lombardi 1991; Steriade 1995; McCarthy 2004). Nonetheless, various approaches that have pursued this line of research for over three decades have fallen outside this ‘mainstream’ and remain controversial, if at all acknowledged beyond a ‘footnote reference’. However, this chapter will not be an exhaustive overview of the various varieties of unary feature theory that are on the market.[1] I will instead discuss two specific issues in Element Theory, which relate to whether a fourth element is needed in addition to the ‘core’ elements |I|, |U| and |A|. This issue arises in two different ways. In one proposal, a fourth element is added which is essentially an opponent counterpart to |A|. This is the |ɨ| (‘ATR’) element proposed in Kaye, Lowenstamm and Vergnaud (1985), and the |∀| element proposed in

[1] For more information, I refer the reader to den Dikken and van der Hulst (1988) as well as Backley (2011, 2012) and van der Hulst (in prep. b).

Radical cv Phonology (see section 3). The latter theory adopts a central principle (called The Opponent Principle) which demands that unary elements come in binary pairs. I refer to the first proposal as the 3/4 problem (I,U,A vs. I,U,A, ɨ/∀). A different way in which the issue of adding a fourth element comes in the form of proposals that either add a 'colorless' element |ə|, called the centrality element (Anderson and Ewen 1987), or that split up the element |U| in two elements (one for 'backness' |ɯ| and one for 'roundness' |ω|). I refer to both of these proposals as the (1+)2/3 problem (A+I,U vs. either A+I,U,ə or A+I, ω, ɯ).[2] In this case, the Opponent Principle of RcvP militates *against* increasing the number of elements. RcvP thus ends up with four elements, forming two opponent pairs (color or place elements: I/U[3] and aperture elements: A/∀). In addition to these four elements, RcvP also comprises two laryngeal opponent elements, |H| and |L|, which cover a range of distinctions in the domain of tone and phonation. Various versions of Government Phonology contain similarly named elements, but there are different proposals for how these accommodate tone and phonation distinctions. In this article I do not discuss these laryngeal elements; see van der Hulst (to appear a, in prep c) for their use in RcvP.

A discussion of element theory in a volume about phonological segments is justified because elements, unlike distinctive features, are autonomous phonological units that have 'independent occurrence'. In this sense, elements are *simplex segments*, whereas phonemes that contain multiple elements are *complex segments*. Given independent occurrence, elements cannot be equated with (binary) features which are

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[2] Kaye, Lowenstamm and Vergnaud (1985) also had another extra element, called the 'cold vowel', which shares some properties with the centrality element of Anderson and Ewen (1987); see den Dikken and van der Hulst (1988) for discussion. This element was later abandoned and central vowels came to be represented as colorless or in terms of empty skeletal positions.
[3] A similar 'two place' model is proposed in Rice (1995).

attributes of phonological segments. Elements are not attributes but rather primitive objects that can occur alone or in combinations. The issue of independent occurrence warrants more discussion since with reference to laryngeal elements, this would have to include the idea of independent occurrence on the tonal tier as autosegments. For reasons of space, I must refer the reader to van der Hulst (in prep. b and c).

2 A very brief history of element theory (ET)

The idea that 'speech sounds' can be viewed as being composed out of smaller units (although not necessarily with stand-alone occurrence) is very old indeed and long predates the binary feature proposals of modern 20th century phonology. Many early works describe the articulatory mechanisms that underlie speech (from Panini to much later writers in the 18th century and beyond), recognizing that individual speech sounds result from an orchestrated collaboration of various articulatory actors and their movements (see Fromkin and Ladefoged 1981). A remarkable early discussion of such units can be found in Erasmus Darwin (1803) who proposed a small set of *unary 'elements'* in terms of which, in his view, all human speech sounds could be represented.[4] Jumping ahead to the 20th century, it is noteworthy that Hockett (1955) also considers the use of *unary* building blocks. In perhaps the most important work on phonology ever written, Trubetzkoy (1939) does *not* propose a set of building blocks as such, although the notion of feature is certainly implied in his account of phonological oppositions, given his use of the term 'merkmal' for properties of sounds. One of his classifications involves privative, equipollent and gradual oppositions, which, if translated into later paradigms, would correlate with unary, binary and multivalued features. While

[4] As reported in Ohala (2004).

Trubetzkoy's three-way distinction suggests three kinds of features, it was Roman Jakobson, who, influenced by the developing field of *Information Theory*, captured all three types of oppositions in terms of *binary features*. This proposal, via Jakobson, Fant and Halle (1952) and Jakobson and Halle (1956), found its way into the theory proposed in Chomsky and Halle (1968). Element theory can be seen as an attempt to capture all oppositions in terms of privative primes.[5] Modern instances of a hybrid approach, as implied by Trubetzkoy's classification of oppositions, can be found in approaches that combine the use of binary and unary features (Goldsmith 1985 and virtually all work in *Feature Geometry*, e.g. Sagey 1986; Clements 1992; McCarthy 1988).

An isolated non-hybrid approach is Sanders (1972), who proposed a 'simplex feature hypothesis'. Then, Anderson and Jones (1974), in their 'Three theses concerning phonological representations', launched a new research program for generative phonology. The first thesis, which was would give rise to Dependency Phonology (DP), was that all phonological relations are asymmetric, reflecting a head-dependent relationship.[6] The second thesis entailed the use of *suprasegmental* constituency (syllable structure, 'feet' to capture stress, and beyond). The third thesis embodied the idea of *intrasegmental* constituency, or unary elements, organized in a set of *gestures*[7] (equivalent to the class nodes of Feature Geometry). As per the first thesis, both supra- and intrasegmental structure were said to be governed by head-dependency relations. Anderson and Ewen (1987) offer a full-blown articulation of this DP program which,

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[5] Proposals have also been made to generalize multi-valued features; see Williamson (1977) and Gnanadesikan (1997).

[6] John Anderson in much subsequent work has shown that asymmetry is a characteristic of *all* linguistic structure; see especially Anderson (2011) for an extensive (three-volume) review of his work in phonology, morphology and syntax.

[7] The term 'gesture' as equivalent to 'class node' is unfortunate. The term 'gesture' as used in Articulatory Phonology (Browman and Goldstein 1996) is rather equivalent to the unary elements (called components in DP) themselves.

meanwhile, had only attracted a small following. From the beginning, DP, like Firth's earlier prosodic approach (Firth 1948), failed to be acknowledged outside of Great Britain and, more narrowly, within developments in generative phonology in the United States, even though two of its central theses (suprasegmental structure, including feet, and intrasegmental 'geometry') later emerged as very influential independent developments in mainstream Generative Phonology (without any recognition of DP[8]). The third thesis (unary primes), as mentioned in section 1, has emerged more recently in varieties of Feature Geometry, again without integration of DP results.[9]

The core set of unary elements, proposed in DP, is formed by the 'color' or 'place' elements |I|, |U|, and the 'aperture' or 'sonority' element, |A|.[10] This tripartite division was certainly implied in Jakobson's work, who regarded color and sonority as the two primary axes for vowel systems (Jakobson 1941/1968). The 'names' (i.e. 'A', 'I' etc.) of these elements finds its origin in the fact that, as phonological primes, they were first motivated in early DP work for vowels, but, from the start, the claim was that these elements generalize over both vowels and consonants.[11] These same three elements show up as 'particles' in *Particle Phonology* (Schane 1984, 1995). A crucial difference between DP's use of the three primes and Schane's particle theory is that in DP the

[8] The use of dependency structure among syllables to represent stress was later proposed in Liberman and Prince (1977), giving rise to metrical phonology. The use of groupings of elements within segments, which was discussed in van der Hulst and Smith (1982), prefigures the class node idea of Feature Geometry proposed in Clements (1985) and Sagey (1986).

[9] As is shown in Den Dikken and van der Hulst (1988), the four unary 'major articulator' feature of Feature Geormetry ([labial], [coronal] and [pharyngeal]) as very similar to the unary elements |U, I, A), with the fourth articulator [dorsal], shared usage with 'fourth' element (whether |ə|, |v|, |ɨ| or |∀|).

[10] Donegan (1978) also recognizes palatality, labiality (color properties), and retraction (a sonority property) as the three basic vowel ingredients but still uses binary features in the formal representation of segments and processes or rules.

