Degrees of complexity in phonological segments

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1. Introduction

Phonological complexity is a wide-ranging issue. The term is often used with reference to *segmental* complexity, and this is the topic of the present article. However, other phonological aspects have also been described as involving a simple-complex dimension, such as (a) the size or structure of phonological *segment inventories* (see e.g. Maddieson (1984), and research based on such typological studies), (b) *syllable structure* and *phonotactic word structure*, especially at word edges, and (c) *foot structure* and *higher prosodic levels* (although the third area is much less addressed than the other two in typological studies). Complexity can also refer to the component that relates inputs (underlying forms) to outputs (surface forms), including the form of rules and/or constraints, derivational length, rule order and intermediate derivational levels. The relation between these areas of complexity (and other linguistic areas, such as the morphology and syntax of a language) with segmental complexity is interesting (see e.g. Maddieson (2005, 2010); van der Hulst (2017)) but does not concern us here. Instead, we will focus on phonological complexity in the segmental domain.

We first ask whether there is a distinct notion of 'complex segment'? To answer this question, we have to decide whether we approach it from a phonological or phonetic perspective. From a phonetic point of view, *all* 'segments' (a unit which is hard to define phonetically in the first place) are complex, since, roughly speaking, *all* segments are produced using various parts of the vocal tract. It therefore makes little sense to regard *any* segment as not being articulatorily 'complex'. From an acoustic point of view, it is also the case that *all* 'segments' are 'complex', given the array of parameters involved in representing speech acoustically. However, not all segments are *equally* complex. While some segments 'merely' involve an egressive airstream, which after passing through an open glottis, is 'held up' and then released at a single point of structure (such as the segment [p]), other segments may involve specific vocal fold positions (some of which itself may be quite complicated, as in segments involving 'creaky voice'), laryngeal movement, lowering of the velum (nasality) and multiple strictures, either simultaneously or in sequence. Such articulatory properties leave multiple traces in the acoustic profile of these segments; articulatory complexity no doubt correlates with acoustic complexity, although the relationship between articulatory and acoustic parameters is by no means one of a simple one to one mapping. The phonetic and phonological literature contains frequent references to relative notions such as 'ease of articulation' as well as 'ease of perception'. It seems reasonable to assume that the axes of articulatory and acoustic complexity on the one hand and the axes of articulatory and perceptual ease on the other are correlated in some way, again not in a simple manner.

Secondly, we should be aware that the notion of 'complex segment' has traditionally been used for a number of diverse and different kinds of 'phonetic events', such as affricates, prenasalized obstruents, consonants with a secondary articulation, clicks, even flaps (Banner Inouye 1989), and so on. Although both phonetic studies and traditional segment typologies (which are codified in the IPA notation) provide important cues and pieces of evidence with respect to what might qualify as a 'complex segment', there is no consistent mapping from phonetic analysis or IPA to a coherent notion of complex segment. While we discuss 'complex segments' in section 5, our main point here is that complexity is *a relative notion* which implies that there is no class of 'complex segments' which can be sensibly opposed to a class of simplex segments.

Thirdly, in considering the notion of 'complex segment', there also is a sizable literature on the question as to whether a phonetic 'event' (such as the initial or final consonantal events in English *church*) constitutes one (phonological) segment or two. Here complexity at the level of syllable structure enters into the discussion, because a major criterion for analysing a complex phonetic event as a single segment is having a distribution that is analogous to that of 'simple' phonetic events which un- or less controversially constitute a single segment. For example, if a language overwhelmingly displays a CV syllable structure (i.e. with simplex onsets), it is possible that a phonetic event such as [^{m}b] could be analysed as a single (complex) consonant – and additional evidence would strengthen the point.[1] That said, the distinction between segmental

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[1] Here we are thinking of evidence, for instance, from reduplication: if a cluster simplifies in reduplication , but an affricate or segment with secondary articulation does not, as in Ewe, this is prima facie evidence that these segment types are single segments (Sagey 1986: 86).

complexity and syllabic complexity is by no means clear, as evidenced by several proposals to analyse what some would call complex onsets as complex segments (see e.g. Hirst (1985, 1995), Lowenstamm (1996, 2003), Duanmu (2008)).

In this article, we will not enter the (mine)field of the various axes of phonetic complexity, whether referring to articulation, acoustics or notions of 'ease'. Accepting that the full study of linguistic speech (or sign) requires *both* phonetic and phonological analysis, we will here focus on the role of the latter. Given certain assumptions and 'first principles' regarding the organization of phonology (here focusing on representations), inspired by Dependency Phonology (Anderson & Ewen (1987), Anderson (2011b)), we will primarily try to understand complexity foremost as a *relative property of phonological representations*. While such representations in terms of both their basic units and structure are squarely representations of **phonetic substance**, we do not believe that they are isomorphic copies of the phonetic substance subject to only mild abstraction, such as in **Articulatory Phonology** (Browman and Goldstein's (1986, 1992)), which is essentially a model of articulation. Rather, phonological representations are **grammaticalizations** (more precisely: **phonologizations**) of phonetic substance.[2] We here intend to focus on the *cognitive system* that guides phonologization, which, essentially, is a categorization system, imposing a categorical structure onto the phonetic substance. A proposal for such a system is the theory of phonological structure proposed in van der Hulst ((2005), in prep.), with earlier publications preceding this work) which is called **Radical CV Phonology**, a development of **Dependency Phonology**. We will review the structural levels that this theory defines (up to and including syllabic structure) and systematically consider the potential for relative complexity at each level in relation to what is known (to us) about phonetic properties that can be used contrastively in segmental systems of particular languages. We will also address the correlation between complexity and what is called 'markedness'.

This article is organized as follows: in section 2, we will discuss complexity in relation to markedness, while section 3 briefly states five assumptions we adopt concerning phonological primes ('features'). Section 4 offers a brief introduction to RcvP, focusing on its guiding principles and elementary units, the connection between

[2] This leaves open whether the phonetic substance is perceptual (a perceptual representation or image of the acoustic signal), as proposed by Anderson (e.g. Anderson (2011a)), and/or some sort of articulatory plan (see below).

the segment and the syllable (including a perspective on the relation between major class and syllable structure) and providing the representation of different groups of features (laryngeal, place and manner). While our point here is that all segments that contain more than one prime (which is actually all segments) are complex, section 5 is focussed on the traditional notion of 'complex segments'. Here we show that there is no coherent notion of complex segment and that the members of this traditional class display complexity at different levels in the structure. In this section, a brief discussion of complexity for vowels is included. Finally, section 6 presents a short discussion of recent proposals to resolve syllabic complexity, with repercussions in the segmental domain. We state our conclusions in section 7.

2. Relative complexity and markedness

Above we made the point that we cannot derive a phonological account of segmental structure by 'simply' mapping the results of a phonetic investigation of the speech signal onto a phonological representation, although in some cases, such a direct mapping may seem plausible, for example when we say that a labial-velar segment [kp] is phonologically complex because it has two places of articulation, or when we say that an affricate is a complex segment because it has two phases which differ in manner of articulation. However, when we look at basic vowel types, it is less obvious why we would regard mid vowels such as [e] and [o] as more complex than the peripheral vowels [i], [u] and [a], and why we would regard a rounded vowel such as [ö] as even more complex than [e] and [o]? All vowels use the same articulators (the tongue body, the lips and the larynx), positioned in some way with respect to a single 'target' state. Nonetheless, we will argue that such complexity differences obtain (which in fact correlate with usual claims concerning relative differences in markedness among these vowels).

The expectation that all vowels (indeed all segments) are equally complex is a logical consequence of the theory of segmental structure that was developed by Chomsky & Halle (1968) (SPE), where the vowels [i], [e] and [ö] are all identical-looking bundles of the same set of binary features, so that, without further stipulations, there is no reason to distinguish between these vowels (or *any* other vowel *or* consonant) in terms of complexity or markedness. We might say that representations in SPE respect a principle of uniformity: all segments are represented alike, and differences in status (in terms of complexity or markedness) are considerations that are external to the theoretical machinery. Even segment types that are traditionally called ‘complex’, such as affricates or prenasalized consonants, have the same formal complexity as ‘simple’ consonants in the SPE model, since they are merely distinguished from the latter in terms of members of the universal feature set such [±delayed release] or [±prenasal]. The conclusion is that there is no direct reflection of complexity or markedness in the SPE model.