[11] This recaptured the original claim of Jakobson, Fant and Halle (1952) who also proposed a unified set of features for consonants and vowels. Chomsky and Halle (1968) adopted largely distinct feature sets for these two major categories. Clements (1992) then also recaptured the idea of a unified set within the Feature Geometry approach, capturing, without recognition, the unified approach of DP.

relative 'prominence' of a prime is expressed in terms of its role as either a head or a dependent in the relevant class node in the segmental structure, whereas Schane uses an *additive* model in which, for example, 'more palatality' is expressed by multiple occurrences of the particle |I|.

Meanwhile, DP's core properties had been re-invented in Government Phonology (GP; Kaye, Lowenstamm and Vergnaud 1985, 1990)[12] which, while itself hardly acknowledging DP, was (and is) equally ignored in 'mainstream' phonology. Kaye, Lowenstamm and Vergnaud (1985) present a model of intrasegmental structure which is essentially like that of DP; the notion 'government' is simply the inverse of the notion 'dependency'. Relative prominence of elements is expressed, as in DP, in terms of a notion of headedness.[13] GP did not, however, adopt the notion of grouping of elements *within* the segmental structure; see den Dikken and van der Hulst 1988 for a detailed comparison of both models. Both DP and GP then introduce additional elements. The DP inventory proposed in Anderson and Ewen (1987) ends up being quite rich and there has been very little development after this seminal publication with one exception (discussed in section 3).[14] The element inventory of GP on the other hand has been subject to numerous modifications, eventually leading to a consensus among GP proponents to use a mere six elements (Kaye 2000; see Backley 2011, 2012; van der Hulst in prep b for detailed discussions):

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[12] I first learned about this proposal from a presentation by Jean-Roger Vergnaud GLOW workshop in Paris in 1982.

[13] For intrasegmental structure (Kaye, Lowenstamm and Vergnaud 1985) use the terms 'kernel' and 'operator' instead of 'head' and 'dependent'. Also, an early idea that elements are feature bundles which account for their phonetic interpretation as stand-alone units and in combination with other elements was later abandoned.

[14] Anderson (2011, volume III provides Anderson's update of Dependency Phonology, including a discussion of RcvP.

(1) a. |A|, |I|, |U|

b. |ʔ|, |H|, |L|

Backley (2011) presents a particular version of this 6-element theory with many examples and motivations. He demonstrates how the elements in (1a) can be used to characterize 'plain' vowels as well as place-properties of consonants. The elements in (1b) come into play when vowels have nasality, laryngeal/phonation properties and tonal properties and to characterize laryngeal/phonation and manner properties of consonants.

The richness of phonetic coverage of each element in (1) is due to the fact that elements can be heads or dependents: a structural difference with implications for the phonetic interpretation of the elements. As pointed out in detail in van der Hulst (2010), approaches that use dependency (or government) capture the set of phonetic differences that can play a distinctive role in languages in terms of a set of primes that is significantly smaller than the set of features in binary feature theories. This is, firstly, because each element has two interpretations, depending on its role as either head or dependent. A second cause results from the fact that elements generalize over vowels and consonants. As a consequence, element theory formally unites phonetic distinctions for which traditional theories must use independent pairs of features, such as [±son] and [±voice], [±round] and [±labial], [±high] and [±ATR], [±high tone] and [± stiff vocal cords] etc. This eliminates the need for arbitrary rules that state implications such as [+son] → [+voice]. In a dependency-based element theory, there is an affinity between voicing and sonority because both are interpretations of the same element (see Anderson and Ewen 1987; van der Hulst 1995, in prep. c for specifics). Additionally, using unary primes renders superfluous the attempts of 'Radical underspecification' theorists (Archangeli 1984, Kiparsky 1982) to capture the universal asymmetry between the active and inactive poles of phonetic dimensions. For example, for the dimension of lip posture phonology only acknowledged rounding as active. This is captured in a unary approach by adopting the unary element |U|, while binary theories must include an ad hoc statement that declares [-round] to be a 'default value'.[15]

Whereas the use of the three elements in (1a) is standard in GP and DP, to add only those in (1b) is characteristic of the GP approach; DP has equivalents to these elements (with somewhat different uses) but adds several other elements to the inventory. In (2), following Backley (2011), I provide the interpretations of these three elements, although for present purposes I have omitted some details:[16]

(2)		Head	Dependent
	|ʔ|	glottal stricture	stricture in the oral cavity
	|H|	voicelessness, aspiration	frication
		vowels: high tone	
	|L|	voicing	nasality
		vowels: low tone	

With these six elements, Backley describes numerous contrastive segment types and processes, claiming that the system is sufficient for representing all phonetic distinctions

[15] Kaye (1988) demonstrates that the unary approach should always be explored first, since, unlike binary approaches, it can actually be falsified.
[16] I describe Backley's system in more detail in van der Hulst (in prep. b) where I compare it to my own system, which I discuss in section 3.

that are needed to capture what is traditionally called phonemic contrast in the world’s languages.[17] Each possible phonemic segment is described in terms of a (possibly null) set of elements. One noteworthy aspect of his proposal (shared with other version of GP) is that element expressions may be *headless* which means that no element is the head of the expression. For example, an expression consisting of the elements |A| and |I| can take three forms: $|\underline{A}\ I|$, $|A\ \underline{I}|$, |A I| (where underlining indicates headedness). The use of headless expressions is almost equivalent to DP’s use of expressions in which there is so-called *mutual dependency*: |A⇐I|, |A⇒I|, |A⇔I| (in this notation, the dependent is at the point of the arrow). The only difference between these two mechanisms is that the notion of mutual dependency can not apply to a single element, whereas headlessness does. In that sense, headlessness is a more powerful device than mutual dependency. In my own approach, described in section 3, both headless expressions and mutual dependency are rejected.

Summarizing, hallmarks of both DP and GP have been the use of (a) unary primes and (b) an asymmetric relation of dependency/government. Additionally, all primes were always meant to generalize over properties of consonants and vowels. Both aspects allow an array of related phonetic interpretations for each prime. A difference between DP and GP is that DP proposes an intrasegmental grouping of the elements in terms of gestures a.k.a. class nodes.

3 Radical CV Phonology

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[17] Implicit here is the claim that phonological theory does not need to supply vocabulary to express detailed phonetic properties that play no distinctive role in the languages of the world.

3.1 Basic principles

In my own work on phonological primes, I have developed an approach which takes its initial inspiration from DP (van der Hulst 1988ab, 1993, 1994ab, 1995, 1996, 2000ab, 2005, 2012a, in prep c). Like DP, I use intrasegmental grouping of elements. However, I deviate from the specific grouping proposal in Anderson and Ewen (1987). In van der Hulst (2005), following Clements (1985), I adopt the view that each segment maximally has a tripartite structure consisting of three **classes**: the Laryngeal, Manner, and Place class, the latter two being subclasses of the superclass, *Supra*laryngeal. In van der Hulst (to appear a and in prep c), I elaborate this tripartite structure as in figure 1. Within each class, we find two subclasses that I call **dimensions** (adopting this term from Avery and Idsardi 2001[18]), and each dimension contains two elements (which, referring to their articulatory correlates, we could call **gestures**):[19]

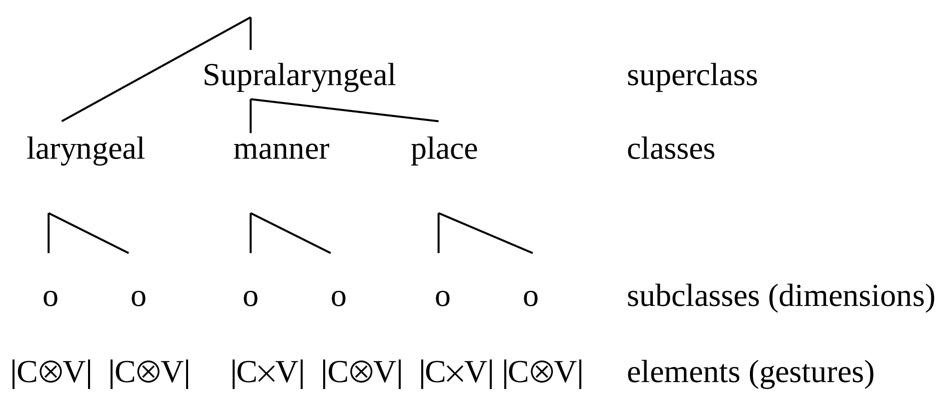

Figure 1 The ‘geometry’ of phonemes in Radical cv Phonology

[18] Avery and Idsardi (2001) propose a theory of features which also introduces the notion of antagonistic pairs, referring to Sherrington (1947) who claimed that muscles are organized in antagonistic pairs. In their theory (unlike in RcvP) members of a pair cannot both be active in a single segment nor can both be distinctive in a single language. For a comparison of this theory, called Dimension Theory, to RcvP, I refer to van der Hulst (in prep.).

[19] The RcvP geometry has an ‘X-bar’-like organization. In van der Hulst (in prep. c), I speculate that this particular organization, which appears to be shared between (pre-merge versions of) syntax and phonology in which heads can have two type of dependents (‘complements’ and ‘specifiers’) is perhaps not accidental.

Note that I distinguish between head dimensions (dominated by a vertical line) and dependent dimensions. The internal combinatory properties of head and dependent dimensions are not the same. Dependent dimensions do not allow combinations of elements at all (indicated by '|C⊗V|'); I return to RcvP-combinatorics below in more detail. The various labels for the classes are for convenience only, having no formal status in RcvP. Each unit in the structure can be defined in purely formal terms. The elements |C| and |V| are also strictly formal units. As mentioned, I assume that the limitation of the set of elements to two units per dimension can be seen as resulting from a basic principle of categorization, called The Opponent Principle.[20] Assuming that each subclass in Figure 1 correlates with a 'phonetic dimension', |C| and |V| correlate with maximally opposed phonetic categories within such a dimension. This, however, does not entail that phonemic[21] contrast that refers to a given dimension must be expressed in terms of |C| *versus* |V|. A strictly minimal way of representing contrast will make use of the zero option. Thus, contrast for a given dimension can be expressed in terms of |C| versus zero or |V| versus zero; of course one expects that a choice between these two options comes with empirical consequences. For example, in the tonal dimension, either |V| (low tone) or |C| (high tone) may behave as the 'marked' option with the other option

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[20] A question that could be asked is why the Opponent Principle (or an extended version of it) does not enforce four phonetic spaces rather than three. I discuss this matter in van der Hulst (in prep. c) where I consider alternative segmental structures. It is noteworthy that Anderson and Ewen (1987) and other proponents of DP did propose four gestures; see den Dikken and van der Hulst (1988) for a review. In Figure 1, I use the terms 'place' for 'color elements' and 'manner' for aperture or sonority elements. These labels, which I use here interchangeably, have no theoretical status since each class node has a unique *structural* definition.

[21] Since I use the term 'phonological' as comprising both the study of contrastive or distinctive units at the cognitive level and of phonetic categories (as well as the relation between them), I will refer to the level of cognitive ('symbolic' or 'formal') representations as 'phonemic'.

being a ‘default’.[22] While the elements are strictly substance-free cognitive units, they do correlate with phonetic events (or phonetic categories). In fact, we can think of elements as (subconscious) cognitive concepts that correlate with phonetic events/categories. The relation between formal units such as elements and phonetic events is referred to by terms like ‘phonetic interpretation’ or ‘phonetic implementation’. Naturally, since the elements |C| and |V| occur in all six dimensions, these elements correlate with a wide variety of phonetic interpretations. In (3), I indicate some of these interpretations for the three head dimensions, mostly in very rough articulatory terms:

(3)	|V|-elements	|C|-elements
	|Place: V| = labiality	|Place: C| = palatality
	|Manner: V| = continuant, lateral	|Manner: C| = non-continuant, nasal
	|Lar: V| = voicing/spread, L tone	|Lar: C| = fortis/glottal, H tone

The exact phonetic interpretation of the elements is dependent not only on (a) which dimension they occur in, but also (b) on their status as head or dependent within the dimension (see below) and (c) whether they occur in a syllabic C-position (‘onset’) or a syllabic V-position (‘rhyme’)[23].

In each dimension, then, the two elements form an **antagonistic pair** which is enforced by The Opponent Principle. The members of such a pair correlate with opposite extremes within a certain ‘phonetic dimension’. These two members must have

[22] This is reminiscent of Radical Underspecification Theory and, indeed, there are a few cases, especially in the laryngeal class, in which elements theory uses two opponent elements that correspond to the use of the plus and minus of a binary feature such as [±high tone] or [±voice]; see van der Hulst, to appear a.

[23] I must refer to van der Hulst (in prep. c) for an RcvP account of syllable structure and of the segment-syllable connection (see van der Hulst 1996) for an early account.

independent status because, unlike the values of binary features, they can sometimes be combined (and then enter in head-dependency relations). For ease of use, in many cases, I will adopt the mnemonic element *names* drawn from other element theories. Specifically, I will use element names of Dependency and Government phonology, such as |A, U, L,∀, I, H|. I do this to avoid cumbersome (although more accurate) expressions such as '|Place: V|' (= '|U|') (where the term 'place' is a shorthand for a structural position in the segmental structure):

(4)

|V|-elements	|C|-elements
|Place: V| = |U|	|Place: C| = |I|
|Manner: V| = |A|	|Place: C| = |∀|
|Lar: V| = |L|	|Lar C| = |H|

In comparing RcvP to other feature theories, I will also sometimes use labels such as [round], [ATR] etc. Where it is relevant to remind the reader of the C- or V-nature of an element, I will write 'V/U' or 'V/[round].

As mentioned, in some dimensions, elements can enter into combinations where each combination is maximally binary. This is indicated in Figure 1 by '|C×V|'. Specifically, this is needed in the head dimensions of Manner and Place. However, this level of complexity is not required in the Laryngeal head dimension (see van der Hulst, to appear a). In addition, none of the *dependent* dimensions require combinations of |C| and |V|; this is indicated by '|C⊗V|'. The fact that combinations are allowed in head dimensions but not in dependent dimensions is a clear instance of a head-dependent asymmetry. While dependents can never be more complex than heads, heads typically allow *greater* complexity than dependents (Dresher and van der Hulst 1998; Harris 1990). Thus, the Manner and Place class allow the following 12 structures:

(5)

	Head dimension	Head dimension+dependent dimension	
	C	C+C	C+V
	CV	CV+C	CV+V
	VC	VC+C	VC+V
	V	V+C	V+V

Note that we admit that the absence of a dependent dimension specification can be contrastive with the presence of a dependent specification (which can be either C or V). The option of having structures that *lack* a head dimension element, which would create two additional possibilities (∅+C, ∅+V), is simply not available as part of the RcvP syntax (because dependents cannot be more complex than heads). As a result, elements in dependent nodes can only be present if there is an element in corresponding head nodes.[24] As indicated in (5), the four-way distinction in the first column regards the combinations of elements within the head dimension. The second and third columns represent a combination of each of these four options and one element in the dependent dimension.

[24] The idea that *within a class*, the head dimension elements must be activated before we get to the dependent elements is analogous to the fact that in vowel systems, the manner class (more specifically its head dimension which accounts for aperture) must be activated before we get to the place dimension elements. It has been shown in typological studies of vowel systems that a minimal system would use only manner (i.e. aperture), leading to a so-called *vertical vowel system* found in some Northwest Caucasian languages (Kabardian, Adyghe); see Lass (1984). There are no vowel systems that only use place distinctions. This further motivates the head-status of the manner class (which expresses aperture for vowels and stricture for consonants).

The full array of structural possibilities in (5) is only exploited in the manner class (for both consonant and vowels) and in the place class *for consonants*; for vowels, apparently, we do not need the dependent place dimension; see (8 below).[25] The laryngeal class is the most limited class in that element combinations are excluded in both the head and the dependent dimension. As I show in van der Hulst (to appear a) the laryngeal class only needs the following subset of options:[26]

(6)	C	C+C	C+V
	~~CV~~	~~CV+ CV~~	~~CV + V~~
	~~VC~~	~~VC+C~~	~~VC + V~~
	V	V+C	V+V

In this chapter, I cannot justify the required set of RcvP-structures, and I must refer the reader to van der Hulst (in prep.c) for a full exposition.

The possibility of combining elements within a head dimension can be seen as one way of capturing the fact that some phonetic dimensions can give rise to more than two contrastive options, forming a 4-way scale. The combination of elements can be seen as an instance of **recursion** as an element can be said to contain an instance of itself (or of the antagonistic element): [27]

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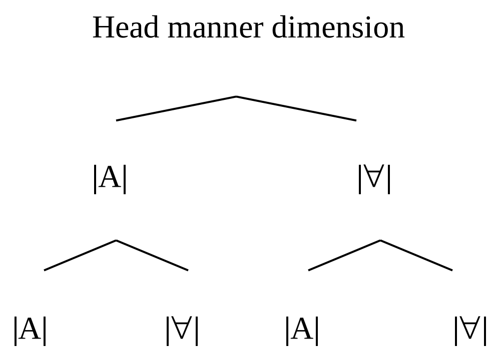
[25] This correlates with the fact that universally there are many more consonant distinctions than vowel distinctions, which correlates with the greater role that consonants play in lexical phonemic contrast. This asymmetry is paradoxical since vowels are heads of syllables.