Theories like SPE that adhere to uniformity can take extra measures to capture complexity (and markedness) asymmetries using the notion of *underspecification*. However, it is by now well-known that a much more direct (and, in our view, more promising) approach to segmental complexity and markedness is made in theories that reject the principle of uniformity and represent segments in terms of unary features. The best known theory that develops this path is Dependency Phonology (DP; Anderson & Ewen (1987), and much related work; see van der Hulst & van de Weijer (2017) for a recent overview). The main innovation that is relevant here is that segments may differ in the number of unary features (which we will henceforth call *elements*) that is required for their representation.[3] In this approach to segmental structure, the representation of segments is not uniform, but instead directly reflects the relative phonological complexity of segments. For instance, in this theory, the difference between the vowels /i/ and /e/ could be represented as follows (depending on the language, and leaving out many important details, thus still keeping this fairly ‘informal’), where V = Vowel, and |I| and |A| refer to DP elements roughly corresponding (in articulatory terms) to ‘front’ and ‘low’:

(1)

[i]	[e]
V	V
|	/\
I	I A

That is, in this theory the vowel /e/ (in a particular language) is *defined* as a complex segment, whereas /i/ is not: in other words, complexity is not a pre-theoretical notion

[3] The term element is borrowed from Government Phonology (Kaye, Lowenstamm & Vergnaud 1985) and descendants (cf. Backley (2011)), which also adopt the notion of unary primes and, in fact, also the asymmetric relation of dependency that holds when elements are combined; see below.

that is defined phonetically (or by any tradition), but is a formal result of the way segments are represented. Of course, such an approach leads to numerous questions, such as the following:

(2)a. What is the range of segments that is predicted to occur in such a theory?
b. Does relative complexity always correlate with relative markedness?
c. Are there limits on complexity?
d. How does complexity relate to phonetic implementation (in particular phonetic linearization of phonological information)?

Answering the first question (2a) depends, of course, on the basic units that are adopted in the theory as well as the number and nature of different organizing levels. In this chapter, we investigate the predictions made in Radical CV Phonology (RcvP; van der Hulst (1995, 1996, 2000a, 2005, 2015a, b, in prep.). In section 4, the outlines of this theory are presented to the extent that they bear upon the discussion of complexity investigated here. Before this, however, we mention some theoretical assumptions shared by both DP and RcvP.

First, consider the five representations in (3):

(3)a. L	b. L	c. L	d. L	e. L
	|	/\	/\	/|\
	x	x y	x x	x y z

We assume that only (3b) and (3c) are well-formed. We thus exclude empty nodes[4], nodes that dominate two identical elements and nodes that dominate more than two elements.

Secondly, in frameworks such as Dependency Phonology it is assumed that a combination of elements can lead to a declaration of the relation between the two elements: one or the other must be the head (bar the possibility of equal or mutual dependency, which is not recognized in RcvP). We illustrate the usefulness of the head-dependent relation in (4), using two alternative notations, where the vowels /e/ and /ɛ/ differ in which element is the head (we are not committing ourselves at this point to the unit to which these features attach):

[4] Strictly speaking, this would disallow a notion of empty-headed syllable, as most explicitly promoted in versions of Government Phonology.

(4) a.

[e]	[ɛ]
/\	/\
$\underline{\text{I}}$ A	I $\underline{\text{A}}$

b. {I;A} {A;I}

In (4), both [e] and [ɛ] are complex segments consisting of the same elements; in the first the element |I| is head (represented here by underlining or preceding a semi-colon), and in the latter the element |A| is head. The presence of the head-dependent relation represents a major difference between element-based frameworks on the one hand and feature geometry proposals (Clements 1985, Sagey 1986) on the other.[5] Arguably, if there is only one mid vowel, say [e], there is no need to specify a dependency relation, which means that the presence or absence of a dependency relation can itself be considered a form of complexity. The extra dimension that this example introduces is that complexity is dependent on the notion of underspecification or, put differently, on a decision to represent segments minimally, i.e. in terms of only their contrastive properties.

Turning to the question in (2b), of the relation between complexity and markedness, we take as a starting point that 'more complex' entails 'more marked', but we will allow for the fact that that is specific cases the *absence* of a mark leads to being more marked. The directness of the correlation reflects the fact that 'marked' literally means 'provided with a mark' (which translates Trubetzkoy's use of the German term *Merkmal*, which can also be translated as 'feature'; see Trubetzkoy (1939 [1960])). We assume here that markedness is typically manifested by the following 'diagnostics':

(5)a. Marked segments (and structures) appear later in first-language acquisition than unmarked ones.

b. Marked segments are less common across languages and within a language, compared to unmarked ones.

c. Neutralization of a marked-unmarked pair of segments (or structures) will favor the unmarked segment or structure.

[5] The element theory adopted in Schane (1984), using the typical AIU set, does not invoke dependency. Instead, it permits multiple occurrences of the same element, a combination of (3d) and (3e).

Much of the literature in Dependency Phonology is devoted to illustrating these diagnostics. For instance, with reference to the vowel contrast in (1), the vowel /i/ is commoner in vowel inventories than /e/ (Maddieson 1984: 125), it appears before /e/ in acquisition (e.g. Stoel-Gammon & Herrington (1990: 147-8)), and it is often the output of neutralization between /i/ and /e/ (e.g. in Brazilian Portuguese, Wetzels (1995)). The approach to the analysis of neutralization in (5c) is closely based on the insights of Trubetzkoy (1939 [1960]), where these types of oppositions are regarded as privative. Theories that employ privative elements for segment representation are eminently suited to make sense of these kinds of observations and processes.

Let us now turn to our remark that being more complex sometimes implies lesser markedness. This paradox can be illustrated at the level of syllable structure as follows. A syllable without an onset is formally less complex than a syllable with an onset. Yet, all linguists agree that CV is less marked than V (again, on the basis of typology, acquisition, and other facts). In this sense, CV represents the minimal syllable and this makes V *sub*minimal, which is more marked. At the level of foot structure, a similar point can be made. A branching foot (e.g. a trochee) is considered to be less marked than a unary foot (often, to make this point, referred to as a degenerate foot). Again, a binary structure of two syllables constitutes a minimal foot. At the segmental level, assuming that segments combine three types of units (laryngeal, manner and place; see below), it could be argued that segments minimally require the presence of both manner and place (forming a supralaryngeal unit; the laryngeal unit in this view can be added as an 'extra' indeed adding to complexity). A placeless or mannerless segment, while formally simpler, is generally taken to be marked. To make matters more difficult, it turns out that the relation between complexity and markedness can be *context-sensitive*. A placeless vowel – like schwa[6] – can be unmarked in the weak syllable in a trochaic foot, whereas a branching rhyme can be unmarked in the strong syllable (giving it intrinsic syllable weight). The example of rounding in vowels may be of a similar nature. The rounding of [u] is unmarked, whereas that of [ü] is marked. The unmarkedness of roundness in back vowels has been said to be due to the notion of *enhancement*.

[6] If a schwa is not only placeless, but in fact has no property at all (as has been widely assumed), this raises the issues as to whether a nucleus with a schwa is an empty syllabic node which would run counter to our claim that empty nodes are not well-formed. We do not address this issue here.

Sometimes, apparently redundant properties are preferably present because they enhance the acoustic signature of a segment in contrast with other segments.[7]

In this article, we do not attempt to develop an explicit account of the relationship between complexity and markedness and we conclude that this is a matter that deserves further scrutiny. We tentatively conclude that in some cases greater complexity is unmarked if the structure would otherwise be *sub*minimal or perceptually *sub*optimal.

Turning to question (2c) (are there limits on complexity?), what is at issue here is whether a phonological theory delivers a *closed set* of representations, while only allowing structures that have been shown to be contrastive in a given language, or whether the theory is a system that defines an open set of categories.
We will argue in favor of the second view, but, at the same time, note that this does not imply that 'anything goes'. As we will see, there is a reasonable 'binarity constraint' that would limit complexity in phonology (and perhaps also beyond phonology). In addition, within a dependency approach it is 'reasonable' to find that dependent units will tend to display less complex structure than heads, in some cases, universally so (based on the empirical finding that certain types of contrast have never been attested thus far). RcvP defines a set of categories that range from maximally simple to increasingly complex structures, as we will see below. Given that languages do not seem to demand very large sets of segments, we will subscribe to the principle that simple (or rather, relatively simple) categories will be used before more complex categories (which is a variant of the principle of 'Ockam's Razor'). So, whereas the set of permitted phonological structures is large (although perhaps not infinite if a binarity constraint is adopted and head/dependency status is considered), no segmental inventory will reach into the outer layers of the large set unless the inner layers have been used. In addition to the formal considerations) (binarity, head/dependent status), this has two substantive reasons. Firstly, there are practical limitations due to the size of segmental inventories that languages require (which are fairly modest compared to the large set of possible structures). Secondly, the phonetic differences between increasingly complex structures will diminish to a point where the articulatory or the perceptual system has trouble keeping them apart.

[7] For enhancement see Stevens, Keyser & Kawasaki (1986) and Stevens & Keyser (1989)). In the example of back rounded vowels, the context-sensitivity of rounding disappears within an element framework that includes the U-element (which conflates backness and roundness, which, together conspire to lower the second formant). However, proponents of enhancement theory provide other examples as well.