[26] Both laryngeal and place are dependent classes, but the place class is included in the super class, supralaryngeal. Thus, the fact that the place class allows more structures than the laryngeal class is, once more, an example of an expected head-dependent asymmetry.

[27] Salting (2005) proposes a model, 'the nested subregister model', which also represents phonological categories in terms of a double split. He applies this to vowel height and place categories and discusses the parallels of his model to RcvP.

(7) a.



b.	$\underline{A}$	$\underline{A}$ ∀	$\underline{\forall}$ A	$\underline{\forall}$	
ci.	high	high-mid	low-mid	low	(vowels)
cii.	stop	affricate	fricative (mellow)	fricative (strident)	(obstruents)

This being so, I will follow the practice in Dependency and Government phonology in which the left- and right-hand options in structure (5a) are simply written as |$\underline{A}$| and |$\underline{\forall}$| rather than as |$\underline{A}$,A| and | $\underline{\forall}$,∀|[28]. The combination of elements within a dimension captures the discrete scale-like character of contrastive option within a phonetic dimension and results in a fixed limit on the number of categories (up to four). In (7c), I indicate, in rough terms, the interpretation of the four manner categories for vowels and obstruents respectively. The distinction between these major categories of phonemes is made in terms of syllable structure positions (see van der Hulst 1996, in prep. c). One

[28] See van der Hulst (in prep. c) for further discussion of this point.

might ask why this recursive split of phonemic categories halts after one loop. I surmise that this is due to the fact that a further corresponding subdivision of phonetic spaces would create problems for the auditory detection of the distinctions between the resulting categories.

A reduction of the set of elements to just two elements, |C| and |V|, is possible because each dimension contains exactly two elements. This allows us to say that the element labels |A|, |U|, |L| etc., because they occur under structurally different nodes, are paradigmatically speaking in complementary distribution, and thus can be reduced to one and the same element, viz. |V|. The same holds for |∀|, |I|, and |H|, which can be reduced to |C|. Complementary distribution is a familiar criterion that is used to reduce allophones to phonemes (where allophones are in complementary distribution in a syntagmatic sense). However, the same criterion can be applied to elements, provided that the elements that we reduce to either |C| or |V| have something in common. Commonality, known as *phonetic similarity*, again is a criterion for grouping allophones under one phoneme. In the case of elements, the commonality is that |A|, |U| and |L| represent vowel- or rhyme-oriented choices, and so reduce to |V|, while |∀|, |I|, and |H| represent consonant- or onset-oriented choices, and reduce to |C| (again the choice of labels is merely for convenience). It is important to note that |C| and |V|, despite their respective onset and rhyme bias, can occur in *both* onset and rhyme positions. For example, in the manner head dimension, |A| is a vowel-oriented element because in the syllable nucleus (i.e., the head of the rhyme), this element is the preferred (unmarked, optimal) choice, denoting maximal openness and sonority. On the other hand, |∀| is a consonant-oriented element, because it is preferred in the syllable onset, where it denotes closure and hence minimal sonority.

Backley (2011) observes that his six GP elements form 'antagonistic pairs' -- much as in RcvP (a model that he refers to in other places in his book) although his model provides no formal basis for any such groupings by lacking the dimension class nodes. In RcvP, on the other hand, antagonistic (or opponent) grouping forms a pivotal and formal part of the theory since it expresses the idea that phonology is based on contrast.

In summary, given the anatomy of the human speech apparatus, RcvP acknowledges classes within which contrast can be expressed. Within these classes, the Opponent Principle enforces an equipollent contrast between two elements that can be multiplied within head dimensions by two using dependency relations, leading to a maximal four-way scale. The possibility of adding on a dependent dimension allows for a limited set of further distinctions.

In a sense, RcvP can be understood as a meta-theory of phonological features/elements. The Opponent Principle and the 'X-bar' architecture of the phoneme give predict a limited set of features/elements that, as I show in detail in van der Hulst (in prep c), that conforms to a number of empirically well-motivated partial feature theories in the domains of tone, phonation, place and manner.

3.2 Vowels

Ignoring the laryngeal elements (for phonation, nasality and tonal properties), the place and manner elements of RcvP characterize vowels into 25 categories, which roughly correspond to following IPA symbols :[29]

[29] Where different IPA-symbols are placed within a single cell, the claim is that the corresponding phonetic differences do not occur contrastively in any language. Needless to say, the proper placement of vowels in specific languages in cells cannot depend on what kind of IPA symbols we use for them, but rather on the way in which these vowels function in the phonological system (systems of contrasts, phonotactic

(8)

	<u>I</u>	<u>I</u>U	Placeless	<u>U</u>I	<u>U</u>
<u>∀</u> + ∀	i	y	ɨ ~ ɯ	ʉ	U
<u>∀</u>	ɪ	ʏ	ᵻ	ᵿ	ʊ
<u>∀</u>A	e	ø	ɘ ~ ɤ	ɵ	o
<u>A</u>∀	ɛ	œ	ɜ ~ ɐ ~ ʌ	IPA	ɔ
<u>A</u>	æ	ɶ	a	ɑ	ɒ

IPA symbol: open mid rounded # 395 in vowel chart
See http://www.langsci.ucl.ac.uk/ipa/IPA_Number_chart_(C)2005.pdf

We arrive at this table as follows. As mentioned, the full array of place options is only used for consonants; for vowels we only need the structure in (9a). For manner, vowels (and consonants) use the full array of structure in (5), here repeated in (9b):

(9)

a. Vowel Place options

C	~~C+C~~	~~C+V~~
CV	~~CV+C~~	~~CV+V~~
VC	~~VC+C~~	~~VC+V~~
V	~~V+C~~	~~V+V~~

b. Vowel Manner options

(+C = nasal cavity; +V = pharyngeal cavity, i.e. advanced)

CHANGE TO (+C = pharyngeal cavity, i.e. advanced; +V = nasal cavity)

distribution, and rules). The chart in (8) deviates slightly from that in van der Hulst (2012a). I discuss alternatives in van der Hulst (to appear c).

C	C+C	C+V
CV	CV+C	CV+V
VC	VC+C	VC+V
V	V+C	V+V

By combining the manner and place options, we allow 16 structures. I have added one row for high advanced vowels that are distinguished from high non-advanced vowels by having a dependent dimension specification |∀|.[30]

We must bear in mind that in RcvP, headedness is stated *per dimension*. Also, I remind the reader that, unlike in GP, dimension expressions cannot be head*less*; nor does RcvP acknowledge the DP option of mutual dependency. The rejection of headless or mutually dependent expressions constitutes a major difference between RcvP and DP or GP. All three approaches, however, allow the null-option (but only in the absence of a dependent).[31] This last point raises an important issue. By allowing a 5-way distinction along the place axis (including the placeless option), we de facto admit that the absence of a dependent place specification can be contrastive with the presence of a dependent place specification. We have observed in section 3.1 that this is also true at the level of dimensions (see 5). In other words, to characterize central vowels as placeless is unproblematic.

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[30] The expression of ATR in terms of a dependent dimension element |∀| allows a second structure for the three lower rows in (8). I discuss the use of these structures in van der Hulst (in prep c) where usually I argue that such additional structures, while formally available, are excluded by a constraint that bars the dependent |∀| for segments that contain |A|.

[31] This is why a vowel can only be mannerless when it also is placeless. This delivers the empty vowel, often realized as a 'schwa'.

In closing this section, I return to the point that elements have a variety of phonetic interpretations. The following table makes this explicit by focusing on the fact that the articulatory properties of the elements, can be unified in acoustic terms, i.e. in terms of their effect on formant properties:

(10) Dual interpretations of elements for vowel structures

	Head	**Dependent**	**Both**
H (C_{lar})	high register	high tone	raising F_0
L (V_{lar})	low register	low tone	lowering F_0
∀ (C_{man})	ATR-Closed	Open	Lowering of F_1
A (V_{man})	RTR-Open	Closed	Raising of F_1
I (C_{place})	Front-Spread	Spread	Raising of F_2
U (V_{place})	Back-Round	Round	Lowering of F_2

The laryngeal elements, |H| and |L|, determine the fundamental frequency (F_0, correlating with pitch level) of vowels, allowing for tonal distinctions.[32] The elements |∀| and |A| determine the relative size of the pharyngeal cavity which has consequences for the oral cavity. |∀|, by advancing the tongue root, increases the pharyngeal cavity and consequently decreases the oral cavity. This lowers F_1. This effect can be *phonetically enhanced* by closed jaw position. The element |A|, by retracting the tongue root, does the opposite and thus raises F_1. Open jaw position enhances the effect of |A|. The color elements |I| and |U| bear on the length of the oral cavity in front of the oral stricture,

[32] For the laryngeal elements, RcvP acknowledges the distinction between register and tone proper proposed in Yip (1980).

which is longer for back vowels that have lower F_2. Lip rounding increases the length of this oral 'tube', which is why lip rounding is said to enhance backness by lowering F_2 further. Given this view of the duality of elements, we can say that in dependent position, elements activate the *enhancing* mechanisms only.[33]

In this section I have discussed the basic architecture of RcvP with specific reference to place and manner elements of vowels. We have seen that the inventory of elements reflects a cognitive principle of categorization (the Opponent Principle), which promotes a binary polar contrast within each phonetic dimension. This principle captures the core foundation of phonology which is to achieve the optimal expression of *contrast*. Given that there are three classes of elements (laryngeal, manner, and place), each capturing two dimensions that allow for only two elements, all contrast can be expressed in terms of two unary elements. Interestingly, the search for phonological primes ends up with **one binary pair** of unary elements rather than with an arbitrary list of binary or, for that matter, unary features.

4 The 3/4 problem

When comparing the two models (current GP and RcvP), one might conclude that there is very little difference (here, for the sake of comparison, using the 'convenient' element labels that have no official status in RcvP):

(11)

	RCVP	**GP**

[33] For the notion of enhancement see Stevens and Keyser (1989, 2010) and Stevens, Keyser and Kawasaki (1986). In van der Hulst (to appear a) I argue that *phonological* enhancement results from adding an element in a dependent dimension that is identical to the head element.

Manner	A ∀	A ʔ
Place	U I	U I
Laryngeal	L H	L H

However, there are some substantial differences with regard to the interpretations of the six elements in their various head and dependent roles. Referring to van der Hulst (in prep.c) for an extensive comparison, I will briefly focus on the elements |∀| and |ʔ|.

In RcvP, the element |∀|, like |ʔ| in GP, represents non-continuancy in consonants, this same element represents ATR (and vowel height) in vowels only in RcvP (see 8). The element |ʔ| is not so used in GP. It *can* be used for vowels, but then it denotes a phonatory property like laryngealization or glottalisation. So, how does GP represent ATR?

Interestingly, Kaye, Lowenstamm and Vergnaud (1985) proposed a fourth element (|ɨ|), which, like my |∀|, was meant to express 'ATR', but this element (which had the arbitrary restriction that it could only be used as a head) was later abandoned, being replaced precisely by the mechanism that RcvP has excluded, namely a contrast between being headed (implying [ATR]) and being headless; I call this *contrastive use of headedness*.[34] For example, in current GP (including Backley's 2011 version), the difference between /i/ and /ɪ/ is that the former vowel has a headed element, e.g. |I̲|, while the latter is non-headed |I|. One might conclude that not much is at stake here (a trade-off between an extra element or allowing headless expressions). However, it should be clear that the extra element, |∀|, is 'predicted' by the 'contrastive logic' (i.e. the Opponent Principle) of RcvP: each dimension contains two antagonistic elements. Thus, there *must* be a counterpart to |A| in the manner dimensions. Given that this is so, a possibility

[34] See also Ritter (1997) for a proposal to extend the use of contrastive headedness to consonantal expressions.

presents itself to avoid headless expressions, which are at odds with the foundational assumption of a 'pure' dependency approach that *only combinations* of units are characterized by an asymmetric relationship of dependency. From this 'first principle,' it follows that neither headless expression (nor expressions showing 'mutual dependency') should be considered.

Although all versions of element theory contain elements in addition to the core set |IUA|, it could be argued that RcvP (as the *original* GP theory) puts forward a fundamental change of the element approach. Clearly, additional elements are needed for distinctive properties involving nasality, tone, phonation, and perhaps for various types of consonantal stricture. However, the addition of |∀|, as a counterpart to |A|, just for basic vowels, presents a complication of the core set, which derived much of its appeal from giving a straightforward explanation for the 'triangular nature' of the majority of vowel systems that, generally, show less vowel contrast in the lower regions of the vowel space than in the upper region. This being said, even DP did not confine itself to the basic IUA-set when more complex vowel systems were considered. In fact, Anderson and Ewen (1987) add both an ATR-element and a 'centrality' element to their system, whereas Kaye, Lowenstamm and Vergnaud (1985), as shown, adopted their |ɨ| element, as well as a special element called the 'cold vowel' which shared some characteristics with DP's centrality element.

In the next section, I will suggest that there are, in fact, reasons for supporting a triangular element system, but that there are also reasons for supporting a quadrangular system. The 'pressure' for '3' comes, as I will show, from properties of the human articulatory apparatus, which, when considering the available muscular activities of the tongue, suggest three constriction loci. I will base this claim on the work by the phoneticians Sidney Wood and Ken Stevens. The pressure for ‘4’, on the other hand, comes from a cognitive force that I have called The Opponent Principle, which captures the idea that the phonetic resources for speech are categorized in a system of opponent elements that correlate with maximally dispersed acoustic events. My claim is that this cognitive force, which provides a raison d’être for phonology as being distinct from phonetics, is responsible for ‘creating’ the fourth element (namely |∀|) which functions as the counterpart to |A|. As I will argue, the element |∀|, in need of an articulatory basis, either draws on the same articulatory resources that also underlie the element |I| or correlates with the overall tenseness of the articulation.

5 Wood’s system of articulatory features

The phonetician Sidney Wood (e.g., Wood 1979, 1982, 1990) recognizes four constriction locations for vowels, three of which are taken to be basic and thus deserving of their own distinctive feature. I summarize Wood’s views on constrictions locations in the following table, IPA-symbols, features, and articulatory and/or acoustic correlates:

(12)

Constriction locations	**Muscle activity**	**Vowels**	**Features**	**Phonetic effects**
Palatal	genioglossal activity	[i-ɛ, y-œ]	[palatal]	-widens the lower pharynx -raises the tongue body
Palato-velar	styloglossal	[u, ɯ, ʊ]	[velar]	-draws tongue toward nasopharynx

	genioglossus palatoglossal		[palatal]	-widens lower pharynx (F1 below 350Hz) - locates palate-velar constriction precisely - F2 beyond 1250 toward 1500
Pharyngo-velar (i.e. Uvular)	styloglossal superior pharyngeal constrictors	[o], [ɔ],[ɤ]	[velar] [pharyngeal]	 - F2 about 800 Hz for rounded [o]-like vowels
Pharyngeal	hyoglossal *and/or* superior and middle pharyngeal constrictors activity	[ɑ], [a], [æ]	[pharyngeal]	-narrow lower pharynx -raises F1 beyond 600 Hz

Wood also proposes two additional features:[35]

(13) a. [open] refers to lower mandible position

b. [tense] refers to:

(1) increased activity in the lingual musculature for the bunched tongue position ([i,e,u,o] vs. [ɪ,ɛ,ʊ,ɔ]),

(ii) more laryngeal depression, and;

(iii) increased labial activity for rounded vowels [u,o] vs. [ʊ,ɔ]

The four constriction loci correspond with the following vowels (among others; see 12, third column):

[35] It would seem obvious that Wood also needs to recognize the feature [round], although he does not mention this feature in the sources that I consulted.

(14) [i] [u]

- [o]

[a]

The ‘missing’ [e] type vowel would result from combining the ‘[i] constriction’ with an open jaw position.