Now consider question (2d), which asks how complexity relates to phonetic implementation. Note that the combinations of features in (4), despite the fact that they involve complexity, denote 'simple' cardinal vowels. Presumably, this is because the elements |I| and |A| can combine into a simple phonetic segment. Might it also be possible to combine two elements that cannot 'blend' into a single articulation, i.e. that would have to be pronounced in sequence? This would appear to be the case in affricates, for instance, regardless of the question whether the two phonetic parts should be analysed as two values of a distinctive feature (as in developments after SPE, see e.g. Campbell (1974)), or as two unary features, [stop] and [cont] (see Lombardi (1990), van de Weijer (1992, 1996)). We can turn this question around and establish that a (phonetic) consonant sequence should not necessarily be analysed as a phonological sequence. The issue has often been discussed with respect to affricates (e.g. Hill (1958), Lin (2011), and, recently, van de Weijer (2014a)), but also for prenasalized stops (e.g. Herbert (1975, 1977), Lisker (1976) and Hyman (2003)) and even for /s/ plus stop clusters (van de Weijer 1996). Here we touch on the important topic of serialization (or linearization) of phonological material. It is often assumed, or explicitly stated, that there is no *intra*segmental linear order. The set of elements that characterizes a segment is an unordered set, albeit a set that contains subsets (expressing the idea of element grouping, already envisioned by Chomsky & Halle (1968: 300) themselves). However, predictability of linearization is not confined to the mapping of segmental phonological structure onto phonetics. At the level of syllable structure, where linear order is typically taken as being lexically specified, feeding into a syllabification algorithm, Anderson (1987) makes the important point that if syllabic *grouping* is taken as lexical information, linear order of segments can be largely derived from the sonority sequencing generalization which postulates a rise of sonority toward the syllable peak and a descent following the peak (see also Navarro, this volume).[8]

3. Five theses concerning phonological primes

[8] According to Clements (1990), the ascent towards the vowel is steep, whereas the descent after the vowel is modest; we return to this in section 4.2.

Before we turn to a brief outline of RcvP, we wish to briefly discuss where we stand (following, for the most part, the view of John Anderson) with respect to five fundamental questions concerning the nature and specification of phonological features.

3.1 Are features based on perception or articulation?

John Anderson's thesis is firmly that phonological primitives are perception-based (Anderson 2011a). This view is shared with proponents of Government Phonology (Kaye, Lowenstamm & Vergnaud (1985); Scheer (2004); Backley (2011)). Anderson argues that both syntax and phonology are grounded in cognitive substance: conceptual (meaning) substance and perceptual (phonetic) substance, respectively. The exclusion of articulation is presumably based on the idea that motor movement, while it has to be driven by an articulatory plan that as such is cognitive, does not count as a 'cognitive substance'. Also, articulation is secondary to perception. Children form accurate representations of the speech signal before they themselves can articulate speech 'correctly'.

We will suggest a compromise view and argue that there is no need to exclude articulation from the grammar, but rather that both acoustics and articulation deliver cognitive substances that provide the 'raw material' that phonological elements categorize. To include articulation as a cognitive substance, we do not have to rely on the motor-theory of speech perception (Liberman & Mattingly 1985). Arguably, alongside percepts of the acoustic speech signal, speakers also have *proprioceptions*, which refer to "the sense of the relative position of one's own parts of the body and strength of effort being employed in movement" (Glanze, Anderson & Anderson 1990).[9]

3.2 Are features innate?

We do not believe that features are innate. Here we broach a large and important topic on which several researchers have weighed in (see e.g. Mielke (2008), and recently

[9] Van der Hulst (2015b) suggests that the relative importance of articulation and perception might be different for consonants and vowels (showing a kind of head/dependency difference). In the former articulatory properties may be more salient than acoustic properties, while this may be the reverse for vowels.

Duanmu (2016)). We will only mention one argument (against innate features) which is related to sign language phonology. Several phonologists (see e.g. van der Hulst (1993a), Morén (2003), Krämer (2012)) have argued that attempts to postulate a single set of features that apply to both modalities (spoken and visual) fail, because there is no reasonable relationship between a unified set of features and phonetic implementation (see van der Hulst (1993a) for a review of the early literature and a proposal). Adopting the view that features are responsible for allowing the expression of contrast, we suggest that features for spoken languages and for sign languages (or for any other modality that might lend itself to the expression of a human language) result from a categorization principle that splits phonetic substances into two opposing categories. Van der Hulst (2015b) calls this the **Opponent Principle**. This principle (which is rooted in categorical perception; see e.g. Kuhl (1991), among many others) directs a specific categorization of phonetic substance that 'produces' feature systems for spoken and signed languages in the course of ontogenetic development.[10] The splitting is a recursive process, which means that categories resulting from a split can themselves be subject to a further split. Given an inventory of segments for any language, this procedure delivers a minimal specification for each element class.[11] As we will show in the next section, recursive splitting gives rise to categories of increasing complexity (and markedness).

3.3 Are features, or is phonology in general, substance-free?

Sometimes it is argued that phonology should be 'substance-free', i.e. not refer to the phonetic content it describes (see e.g. Hale & Reiss (2000), Blaho (2008), Iosad (2013), Reiss (2018), and references cited there.. In one sense, this thesis is self-evident. Phonological generalizations *never* refer to the substance that the categories and structures phonologize; the only make reference to the symbolic units that have phonetic substances as their 'meaning'. This point was already made very explicitly in the Glossematics theory of Louis Hjelmslev (Hjelmslev 1943 [1953]) . However, that said, what the substance-free thesis does not imply, at least not for us, is that these categories and structures are in some sense 'unrelated' to phonetic substance. As mentioned above,

[10] See van der Hulst (1993b, 2000b) for an application to sign language.
[11] In this sense, RcvP's basic assumption is very similar to Dresher's (2009) Successive Division Algorithm.

we assume with Anderson that features[12] are substance-based, arising during the process of language acquisition, based on perceptions (and proprioceptions) and guided by the recursive splitting process. We therefore would not accept features that are 'purely abstract' (that are phonetically 'meaningless', as proposed in Foley (1977)), nor that structures can arise that are 'phonological unicorns', i.e. constellations that are well-formed, but that are not phonologizations of actual phonetic events that occur in human languages.

3.4 Are phonological representations fully specified?

We adopt Anderson's view that phonological representations are minimally specified and that the criterion for specification is **contrast**.[13] Using unary elements dramatically reduces the need for underspecification, but this notion is still relevant if only contrastive element specifications are postulated in lexical representations (see van der Hulst (2016)). However, minimal specification does not entail a system of rules that fill in redundant information. We assume that minimally specified representations are directly phonetically implementable and implemented.

Adherence to minimal specification bears directly on the issue of complexity. In computing complexity, if only contrastive specification is adopted, we do not evaluate fully specified representations (which would be the only option in Articulatory Phonology or Exemplar-Based approaches; see Johnson (2007)). We also note here that, contra Optimality Theory, we crucially assume that lexical representations, and thus their minimally specified nature, matter.

3.5 Is there such a thing as a segment inventory?

Anderson assumes that contrast (and ultimately the notion of segmental inventory) is relative to syllabic positions and refers to this as the idea of *polysystematicity*, a view that rejects the notion of a phoneme as a unit that generalizes over sets of segments that occur in different syllabic positions. We ourselves are doubtful that there is no 'reality'

[12] Similar to the acquisition of, for instance, OT constraints (van de Weijer 2014b, 2017).
[13] See Dresher (2009) for a perspective on minimal specification using binary features.

to a unifying notion of say, the phoneme /l/ (as a unit that subsumes the l-sounds in English *lip*, *blink*, *silly*, *health, already* and *pill* which all differ in phonetic details, being, as such, in complementary distribution), but we do realize that familiarity with an alphabetic writing system can have an influence on this unification (see Anderson (2014)), although it strikes us as more plausible that this unification was and is the psychological basis for the invention and use of alphabetic writing. But even if we grant a cognitive status to phonemes (independent of their distribution), this does not imply that phonemes will be specified with the same degree of complexity in all positions, because minimal specification will indeed require that in positions in which there is neutralization of contrast fewer specifications are necessary. For example, in *blink*, /l/ only contrasts with /r/, whereas in final position it contrasts with a much larger set of segments, at least in English.

After these preliminaries, let us briefly introduce the framework within which we will implement our notion of relative complexity.

4. The RCVP framework[14]

The account developed in van der Hulst (to appear-a) (and references cited there) adopts the following principles, which are relevant to the discussion of complexity:

(6) <u>Fundamental principles</u>

a. Phonological primes are unary (they are called *elements*), organized into classes[15]

b. Each class is populated by the same two elements, |C| and |V|

c. Element specification is *minimal*

Radical CV Phonology (RcvP for short, van der Hulst (1995), (2015a), (2015b), (in prep.)) is a version of Dependency Phonology (DP; Anderson & Ewen (1987)).[16] In the

[14] See van der Hulst (in prep.) for details concerning the model summarized in this section.

[15] The idea to acknowledge element classes occurs in the earliest version of Dependency Phonology (e.g., see Anderson & Jones (1974)). The same idea later led to versions of what was called 'feature geometry' (see Clements (1985)).

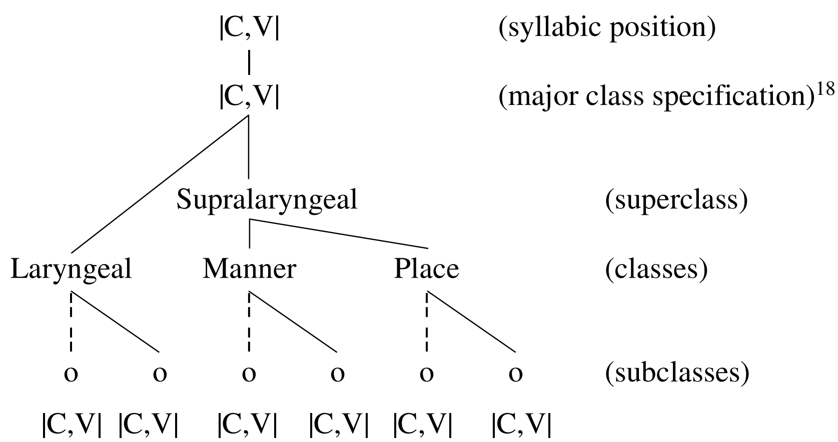
[16] The present state of RcvP differs somewhat from van der Hulst (2005), making use of a discussion of this proposal in Anderson (2011b), who, in his turn, adopts some aspects of van der Hulst (2005), thus modifying some aspects of the proposals in Anderson & Ewen (1987).

next two subsections, we will deal with the representation of segmental structure (§ 4.1) and syllable structure (§ 4.2), respectively. Our goal is to outline the model, stressing its internal consistency and empirical coverage. It is impossible to motivate every aspect of the model (by itself, or in comparison to other models). For much of that we refer to van der Hulst (in prep.).

4.1 The formal representation of segmental structure and its phonetic interpretation

In (7) we represent the full RcvP geometry:

(7) The 'geometry' of elements in Radical cv Phonology[17]



The various labels for the classes are for convenience only and have no formal status in RcvP; they serve the function of making the symbolic phonological representation 'readable' by using their phonetic correlates as informal labels. Each unit in the structure can be defined in purely structural terms. The elements |C| and |V| are also strictly formal units, which, depending on their place in the segmental structure (and their role as head or dependent), correlate with specific phonetic properties. Additionally, their interpretation is also dependent on the syllabic position of the entire segmental structure, which means that both elements have different (albeit related) interpretations for each syllabic position in all three classes.

[17] This geometry deviates somewhat from the one adopted in Anderson & Ewen (1987) and bears a close resemblance to the original geometry that was proposed in Clements (1985). In van der Hulst (in prep.) this model is compared to other models with which it shares certain properties.
[18] It is assumed here that the major class specifications and syllabic positions, although both characterized as C/V structure, are distinct; see below.

Within a subclass, an element can occur alone or in combination. This allows for a four-way distinction in which two structures are formally complex in combining two elements:

(8)a.

C	C	V	V
	|	|	
	V	C	

b. {C} {C;V} {V;C}[19] {V}

The two elements can furthermore occur in a secondary (dependent) subclass, which, if we also allow a four-way distinction there, leads to the following set of possible structures:

(9)a. Primary (head) structures:

{C}	{C;V}	{V;C}	{V}

b. Primary structures with add secondary (dependent) structures:

{{C}c}	{{C;V}c}	{{V;C}c}	{{V}c}
{{C}c;v}	{{C;V}c;v}	{{V;C}c;v}	{{V}c;v}
{{C}v;c}	{{C;V}v;c}	{{V;C}v;c}	{{V}v;c}
{{C}v}	{{C;V}v}	{{V;C}v}	{{V}v}

In van der Hulst (2015b), it is proposed that the limitation of the set of elements to two units per class can be seen as resulting from a basic principle of categorization (rooted in categorical perception), called **the Opponent Principle**, which two opposed categories.[20] Assuming that each subclass in (10) correlates with a 'phonetic dimension', |C| and |V| correlate with (and phonologize) opposed phonetic categories within such a dimension. The opposing categories comprise two non-overlapping intervals within which certain phonetic correlates are optimal in terms of achieving maximal perceptual

[19] Recall that DP uses 'x;y' to indicate that x is the head and y is the dependent. Underlining, used in Government Phonology, is an alternative notation to indicate headedness.

[20] A question that could be asked is why the Opponent Principle (or an extended version thereof) does not enforce four phonetic spaces rather than three. This is because the emergence of categories is also dependent on the phonetic substance, which, in specific cases, does not allow for a four-way distinction. This is discussed in van der Hulst (in prep.). Below we will see that there are only three major class categories (obstruents, sonorant consonants and vowels) and, essentially, only three distinct syllabic positions.

contrast with minimal articulatory effort.[21] While the elements are thus strictly formal cognitive units, they do correlate with phonetic events (or phonetic categories, covering a subrange of the relevant phonetic dimension). In fact, we can think of elements as (subconscious) cognitive percepts and propriocepts that correlate with phonetic events/categories.[22] The relation between formal units such as elements and phonetic events is referred as **Phonetic Interpretation** (or Implementation), (PI), which embodies a set of interpretation functions (see 10)). Naturally, since the elements |C| and |V| occur in all classes, these elements correlate with a wide variety of phonetic interpretations. Additionally, interpretation is dependent on syllabic position and major class specification:

(11) Phonetic Interpretation Functions for elements in head classes[23]

PI (|Man: C|, head class, consonant, onset) = [[stop]]
PI (|Man: C|, head class, vowel, nucleus) = [[high]]

PI (|Man: V|, head class, consonant, onset) = [[fricative]]
PI (|Man: V|, head class, vowel, nucleus) = [[low]]

PI (|Place: C|, head class, consonant, onset) = [[palatal]]
PI (|Place: C|, head class, vowel, nucleus) = [[front]]

PI (|Place: V|, head class, consonant, onset) = [[labial]]
PI (|Place: V|, head class, vowel, nucleus) = [[round]]

PI (|Lar: C|, head class, consonant, onset) = [[fortis]]
PI (|Lar: C|, head class, vowel, nucleus) = [[high tone]]

PI (|Lar: V|, head class, consonant, onset) = [[voiced]]
PI (|Lar: V|, head class, vowel, nucleus) = [[low tone]]

We refer to van der Hulst (in prep.) for a complete discussion and motivation of all the interpretations.

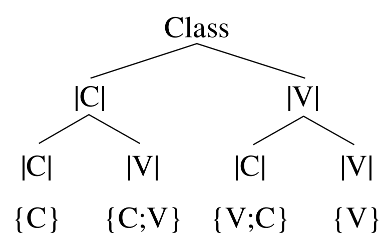
A guiding principle of DP is the **Structural Analogy Assumption** (SAA), which states that representations in phonology and syntax differ mostly due to the fact that these two planes have a different set of basic categories, due to the fact that they are

[21] A category thus has a prototype character with optimal members, prototypes, and suboptimal members.
[22] As mentioned, we assume that elements have both an acoustic correlate (a percept) and an articulatory plan (a propriocept).
[23] We focus here on articulatory interpretations. There are also (psycho-)acoustic interpretations; see § 3.1. The '[[…]]' indicates 'phonetic interpretation/implementation'.

grounded in different substances. Since phonology and syntax categorize different substances (phonetic percepts and semantic concepts, respectively), we expect their sets of basic categories to be different. What the SAA states is that phonological structure and syntactic structure display identical *structural relations*, such as, in particular, dependency relation between head and dependents.[24] However, structural analogy also promotes ‘replication’ of the same structures *within* planes. RcvP extends this idea to the segmental structure, and postulates that the various classes within the segmental are structurally analogous to the extent that all make use of the structures in (10). Van der Hulst ((2015b), (in prep.)) presents detailed proposals for the use of all twelve structures in every syllabic position, some of which will be reviewed here.

The possibility of combining elements within a head component captures the fact that some phonetic spaces can give rise to more than two phonetic categories. Alternatively, the four-way array in (8) can be seen as an instance of *recursive splitting*, in that the category corresponding to each element an element can be split into two smaller categories, leading to two subcategories of what now has become a supercategory.[25]

(12)



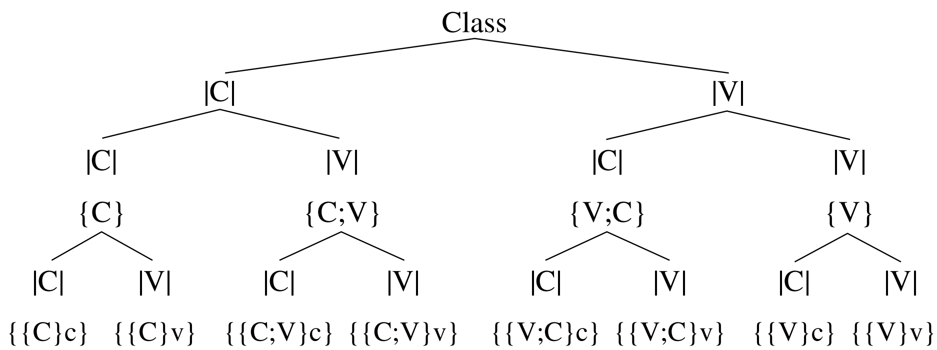
Given that each category is labeled as C or V, it is necessarily the case that one subcategory is unmarked vis-à-vis the other within a supercategory. Thus, |C| is the unmarked category as a subclass of a C supercategory. The unmarked status of C-within-C is reflected in the fact that this category is represented as {C} (rather than {C;C}. Note that the combination of elements within a class captures the scale-like character of phonetic categories within a phonetic dimension, while at the same time putting a discrete limit on the number of subcategories (up to four) that result from the

[24] Different types of relations correspond to notions such as complements, specifiers and adjuncts. Van der Hulst (2005) argues that the specific structural relations of ‘X-bar theory’ generalize over phonology and syntax; see den Dikken & van der Hulst (to appear).
[25] 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 location categories and discusses the parallels of his model to RcvP. Staun (2013) refers to this notion of splitting as ‘fission’.

first split cycle. One might ask whether this recursive split of categories halts after one cycle.