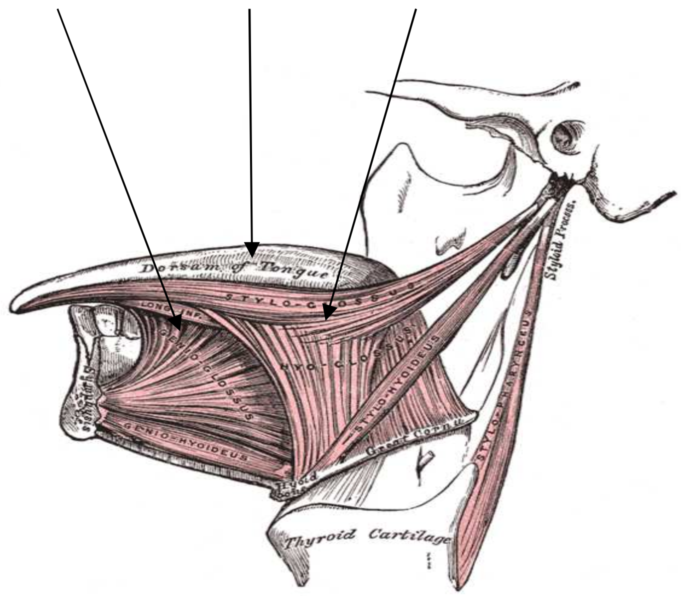
As indicated in the table in (12), Wood proposes *three* phonological features which are very similar to the AIU elements. (As he points out, this three-way distinction is already known from old Indian linguistic traditions.) Each feature correlates with a separate muscle group:

(15)	Palatal :	genioglossus	(~ |I|)
	Velar:	styloglossus	(~ |U|)
	Pharyngeal:	hyoglossus	(~ |A|)

The following drawing[36] shows the three major muscle bundles:

[36] Source: http://en.wikipedia.org/wiki/Genioglossus; From Gray’s Anatomy (40th edition, page 1129).

(16) genioglossus styloglossus hyoglossus



I conclude that Wood's theory supports the triangular IUA system from a muscular-articulatory point of view.

One point of difference, however, is that in Wood's system, high non-front vowels are specified as [+palatal]. This is where the correspondence between his feature [palatal] and the element |I| breaks down:

(17)

	/i/	/u/	/e/	/o/	/a/
Pharyngeal	-	-	-	+	+
Palatal	+	+	-	-	-
Velar	-	+	-	+	-

(18)

	/i/	/u/	/e/	/o/	/a/

A	-	-	-	+	+
I	+	-	-	-	-
U	-	+	-	+	-

However, we can adopt the view point that the element |U| does indeed draw on genioglossal activity. This in itself explains the often observed affinity between |I| and |U| (cf. Ewen and van der Hulst 1988). Thus, rather than linking elements to muscular activity in a one-to-one fashion, I suggest that both |I| and |U| draw on the genioglossal activity; the former more so than the latter. In a sense, this activity characterizes the place node itself.[37] That elements can draw on more than one muscular activity is shown by the fact that Wood makes reference to the genioglossus *and* palatoglossal activity (which elevates the posterior part of the tongue) for his feature [palatal] when it characterizes high non-front vowels ([u,ʊ,ɯ]). Also, as shown in (12), the feature [pharungeal] (i.e. element |A|) also draws on different muscular activities (i.e. hyoglossal activity and pharyngeal constrictors). It would seem though that each feature/element corresponds to a primary muscle group but can also draw on a secondary group.[38] [39]

An obvious criticism of triangular systems has always been that there is no feature/element that captures the natural class of high vowels.[40] Nor does this set express the property of ATR (or ‘tense’), which is why DP and GP added an ATR element (which GP later, as we have discussed, replaced by contrastive headedness). The

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[37] See Ewen and van der Hulst (1988) who propose the ‘higher order’ element |Y| dominates both |I| and |U| to capture this point.

[38] One might say that here we seem to be dealing with a head-dependency and an enhancing phenomenon at the muscular level, i.e. below the level of elements.

[39] See Halle (1983) for another account of the complex relation between features and articulatory mechanisms.

[40] This is why Ewen and van der Hulst (1988) proposed the extra element |Y|, which dominated |I| and |U|.

muscular bundle that could be held responsible for advancing the tongue, and thus raising it, is the genioglossus, which is already held responsible for creating a palatal constriction.[41] A crucial point is that RcvP, given its design, *enforces* a fourth element which can capture both height and ATR. Beyond that, analyses of height and ATR vowel harmony systems support the need for this element (see van der Hulst 2012abc, to appear and, especially, in prep a). The important question is now how one can motivate this fourth element in terms of its articulatory mechanism and corresponding acoustic effects? We must first bear in mind that the fourth element can occur in both the head manner component and in the dependent manner component (see Figure 1). When this element occurs in the head aperture component its interpretation can best be described in terms of vowel height or aperture.

When occurring in the dependent manner component, I suggest that there are, in fact, *two* ways in which the fourth element can be phonetically grounded and that these two ways might reflect a pattern of variation among languages that appears to be real. Ewen and van der Hulst (2001) point out that languages seem to be complementary in using either a tense/lax (or peripheral/central) distinction or a [+ATR]/[-ATR] distinction in their vowel system. Here I propose that these different phonetic mechanisms are complementary (in the sense that no language uses both) *because* they are manifestations of the same element, namely |∀| and, moreover, that the ambiguity in the phonetics of this element is caused by the fact that it is not grounded in its own unique primary muscle group and must therefore draw either on a muscle group that is active as the primary

[41] That there is a close affinity between advanced tongue root and palatality is shown, for example, in Turkana vowel harmony where the palatal glide /j/ induces [+ATR] on neighboring vowels; see Dimmendaal (1983) and van der Hulst and Smith (1986).

group for another elements or on the additional phonetic dimension of overall muscle tension.

To begin with the latter option, the most obvious articulatory correlate of the fourth element |∀|, from the view point of Wood's theory, would be the feature [Tense]. In that case, |∀| would correlate with increased overall muscular activity (relative to specified constriction) and some additional properties (see 13b). So, even though the phonetic reality of the feature [tense] has been called into question (Fischer-Jørgensen and Jørgensen 1969), I accept Wood's finding that there is, in fact, an observable set of articulatory correlates for this feature/element. The former option for the fourth element |∀| leads to what has been called [Advanced Tongue Root] (which has often been proposed as a substitute for [tense] *as a phonological prime*). In this case |∀| draws on the genioglossus which is also the primary muscle for the element |I|. It is noteworthy that the element |I| (and Wood's feature [palatal]) correlates with a tongue maneuver that causes both a palatal constriction *and* an advancement of the tongue root. My proposal here is that the *phonetic* properties [ATR] and [tense] are both possible interpretations of the element |∀|.

In conclusion, my suggestion is that the fourth element (as it occurs in the dependent aperture component) either draws on the same phonetic substance that forms the basis for the element |I| or captures the phonetic property of tense which acts as an 'operator' on all constrictions:[42]

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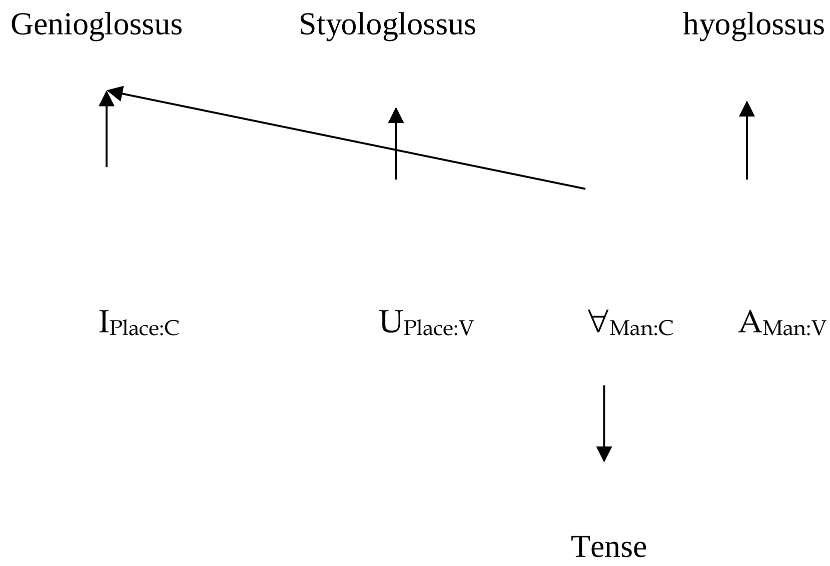
[42] This means that in some way I was on the right track when I suggested in van der Hulst (1988a) that 'front' and 'ATR' are phonetic manifestations of the element |I|.

(19)



Summarizing, my suggestion is that the binary categorization of phonetic dimensions that underlies the architecture of RcvP is rooted in a cognitive principle: the Opponent Principle. Given the biological availability of our articulatory mechanisms, discrepancies may arise between the demands of cognitive systems and the anatomy on which these systems are 'superimposed'. I have suggested that, as a result, the cognitive category |∀| (as it occurs in the dependent aperture component) draws on two types of phonetic substances -- one of which involves 'double dipping'. When this same element occurs in the head aperture component, its interpretation can best be described in terms of vowel height or aperture (in which case many descriptions will also often use the term pair 'tense/lax').