At first sight, given that we have distinguished a head and dependent subclass, one could regard the dependent class as providing a further recursive split of the head categories:

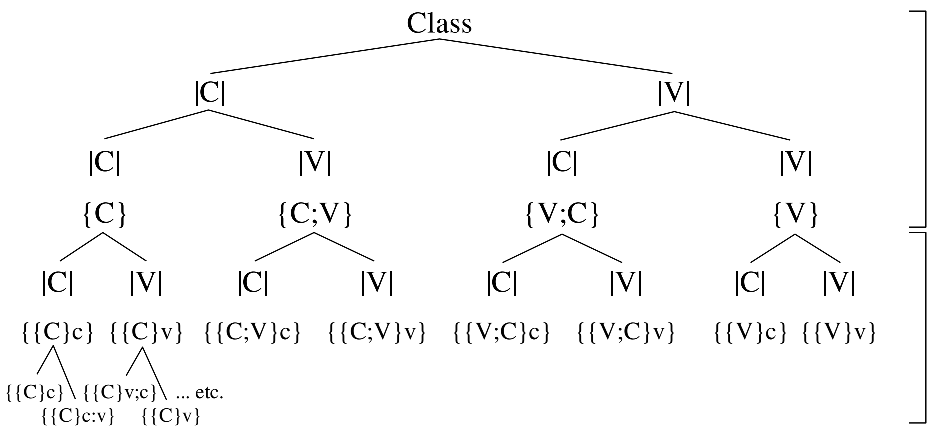
(13)



This results in twelve categories. However, note that while the structures resulting from the second split are *not* added to those of the first (which would produce six categories, namely {C}, {V} plus {C;C},{C;V}{V;C}{V;V}), the structure resulting from the third split *is* added to those that result from the second split (leading to twelve categories). The second split only produces four categories because of our decision to take {C;C} as not being distinct from {C}, reflecting markedness in terms of complexity. This means that splitting *within* a subclass is not additive (it literally divides a category into two new categories), whereas splitting that produces a secondary class is additive (it adds a specification to the categories we already have). We take this to mean that the addition of secondary properties is *not* the result of a third recursive split, but rather that splitting within the head and dependent class is separate and that the head/dependent subclass split is indeed a class division.

Let us now ask whether the dependent class itself allows a recursive second split (as in fact we assumed in 9b):

(14)



The square brackets indicate the first and second cycle of recursive splitting, corresponding in both the head and dependent class.

These additional structures, if truly needed, suggest two recursive splits in both the head and dependent class, resulting in 20 categories, 4 plain and 16 with the four possible secondary specifications (see van der Hulst, in prep.). It turns out that the utility of complex secondary structures ({c;v}, {v;c}) is very limited. The fact that four-way splits are hardly required in the dependent subclass squares with the overall head-dependency asymmetry discussed in Dresher & van der Hulst (1998), which states that a lesser degree of complexity is a hallmark of dependent units. Perhaps there is only one case which may require a four-way distinction in the dependent class, namely in onset head manner, where the dependent class is allowed to engage in combinations:

(15) Manner

Primary	Secondary
C (stop)	C (nasal)
C;V (affricate)	C;V (lateral)
V;C (m-fricative)	V;C (rhotic)
V (s-fricative)	V (pharyngealized)

In (14), we see that the proposal naturally suggests a representation of affricates, i.e. with a {C;V} in the primary manner class. The difference between m- (= mellow) and s- (= strident) fricatives is rare, but occurs in Ewe. We will discuss the interpretation of these representations further in the next section (section 4.3). The idea to represent affricates as {C;V}, with C-headedness grouping them as stops with plain {C}, embodies a compromise between proposals that represent affricates as a sequence of [-continuant] and [+continuant] (since the C when occurring as a head represents non-continuants) and the idea that affricates are 'strident stops' (as proposed in Jakobson, Fant & Halle (1952) and Clements (1999)). The V-element as a head represents fricatives, while as a dependent it represents stridency, which implies that frication and stridency are literally two sides of the same coin (the coin being the V-element), which illustrates that the interpretation of the V-element is sensitive to the head or dependent status of this element. It is fitting that precisely consonantal manner would 'push the limits' of complexity since contrast between morphemes/words is primarily carried by consonantal contrast.[26]

We have raised the question whether the formal apparatus should be limited in order to constrain the set of possible structures. While we note that each subclass only requires two splits at most (on the grounds of what is empirically necessary given the occurrence of contrasts in languages), it *is* formally possible to allow a tertiary cut. We could leave it at that and simply say that we do not expect languages to reach into the third division because the category distinctions would become too subtle, both in terms of articulation and in terms of perception. An alternative would be to add a formal constraint that limits splitting to two times. We will return to this question below.

We want to add here that apart from languages not using very complex structures ever (which would result from more and more splitting), it is also the case that some structures that are not that complex at all, do not receive a plausible or even possible phonetic interpretation. We will give several examples of this point in section 5.1.

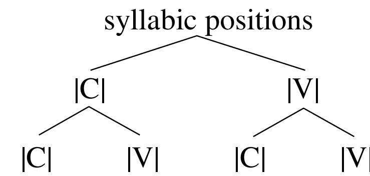
4.2 Syllable structure in RcvP

Having outlined the general framework of RcvP, and before turning to a more detailed account of the phonetic interpretations of intrasegmental C/V structures in each of the three classes, we will briefly discuss the way in which RcvP represents syllable structure. This is necessary, because, as discussed above, the interpretation of intrasegmental C/V structures is sensitive to the syllabic positions of a segment. Faithful to the basic premise of RcvP, the syllable itself is a combination of a C and a V-unit, which, if no further splitting applies, delivers the core CV syllable structure that all

[26] We will see in section 5.1.4 that consonants also use 'extra' structural options in the place class.

languages have. If languages exceed this minimal CV syllable, this results from splitting the C and/or V unit which produces binary branching onsets and rhymes, respectively (as in English or Dutch):

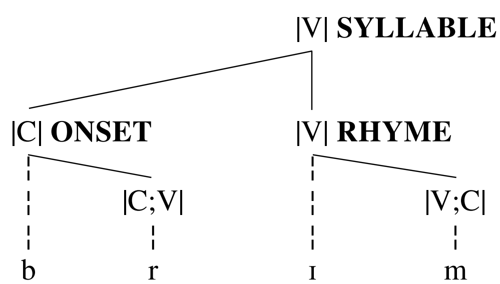
(16) a.



b. {C} {C;V} {V;C} {V}

While the four-way division as such implies no linearization, when combined into a syllable structure, there will be linear sequencing as dictated by the above-mentioned Sonority Sequencing Principle. A dependency representation of a syllable structure that contains all four syllabic categories is as follows (adding convenient labels for each position):

(17) a.

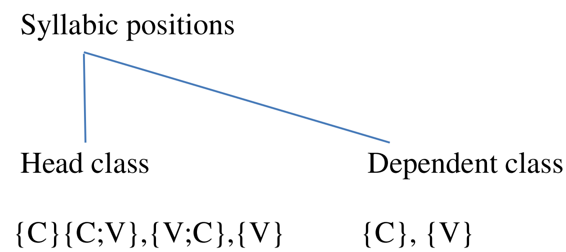


b. **EDGE BRIDGE NUCLEUS CODA**

In ‘classical’ Government Phonology (Kaye, Lowenstamm and Vergnaud 1990) it was assumed that a syllable with four positions represents the universally maximal expansion for syllables that can occur freely (i.e. word-internally, as well as at the word beginning and end). This would, once more seem to indicate that there is, in fact, a two-way split constraint that universally limits the degree of complexity. We therefore tentatively conclude that such a constraint is in effect. This constraint can be stated as a limit on recursive splitting or, alternatively by stipulating that a complex structure can maximally contain two elements. It strikes us that imposing maximal binarity on element structures potentially unites this constraint with other binarity constraints, as imposed, for example on foot structure.

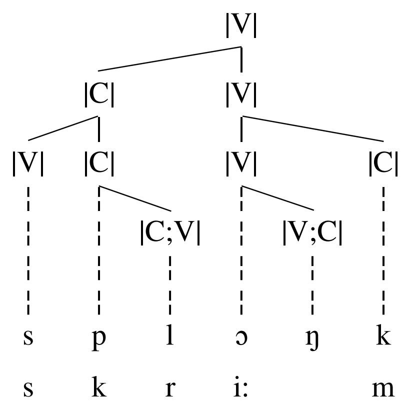
Now, the claim that syllables maximally contain four segments faces problems because syllables that occur at the word edges can display additional complexity. In English and Dutch, for example, the left edge can have tri-consonantal structures of a limited kind. They have to start with /s/ followed by an obstruent + liquid cluster. On the right edge, we find so-called superheavy rhymes containing a tense vowel followed by a consonant or a lax vowel followed by two consonant.[27] If we follow the 'logic' of distinguishing a head and dependent class, we allow a secondary class of syllabic positions (which, we will assume, does not need combinations):

(18)



In the syllable structure, these extra positions occur as being adjoined to the units that contain the primary structures:

(19)



The polysystemic view on segmental inventories holds that each syllabic position has its own contrastive set of segments (see above, § 3.5). The onset head adjunct has a

[27] In English and Dutch, a further word-final syllabic unit (called the 'appendix') is possible. We do not discuss this unit, an additional rhymal adjunction, here. See Anderson (2011b) for a similar treatment of syllable structure, with some extra notation that is suppressed here.

singleton set in English and Dutch, namely /s/.[28] The rhymal adjunct comprises all consonants, but is limited to obstruents if occurring after a sonorant consonant.

As shown in the structure for segments in (7), segmental structure 'starts' a major class specification. An alternative would be that the syllabic positions in (16) directly encode major class (as suggested in Golston & van der Hulst (1999)). However, we will argue below that *both* levels are necessary. We can regard major class specification as a separate tier that associates to the root node or we can regard this information as being part of the root node (as proposed in McCarthy (1988)). At first sight, we would get a four-way major class distinction, as follows:

(20) Major classes

|C| |V|

|C| |V| |C| |V|

b. {C} {C;V} {V;C} {V}

c. stop fricative sonorant consonant vowel

However, the distinction between stops and fricatives can, as we have seen be made in terms of a segment-internal manner distinction (see (15)). We will therefore assume (in line with most existing views[29]) that the major class division is a three-way division, containing only one intermediate category:

(21)	{C}	{C:V}	{V}
	obstruent	sonorant consonant	vowel

The intermediate structure is 'neutral' with respect to dependency or, to put it differently, there is no evidence for a contrast between {C;V} and {V;C}. This delivers

[28] It has also been proposed to regard /s/+obstruent clusters as a kind of complex segment, i.e. 'reversed affricates' (see Ewen (1980), van de Weijer (1996) for discussion, and references cited there). The model proposed here could allow for adjunction to the onset head. We will not try to evaluate the different predictions this makes for the behavior of such units.
[29] In binary feature accounts, this three-way distinction results from disallowing the combination [-consonantal, -sonorant].

the ‘traditional’ three-way major class division. We will show below that distinctions among obstruents and sonorant consonants will be represented in terms of manner structures. We can now consider the relationship between syllabic position and major category in terms of **preference**:

(22)					
	Syllabic position	{C}	{C;V}	{V}	{V;C}
	Major class	{C}	{C:V}	{V}	{C:V}
		{C:V}		{C:V}	{C}
					{V}

(22) shows that a distinction between syllabic position and major class is necessary, because the structure of the syllabic position does *not* (contra Golston & van der Hulst (1999)) uniquely determine the major class of the segments that can occur in each position. However, it does state what the ‘bias’ or ‘preference’ of each syllabic position is. (22) says that the onset head can contain obstruents and sonorants, with a preference for the former. The bridge can only contain sonorant consonants. The rhymal head (like the onset head) does not accept a major class that is opposite to its syllabic bias ({V} and {C}, respectively). This implies that obstruents cannot be syllabic, phonologically.[30] Finally, the coda position is the most tolerant, which can contain all three major classes but prefers sonorant consonants over obstruents and vowels. For the latter two (closed rhymes and long vowels/diphthongs), we are not sure whether there is enough evidence for stating a preference. The preference for {C} in the onset head and {C:V} in the coda acknowledges the idea, put forward in Clements (1990), that sonority in the onset preferably ascends fast, whereas it preferably descends slowly in the rhyme.

In the preceding two sections, our goal was to lay out what we assume concerning aspects of segmental and syllabic representations. We will now proceed with the interpretation of C/V structure below the root node, which, as mentioned above, is relative to both major class specification and syllabic position.

[30] We believe that glides in onset head are sonorant consonants in terms of major class, not {V} and that syllabicity in Imdlawn Tashlhiyt Berber is phonetic (contra Dell & Elmedlaoui (1985)).

4.3 RcvP representations for 'features'

In this section, we discuss the interpretation of the different parts of the segment as envisaged in the RcvP proposal. As we have stated, the interpretation of these structures is relative to both major class specification and syllabic position.

As shown in (23) below, in onset head position, with obstruents as preferred inhabitants, RcvP maximally allows a six-way laryngeal distinction (which is allowed, albeit marginally, in some languages; see Ladefoged (1973)). Most languages settle for a two-way distinction, with either the voiced or the 'fortis' member being the marked one (see van der Hulst (2015a) where the specific laryngeal structures are motivated[31]). For consonantal place, there is a four-way primary distinction and two possible secondary articulations. For manner, there is a four-way primary distinction, with affricates resulting from a {C;V} combination. The 'strident/mellow' distinction for fricatives is rare (e.g. bilabial vs. labiodental, which occurs in Ewe (see e.g. Kim & Clements 2015)). The secondary manner elements deliver an array of 'complex segments' such as prenasalized, lateralized, rhotacized[32] and pharyngealized segments (see § 5.1.2 for details).

---

[31] Specifically, why the primary class for consonants does not allow C/V combinations.
[32] We are not sure that a distinction between 'lateralized' and 'rhoticized' consonants is required. The distinction of retroflection is analysed in terms of secondary place.

(23) Onset head position

|C| (onset head)

|

|C| (obstruent) / |C:V| (sonorant)

Laryngeal[33]

- Primary ⊗
  C (fortis)
  V (voiced)
- Secondary ⊗
  C (constricted)
  V (spread)

Place

- Primary
  C (coronal)
  C;V (coronal)[34]
  V;C (dorsal)
  V (labial)
- Secondary ⊗
  C (palatal)
  V (labial)

Manner

- Primary
  C (stop)
  C;V (affricate)
  V;C (m-fricative)
  V (s-fricative)
- Secondary
  C (nasal)
  C;V (lateral)
  V;C (rhotic)
  V (pharyngealized)

('⊗' indicates that combinations are not required for this subclass)

Naturally, each language 'picks' a subclass of these various options for creating segmental contrast in the onset head. If, in the primary place and manner class usually only one intermediate category is used, this can be specified as {C:V}, i.e. without a phonologically the dependency relation.

When sonorant consonants occur as onset heads (the option that is less preferred than having an obstruent in this position; see (22)), they essentially have the same possibilities as obstruents, minus perhaps most of the secondary manner options which are all sonorant-based (except for pharyngealization). Adding the more sonorant secondary specifications to sonorant consonants perhaps violates a sonority distance constraint.

We assume here that the dependent position in the onset is more restricted than the onset head, effectively displaying a significant neutralization of contrast:

---

[33] We assume that laryngeal distinction produces phonation categories for on onset head positions. Here we do not discuss the details of laryngeal/phonation distinctions; see van der Hulst (in prep.).

[34] This refers to posterior coronals, whereas plain {C} refers to anterior coronals.

(24) Onset Dependent

|C;V| (onset dependent)
|
|C:V| (sonorant consonant)

Manner — Place ⊗

Manner:
C (nasal)
C;V (lateral)
V;C (rhotic)
V (glide)

Place ⊗:
C (palatal)
V (labial)

The dependent position does not need an independent laryngeal specification.[35] Also, the place distinctions are very limited, allowing a palatal vs. labial contrast for glides (as in /kw/ vs. /kj/). Of course, in English (and Dutch) nasals are not allowed in onset dependent (due to a minimal sonority distance constraint; see Steriade (1982), Selkirk (1982), van der Hulst (1984)).[36] It is expected that the dependent onset position allows a lesser degree of complexity than the head position.

This brings us to the contrastive options for the rhymal head:

[35] Kehrein & Golston (2004) account for this by saying that the laryngeal class is a property of the onset as a whole; see van der Hulst (in prep.) for discussion. A similar claim can be made for place properties, at least to some extent.

[36] Onsets like /xn/ or /kn/ in Dutch (*gnoe* 'gnu', *knie* 'knee') can only occur word-initially and are split up in intervocalic position (see Trommelen (1983); van der Hulst (1984)). Initially such clusters are due to adjunction of the velar consonant.

(25) Rhyme head

|V| (nucleus)

|V| (vowel)

Laryngeal[37]

Primary
C (H)
C;V (H-mid)
V;C (L-mid)
V (L)

Secondary ⊗
C (h)
V (h)

Place[38]

C (front-spread)
C;V (front-round)
V;C (back-spread) ‘inrounded’
V (back-round)

Manner

Primary
C (high)
C;V (high-mid)
V;C (low-mid)
V (low)

Secondary ⊗
C (nasal)
V (pharyngeal [ATR/RTR])

Laryngeal distinctions in this case refer to contrastive tone. RcvP claims that phonation and tone are ‘in complementary distribution’, the former occurring in the onset head and the latter in the rhymal head. The secondary tonal specification represents the notion of ‘register’ as occurring in Asian tone languages which can have up to four contrastive tones in both registers (Yip 2002). In these languages contour tones are unitary contour tones where {C;V} and {V;C} refer to rising and falling tones rather than intermediate level tones. African tone systems do not employ register for lexical contrast and in these languages the intermediate structures refer to different level tones.[39] This is an example of an areal difference in the phonetic interpretation of element structures.