6 Articulatory and acoustic correlates of elements

Wood's theory of features is based on articulatory mechanisms. In parallel with his theory, Ken Stevens (Stevens 1972) developed a theory about a specific nonlinear relation between articulatory mechanisms and acoustic effects which shows that the latter can be relatively insensitive to small changes in certain constriction areas (see also Stevens and Keyser 2010). The theory is called *quantal,* because when small changes along an articulatory area pass a certain threshold there is a clear acoustic effect which corresponds with a feature change (or feature value change). In terms of constriction loci in the vocal tract, Stevens' quantal areas correspond exactly to Wood's three features: [palatal], [velar] and [pharyngeal]. Given Wood's explicit account of these three loci in terms of muscle groups, it would seem that a quantal effect emerges when a different muscle group is activated or becomes 'dominant'. It would seem that there is a straightforward correlation between articulatory mechanism and stable acoustic effects.

In GP (as well as in DP), it is usually claimed that the three elements, |I|, |U| and |A|, correlate with acoustic images in the mind of language users. Backley (2011) places articulatory correlates *outside* the grammar. This viewpoint can be traced back to Roman Jakobson's idea that since the acoustic aspect of speech is shared by speaker and hearer (existing 'in between them' so to speak), acoustics must have primacy over articulation. An additional argument that is often made is that articulation is highly variable and that speakers can reach the desired acoustic targets in different ways even when having 'a mouth full of marbles'.[43] But the issue remains controversial since consonants of

[43] See Harris and Lindsey (1995). These authors also suggest that acoustics must have primacy because in acquisition, perception occurs before production. However, this fact does not necessarily entail that babies do not know the correlation between acoustic events and articulation, a correlation that they 'practice' in their babbling stage. The motor theory of speech perception implies that this practice can perhaps be mind-internal (given mirror neurons) and even happen for individuals who grow up understanding language, while never producing it.

different places of articulation can hardly be said to have invariant acoustic properties, given that their identity is revealed by formant properties of following vowels (e.g., see Delattre, Liberman and Cooper 1962). While acknowledging that speakers can adapt articulations in special circumstances to reach their acoustic goals, Taylor (20060 argues, convincingly in my mind, that phonemes must be associated with specific articulatory plans, which, perhaps more for consonants than for vowels, represent what is constant in phonetic events that cannot be easily unified in terms of their acoustic properties. In the so-called *motor theory of speech perception* (Liberman and Mattingly 1985) it is even claimed that we perceive acoustic events in terms of motor representations that cause such acoustic events. This view that has been integrated with theories about mirror neurons (Fowler and Galantucci 2002). To resolve the debate about whether articulation or psycho-acoustics is primary, I suggest that, while all phonemes are represented in terms of elements that correspond to both an articulatory plan and an acoustic image, the dominance of these two aspects differs for vowels and consonants (yet another instance of a head-dependency relation):

(20)	Vowels	Consonants
	Acoustic image	Articulatory plan
	|	|
	Articulatory plan	Acoustic image

After all, in vowels, the articulatory plan is necessarily ‘vaguer’ because the actual target of articulation cannot be contacted. In consonants, on the other hand acoustic properties are less clearly identifiable (especially for obstruents), which suggests that for these types of segments, the articulatory plan must be the unifying factor.

I conclude that there is no need to ban articulation from the grammar, but rather that both acoustics and articulation form necessary parts of the interpretation (i.e. 'meaning') of phonological elements. Whether phonetic interpretation forms part of the phonological grammar is largely a terminological issue. While the computational aspect of phonology need only make reference to structures and element, and thus not to the phonetic correlates of either, a full account of phonology must also include how the formal phonological expression correlate with the production and the perception system (see van der Hulst, to appear c).

7 The 2/3 problem

I now turn to another controversy where RcvP takes a stand that also directly follows from the Opponent Principle. In various versions of element theory, there have been certain problems surrounding the element |U|. Firstly, it has been claimed that |U| can only occur in one combination with |I| (essentially leading to removing dependency as a necessary relation in the combination of these two elements). A second idea, sometimes connected to the first one, has been to add a new element, which in DP is called the centrality element |ə| (an 'anti-color' element), to represent central unrounded vowels. Thirdly, it has been proposed to replace the element |U| by two elements: one for backness and one for roundness. I will first discuss the restriction on |I,U| combinations and argue that this restriction is not only theoretically arbitrary, but also undesirable empirically. The second and third idea have in common that an extra element is added to the color class, which leads to three color elements (or two color elements and one 'anti-color' element). This goes against the RcvP premise that each dimension contains only two elements, which is why this section is said to address a '2/3 problem'. With regard to the '3/4 problem', as we have seen, RcvP must adopt the '4' choice (giving us 2 elements in the manner and place dimensions). In the 2/3 problem, RcvP must adopt the '2' choice to maintain the claim that the place dimensions contain 2 elements. I will discuss the various proposals mentioned above in turn.

Anderson and Ewen (1987: 275) propose to add a separate the element |ə|, "centrality" or "non-peripherality". The reason for this lies in the following. Although the system of DP would in principle allow for two combinations of |I| and |U|, with either one or the other as the head, Anderson and Ewen (1987:275) state that "in virtually all languages, we find at each height maximally one segment containing both |i| and |u|; in other words, dependency relationships holding between |i| and |u| are not required".[44] [45] In their discussion of the representation of central or back unrounded vowels, Anderson and Ewen, reluctant to represent such vowels as colorless (an option the reserve for the schwa vowel [ə]), propose to add a centrality element |ə|. This element, as either a head or dependent in combinations with |U|, allows Anderson and Ewen to represent both central unrounded vowels and central rounded vowels (see Anderson and Ewen 1987 : 224-228 for details).

In the RcvP system, different combinations of |I| and |U|, which are an undeniable theoretical option, are used to account for non-front (central) rounded vowels (often

[44] Anderson and Ewen's notation for element names uses small case letters.
[45] GP also rejected two possible combinations of the element |I| and |U|.

called *inrounded* vowels), whereas central vowels are represented as colorless; see (8). In the RcvP system, there is thus no ‘ban’ on allowing two possible combinations for the color elements. Firstly, such a ban is theoretically ad hoc, and secondly, the statement that no language requires both combinations (I̲U and IU̲) at a given height is incorrect if there are languages that, in addition to a front-unrounded vowel and a back rounded vowel, have two additional rounded vowels, called rounded and inrounded. A case in point is Swedish, which has a well-known contrast between [u] and [ʉ] (see Riad 2013). Anderson and Ewen do not deny that inrounded vowels exist, but they choose to represent them in terms of the combination |u̲ə|. Given a choice between adding an extra element and allowing two combinations for |I| and |U|, it seems obvious that there is insufficient ground for adopting the centrality element.[46]

Next, I will discuss the idea to replace |U| by two new elements. In various versions of element theory, the dual character of |U| (capturing backness and roundness, just like the feature specification [+grave] in Jakobson, Fant and Halle 1962 or the feature [peripheral] in Rice 1995) has been called into question. A number of phonologists, notably Lass (1984: 278ff), Rennison (1990: 187), Ritter (1997: 346) and Scheer (2004: 47ff), have argued that these two aspects of |U| should in fact be given independent status, thus splitting up |U| into two elements, here in Lass’ symbols: |ω| ("labiality" or "roundness") and |ɯ| ("velarity" or "high backness"). These various authors have provided different motivations for this proposal. Lass responds to an earlier version of the DP (in Ewen 1980) where central or back unrounded vowels would be represented as colorless, which he finds unsatisfactory because “all the other classes have positively

[46] Granted, the difference between inrounded and outrounded vowels is typologically rare.

specified content" (Lass 1984: 278). His proposal forces him to stipulate that the element |ω| can only occur as a dependent.