Place distinctions maximally create a four-way contrast, with central or ‘interior’ vowels being placeless (and thus marked). The distinction between inrounded and outrounded vowels occurs in Swedish (cf. Malmberg (1951), Ladefoged & Maddieson

[37] Here we do not discuss the details of laryngeal/tonal distinctions; see van der Hulst (in prep.).
[38] We note that vowel place, given the relative smallness of vowel sets as compared to consonant sets, does not require a distinction between a head and dependent subclass.
[39] We assume that African tone systems do not use register for lexical tone distinctions. Possibly register enters at the phrasal level to accommodate downstep and downdrift; see van der Hulst & Snider (1993).

(1996: 295)). Manner captures vowel height (aperture), where nasalization and tongue root position[40] are expressed in terms of secondary manner elements.

Sonorant consonants that occur as nuclei (syllabic sonorants) have the same structural options as bridge sonorants with the added possibility of laryngeal (i.e. tonal) distinctions. This would also be the structure of sonorant consonants as the preferred option in codas:[41]

(26) Rhyme dependent

|V| (nucleus) / |V;C| (coda)
|
|C:V| sonorant consonant

Laryngeal
C (H)
C;V (HM)
V;C (LM)
V (L)

Manner
C (nasal)
C;V (lateral)
V;C (rhotic)
V (glide)

Place
C (palatal)
V (labial)

Obviously, the syllabic glide option will be difficult to distinguish from a regular vowel.

Possibly the tonal specification of a coda position is more limited than allowing a four-way primary distinction, but no register distinction. Asian tone languages do not bear different tones on the nucleus and coda.

This concludes our review of the contrastive possibilities in the various ‘core’ syllabic positions; we did not here discuss contrastive options in syllabic adjunct positions.

[40] We assume that RTR and ATR are two possible phonetic interpretations of ‘pharyngeal’. Indeed, no language makes contrastive use of both; see van der Hulst (to appear-b).

[41] Possibly, tonal structure for a syllabic consonant or coda consonant is more limited (in not having the choice of secondary ‘register’ specification).

5. The representation of complex segments

We can now turn to how RcvP represents segments, specifically consonants that have traditionally been designated as being ‘complex segments’.

5.1 Complex consonants

In section 4, we outlined the structure of segments and syllables in the RcvP framework, and in the course of this representations were provided for most segments that are traditionally called complex, such as ‘contour’ segments (in the sense of Sagey (1986)) and segments with secondary articulation. The term contour segment is traditionally used for affricates and prenasalized consonants because in binary systems both get two opposite specifications for the same binary feature ([continuant] and [nasal], respectively (sidestepping the question whether similar contouring is also possible for other features, or if it is not, why not).

5.1.1 Affricates

Affricates result from a combination within the head manner class:

(27) affricates Complex primary manner: {C;V}

Non-strident fricatives are {V;C}. They thus have the same complexity as affricates although they are not phonetically complex in the sense of requiring phonetic sequencing.

We will not enter into all the issues that affricates have given rise to in the past decades. We also draw attention to the fact that affricates may also arise as the phonetic realization of palatal or alveopalatal places or articulation, see e.g. Lin (2011) and references cited there; as well as Ladefoged & Maddieson (1996: Ch. 3).

5.1.2 Consonants with secondary manners

In all of the cases below, a primary manner is provided with a secondary manner. We assume here that only simple primary structures actually occur with a secondary manner.[42]

(28)	a.	- prenasalized consonants	Secondary manner {c}
			Prenasalized stops: Manner {{C}c}
			Prenasalized fricatives: Manner {{V}c}
	b.	- lateralized consonants	Secondary manner {c;v}
			Lateralized stops: Manner {{C}c;v}
			Lateralized fricatives: Manner {{V}c:v}
	c.	- rhoticized consonants	Secondary manner {v;c}
			Rhoticized stops: Manner {{C}v;c}
			Rhoticized fricatives: Manner {{V}v;c}
	d.	- pharyngealization	Secondary manner {v}
			Pharyngealized stops: Manner {{C}v}
			Pharyngealized fricatives: Manner {{V}v}

With reference to (28) we make some further observations: prenasalized stops ((28a) often take the place of voiced stops in segmental inventories (that is, such languages contrast voiceless stops with prenasalized stops). In such languages, the nasality could be analysed as a phonetic exponent of voicing (cf. affricates, above). However, there are also languages in which a full set of stops (voiceless, voiced, and prenasalized) contrast, and languages where prenasalized stops result from nasal vowel + stop combinations, or nasal stops followed by an oral vowel. Prenasalized fricatives may be realized as prenasalized affricates, so the latter need not be recognized as a separate contrastive category. No languages contrast the two (Poser 1979, van de Weijer 1996). For general discussion concerning prenasalized stops, see e.g. Herbert (1975), Anderson (1976), Feinstein (1979), Sagey (1986), Piggott (1988), Rosenthall (1992), Maddieson (2009) and Riehl & Cohn (2011).

[42] It would seem that the extra complexity of the secondary subclass is ‘compensated’ by adding secondary properties only to simple head structures to avoid an abundance of complexity.

Lateral fricatives (28b) may be interpreted as lateral affricates. Similar to prenasalized fricatives and affricates, we think no contrast ever holds between lateral affricates and lateralized fricatives.

Rhoticized stops (28c) have rarely been described, but the consonant described as [dr] in Mapudungun (Mapuche) (Zúñiga (2000), Smeets (2008)) is a serious candidate. However, we suspect that secondary lateralization and rhoticization are not, in practice, contrastive since no language appears to have both. Therefore, most likely, we only need secondary 'liquidization' {C:V}.

Pharyngealization ((28c) is usually described as a kind of secondary articulation on a par with labialization and palatalization (see § 5.1.3), but here the RcvP framework suggests to consider this as a secondary *manner* type instead. A possible support for this approach is that labialization and palatalization are more closely related to the vowel types that are expressed by the same elements (round vowels and front vowels, respectively) than pharyngealization is to low or back vowels. Here we note that the secondary articulations of velarization, uvularization and pharyngealization do not tend to contrast in languages (Maddieson 1984), and Jakobson, Fant & Halle (1952) capture all three with the same feature [flat].

5.1.3 Consonants with secondary place

While velarization has been analysed as a secondary manner type, the other two traditional cases of secondary articulation involve secondary place:

(29)	"Secondary articulations"	
	- palatalization	Secondary location: Place {{..}c}
	- labialization	Secondary location: Place {{..}v}

These two cases of secondary articulation are straightforward and attested phonemically in a large group of languages, especially with respect to labialization (Ladefoged & Maddieson 1996: 354ff). There may also be other types of secondary articulation, such as labiodentalization (Ladefoged & Maddieson 1996: 366), which could involve an [ü]-like superimposition, i.e. secondary {cv}. This is not unexpected given that these are independent gestures. However, there is no secondary articulation, for instance, that corresponds to the vowel "/e/". This follows from our assumption that dependents are not complex: they show the three (or four) primary elements.

5.1.4 Segments with two major places

Before we turn to multiple articulated consonants (MACs), clicks and short diphthongs, let us make explicit (with reference to the place class structure in (23)) how place distinctions are represented:

(30) C-Location

Head	**Dependent**		
C (coronal, laminal)		{C}	dental coronal [t̪ d̪]
	c (palatal)	{C{c}}	palatal [ʃ ʒ]
	v (labial)	{C{v}}	rounded coronal [t^w]
C;V (coronal, apical)		{CV}	apical/alveolar coronal [t d]
	c (palatal)	{C;V{c}}	pal. alv/ [t^j]/alv.pal [ɕ ʑ]
	v (labial)	{V;C{v}}	retroflex [ʈ ɖ]
V;C (per./dorsal)		{CV}	plain dorsal, uvular [q ɢ][43]
	c (palatal)	{C;V{c}}	fronted dors[k^j]/pal-vel. [ç ɟ]
	v (labial)	{V;C{v}}	rounded dorsal [k^w]
V (per./labial)		{V}	plain bilabial [p b]
	c (palatal)	{V{c}}	palatalized labial [p^j]
	v (labial)	{V{v}}	rounded (bi)labial [p^w]

The primary structures produce the four-way major place distinction in the first column, while secondary {c} and {v} add secondary articulations which in some case delivers segments that would not necessarily be regarded as phonetically complex (but see e.g. Keating (1988) on palatals).

Both clicks and MACs seem to combine two major places of articulation. The evidence for designating one or the other as the head is inconclusive. [kp], for example can neutralize to either a labial or a dorsal (see Danis (2015)). Regarding clicks, different researchers have treated either the coronal or the dorsal place as pivotal.[44, 45] We suggest that the special option to combine places leaves the headedness unspecified. We will call such structures *compound structures*.