As Scheer (2004: 47ff) points out, an important argument in this debate regards the characterization of velar consonants. Operating under the common DP/GP assumption that consonants and vowels share the same set of elements, we need to deal with the fact that in consonantal place, labiality and velarity are clearly independently needed properties, which seems to require the elements |ω| and |ɯ|. Additionally, as Scheer shows, velars induce an [u] allomorph in Czech vocative formation, [i] occurring after palatal consonants, whereas labials and dentals select the default choice of [ɯ]. Space limitations prevent me from discussing the RcvP account of consonantal place (see van der Hulst, in prep. c). In (21), I provide the characterization of places in terms of the place elements for non-continuant obstruents:

(21) Consonantal place (stops)

	I	IU	Placeless	UI	U
∀[47]	/t/	/c/	/ʔ/	/k/	/p/

The phonetic interpretation of the |U| as a head is [grave] or [peripheral], shared by velars and labials, to which the element |I| adds [lingual] to characterize velars. Given these representations, the generalization that can be stated for Czech vocatives is that only these consonants that have a complex place specification can dispense their head property to the suffixal vowel which delivers [i] after palatals and [u] after velars. There are, to be

[47] This element, which correlates with ATR and closure in the vowel sphere, denotes [-continuant] in the consonantal sphere. The commonality here is *relative closure*; see (7).

sure, other empirical domains that need to be visited. Here I merely suggest an alternative to one of Scheer's empirical arguments for splitting up the element |U|.

While the splitting up of |U| is rejected in RcvP, due to the Opponent Principle, which does not allow three color elements, Anderson and Ewen (1987) provide an additional argument. The proposal to split up |U|, in spite of making a representation of back, unrounded vowels possible without the use of a centrality element, is undesirable since it forces one to give up a direct relationship between 'markedness' (in the sense of frequency of occurrence) and formal complexity which is adequately reflected by the standard DP system. That this is so follows straightforwardly from a comparison of the standard DP representations of a high back rounded vowel and a high back unrounded vowel with those of Lass (1984), given in (22).

(22)	The representation of /u/:	The representation of /ɯ/:
	standard-DP: |u|	standard-DP: |u,i,ə|[48]
	Lass (1984): |ɯ,ω|	Lass (1984): |ɯ|

Thus, whereas in the standard-DP system /ɯ/ is formally more complex than /u/, this situation is reversed in Lass's (1984) feature system. Since it is generally assumed that a high back vowel that is rounded is less marked than an unrounded one, Lass's (1984) system clearly does not mirror markedness (as Lass himself also explicitly acknowledges saying that all markedness consideration should be excluded from phonological representations).

[48] Here I ignore the dependency relations that they provide; see Anderson and Ewen (1987: 227).

However, the correlation between markedness and complexity is deserving of some further discussion. A virtue of unary systems is no doubt that an account of markedness needs much less additional machinery in the form of underspecification, marking conventions and default rules compared to binary theories. Less marked segments contain fewer elements than more marked segments. However, there is one wrinkle in the correlation. RcvP treats unrounded central vowels, such as [ɨ] or [ɯ] (which I take to never be in contrast; see 8) as colorless, which seems to imply that such vowels are less marked than vowels that contain the elements |I| and/or |U|. This is here illustrated with the high vowel row taken from (8):

(23) High vowels

	I	IU	Colorless	UI	U
∀ (+∀)[49]	i	y	ɨ ~ ɯ	ʉ	U

There are two points to be made here. Firstly, by adopting the combination |UI| as the representation for [ʉ] there is no complexity difference between this rather rare vowel and the also rare, but more common vowel [y]. This shows that there are limits on correlations between complexity and markedness. In this case, we have to be satisfied that both [ʉ] and [y] are more complex than the common [i] and [u]. Secondly, assuming that markedness correlates with complexity, it would seem to follow that non-front unrounded vowels [ɨ ~ ɯ] would have to be the most common vowels. However, I suggest that complexity is *not* an actual fundamental determinant of markedness. Rather, what makes segments unmarked is to have a perceptually clear and salient identification,

[49] The dependent dimension element |∀| need not be specified if a language does not have a contrast between two series of high vowels.

which, I submit, is achieved by being characterized in terms of precisely one color element. This is why [i] and [u] are less marked than [y] and [ɯ]. It might now be asked why [ɯ] is more marked than [a] and, also, whether [a] is less or more marked than [i] and [u]:

(26)	[i]	[ɯ]	[u]	[a]
	$\underline{\forall}_C$	$\underline{\forall}_C$	$\underline{\forall}_C$	$\underline{A}_V$
	$\underline{I}_C$		$\underline{U}_V$	

In RcvP, [a] is less marked than [ɯ] because the |A| element is more preferred for vowels than the |∀| element. This is revealed by realizing that the former is a V-element, while the latter is a C-element (see 3 or 10). As for [i] and [u] vs. [a], we have conflicting factors. In its manner element, [a] has the preferred V-element. On the other hand, [i] and [u] have a color identification which [a] lacks. Result: a draw. Finally, comparing [i] and [u], [u] would have to be less marked, because its color element is a V-element. This is seemingly in contradiction to [i] — perhaps because it is a more frequent epenthetic vowel. However, being preferred as an epenthetic vowel does mean being a more preferred vowel. Rather, the contrary is the case: to fill epenthetic slots, languages use the least preferred vowels, i.e. vowels that ‘sneak in’ precisely because they are not very salient.

In conclusion, I have here defended the (what I would refer to as the original) 2-theory *of color* against two versions of the newer 3-theory, one with an extra centrality element and the other with a dual substitute for |U|. The 2-theory follows from the overall architecture of RcvP as demanded by The Opponent Principle. Secondly, is it theoretically preferred in not having to stipulate arbitrary restrictions on element combinations or the exclusive occurrence of elements as either heads or dependents. Thirdly, it is more consistent with the idea that phonological representations give expression to markedness.[50] Finally, as demonstrated in van der Hulst (2011, 2012abc, to appear c, in prep. a) in an extensive study of vowel harmony systems, adoption of the element |∀| is also empirically motivated.

8 Conclusions

In this chapter, I have defended the architecture of RcvP (with specific reference to vowel representations), which is governed by a cognitive principle that favors polar opposites, the Opponent Principle. This principle has a perceptional rational in terms of categorical perception (Harnad 1987) and maximal dispersion (Liljencrants and Lindblom 1972). It can perhaps also be motivated in terms of the neurophysiology of the brain[51]. The relevant principle is that polar opposites within phonetic dimensions form the optimal phonemic contrast. This principle give rises to systems of primes that are not arbitrary

[50] Whether phonological representations should reflect markedness remains, however, an open question; see Newmeyer (2005)

[51] In support of this rather speculative claim, I note that the 3/4 problem is reminiscent of an issue raised by two seemingly incompatible theories of color perception that were proposed in the 19th century. The **trichromatic theory** of Thomas Young and Hermann von Helmholtz claimed that color perception is based on three basic colors for which we have specialized cells (cones) in the retina (red, green and blue). Edward Herring proposed another theory, called the **opponent theory**, suggested that visual perception is driven by a two 'perceptional modules' (red/green and blue/yellow). The difference is that while red and green are paired, for the second pair a fourth 'color', namely yellow, has to be added to the model. The contradiction between these two theories was resolved when it was established that the Young/Helmholtz-theory reflect the anatomy of the retina, whereas Herring's theory is true of a higher processing level that appeals to opponent mechanisms in neural firing. In a similar way, I have argued that the 'trichromatic' theory of elements (I, U, A) is motivated by the anatomy of the articulators, whereas the 'opponent theory (I/U and ∀/A) reflect a higher, cognitive, level of organization which is, presumably, likewise guided by neural mechanisms.

lists (as exemplified by traditional feature theories and all other versions of element theory), but rather to systems that contain opponent opposites, which may, as argued, even lead to primes that are not straightforwardly motivated by a unique or obvious phonetic correlate, namely the element |∀|. I referred to the problem of using three elements (I,U,A) or four (I/U and A/∀) as the 3/4 problem. I discussed in detail - referring to Wood's theory of articulatory features - how the fourth element shares articulatory resources with the element |I|. I then turned to a second problem, the 2/3 problem, which regards a debate between theories that either add a centrality element or split the element |U| in two separate elements. Either proposal increases the set of color elements from 2 to 3. Here, I argued against such an enrichment to 3 elements by showing it to be theoretically undesirable and empirically unmotivated, concluding that we can limit the set of color elements to 2. The overall conclusion is, then, that only four elements are required to represent the place and manner properties of vowels (excluding tone and phonation, which require an additional polar pair of elements, |H| and |L|). With regard to the phonetic interpretation of the elements, two points were made. Firstly, given the fact that elements can be heads or dependents, elements can correlate with different articulatory interpretations that are unified in terms of their acoustic effects. Secondly, it was suggested that, while vowels and consonants share the same set of elements, acoustic interpretation may be more important for the former, whereas the latter are unified in articulatory terms.

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