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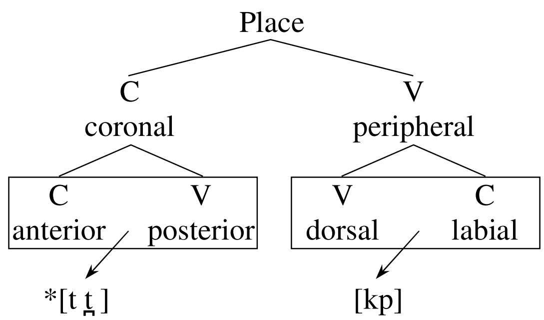
43 Uvulars have secondary pharyngealization. Pharyngeal consonants also have secondary pharyngealization, while they lack a place structure.

44 The coronal part is taken to be the primary location (as suggested by Trubetzkoy (1939 [1960]),Jakobson, Fant & Halle (1952), and Chomsky & Halle (1968)). Danis (2015) shows that clicks reduce or neutralize to or alternate with dorsals in Fwe and Yeyi.

45 References on clicks include Bennett (2008, 2009, 2014), Bradfield (2014), Jakobson (1968), Ladefoged & Traill (1984, 1994), Miller (2017), Miller, Namaseb & Iskarous (2007), Sagey (1986), Traill (1993, 1995), Wright et al. (1995).

First turning to MACs, one might expect two options if the places that are combined in a compound structure have to be 'sisters' in the CV-structure for place:

(31) Compounds with sister place structures



Arguably, combining the two coronal places does not produce a viable MAC because both being coronal it is not possible for the tongue crown to be in two places at the same time.[46] This is different for the two peripheral places which can be combined to produce the only MAC that has been reliably attested, namely labial-velar [kp]. As argued in Bennett (2014), claims for labial-coronals or labial-palatals as single segments are not strong: these events are more likely better analysed as consonant clusters.[47]

If both clicks and multiple articulated segments are in some sense complex place-wise, how do we derive clicks? Rather than combining two sister places, we could assume that clicks involve a compound structure, consisting of a coronal place (either {C} or {C;V} to recognize the fact that the coronal part can differ contrastively) and a 'peripheral place' with dorsal perhaps as default.

(32)	{{C} ; {V}}	dental coronal click
	{{C;V} ; {V}}	alveolar coronal click
	{{C} ; {V;C}}	?labial click
	{{C;V} ; {V;C}}	?labial click

[46] This shows, as also emphasized in Bennett (2014), that the phonology can produce structures that do not have a 'sensible' phonetic interpretation.
[47] Of course, we still need to account for such 'clusters', since they cannot be proper onsets. We will suggest a two-root approach below (§ 6).

The question arises whether the option of allowing a compound combination of a coronal and peripheral place should allow the latter to be either dorsal or labial. If we allow such a contrast, we derive two coronal-labial combinations. While that could deliver a [tp/pt] articulation (with either a dental or alveolar coronal), there is no phonetic mechanism that can create underpressure between the labial and the coronal articulation. So, while this option could be a way of representing [tp/pt] in a manner that is different from [kp] (which combines two sister places), this would not result in a labial click. Labial clicks are very rare (Bennett 2014). It is possible to suggest that bilabial clicks and labial-velar stops have the same representation, and the difference in airstream is 'phonetic' (see Bennett (2014) for a critical evaluation of this idea and important discussion). Although this proposal seems bold, Ladefoged (1968) notes that bilabial clicks are allophones of labial-velar stops in some West African languages. Secondly, we know of no language in which these segments contrast (corroborated by Bennett (2014: 119)), although it is hard to draw firm conclusions given the rareness of these segment types in the first place. And finally, a nasal bilabial click is a possible realization of a labialized nasal /m^w/ in Ndau, a Bantu language spoken in Mozambique (Jones 1911). This suggests that the representations of these kinds of consonants may be quite similar, again making the proviso about the amount of evidence noted above.

In (33) we summarize our proposals for MACs and clicks:[48]

(33)	Click	{{C} : {V}}	dental coronal click
		{{C;V} : {V}}	alveolar coronal click
	?[pt]	{{C} : {V;C}}	
		{{C;V} : {V;C}}	
	[kp]	{{V} : { V;C}}	

Both MAC(s) and clicks involve multiple articulations. For [kp] the airstream is egressive, but a bilabial click has the same places of articulation with velaric suction,

[48] [nasal] is an important aspect of clicks, since every language that has clicks, has nasal clicks (Bennett 2008). Secondly, as is well known, clicks typically have a very restricted distribution: clicks are never codas (ibid.). We suggest that nasal clicks are in fact sonorant clicks. The non-occurrence of clicks in coda position can then be regarded as part of a general pattern in which codas display neutralization of contrast.

and as a result the airstream will be ingressive. However, in the RcvP model, there is no need for independent airstream elements.[49]

We will leave undecided whether the coronal-labial compound combination is viable for [pt]; as mentioned above, this would not equate them with [kp] because the latter combines sister places, while the formal does not. The position that [pt] is a consonant cluster shifts the problem of representing them to the syllabic level, since they cannot be proper onsets.

Turning to the manner class, compound combinations of sister manner structures for obstruents do not create results that produce phonetic events that are viable:

(34) C (stop) + C;V (affricate)
V (strident fric) + V;C (non-strident fricative)

The first structure would essentially be an affricate for which the structure {C;V} is sufficient (and simpler), while the second structure does not lead to a coherent phonetic event if a stridency contour simply cannot be realized phonetically.

Combining non-sister manner leads to yet another representation for affricates which we therefore do not need.

(35) C (stop) + V (fricative)

Combining non-sister manners for vowels might lead to a perspective on short diphthongs that have a rising or falling sonority profile such as [ia], [ua] (see § 5.2.1).

Turning to the laryngeal class, we do not find it likely that there will be a need for combining two head laryngeal option (fortis and voiced) for obstruents, given that voicing does not even allow contours in obstruent clusters. On the vowel side, combining two tones might be useful to represent contour tones on short vowels (see § 5.2.2).

In conclusion, compound structures within the head classes provide an insightful perspective on MACs and clicks, when applied to the head place class for consonants. In all other cases, using this option leads to combinations of structures that are too close

[49] Implosives and ejectives are analysed as phonetic realizations of specific phonation types; see van der Hulst (2015a), (in prep.)).

phonetically, although in some cases (short diphthongs and contour tones on short vowels), this option could be explored further; see §§ 5.2.1 and 5.2.2.

5.2 Complex vowels

In this section, we (very) briefly deal with complexity in vowels. In our view, this can refer to place complexity (as in (short) diphthongs, § 5.2.1), tonal complexity (as in contour tones on short vowels, § 5.2.2) and vowels with special phonation (§ 5.2.3) or manner of articulation types (§ 5.2.4).

5.2.1 (Short) diphthongs

Diphthongs are branching nuclei, but what about so-called short diphthongs? These segments have created some controversy in the analysis of some languages such as Old English (see e.g. Bauer (1956), Hogg (1992), White (2016)). We will not take a stance in this debate, apart from noting that in RcvP it would be possible to represent short diphthongs as having two place structures (just like a two-root labial-velar also counts like a 'short' (normal-length) consonant. In other languages, such as Modern Icelandic, Fijian and Sami, short diphthongs also exist, but it is questionable if there is a phonemic short-long contrast in these cases. Maybe the best possible case for such a contrast comes from Maori where fa.kai.ri 'elevate' contrasts with ka:i.ŋga 'home' (examples from Bauer (1993), cited in Gordon (2006).

5.2.2 Vowels with contour tones

The literature distinguishes two types of contour tones (see e.g. Hyman (2011), Yip (1989), Yip (2002) , etc.): unitary contour tones (as in Asian languages) and compound tones (as in African languages). Consider also the evidence presented by Yip (2002: 203) from Thai, where vowel length is reduced if it is part of a word that appears as part of a compound. Careful instrumental investigation (Gandour 1974, Gandour, Tumtavitikul & Satthamnuwong 1999) has shown that the five-way tonal contrast of Thai (including a HL contour tone) is preserved in such shortened syllables. The same kind of rule occurs in Dschang (Pulleyblank 1986). We analyse the Asian contour tones as unitary tones that result from a regular tonal specification in the head class, with an added secondary register specification. The intermediate head class structures ({C;V} and {V;C}) represent falling and rising tone in register languages. This means that the occurrence of tonal contour in short vowels do not require a combination of primary tonal structures.

Duanmu (1994) has suggested that contour tones on short vowels do not exist, but it would seem that African languages have provided evidence for 'dumping' a tone of a deleted vowel onto a preceding vowel that already carries a tone. This happens regardless of whether the vowel is long or short. We suggest that for those cases a compound structure (two primary tonal structures) could be useful.

5.2.3 Vowels with 'special' phonation

As sonorants, vowels are usually voiced. In this case, voicing is simply implied by these segments being sonorants and no laryngeal specification of voicing is required.[50] If the laryngeal node for vowels is providing tonal structures, specification of voicing is not even possible. Voicelessness in vowels has been claimed to always be allophonic. An example, for instance, comes from vowel devoicing in Japanese, which devoices high vowels between voiceless consonants and word-finally after voiceless consonants (see e.g. contributions to van de Weijer, Nanjo & Nishihara (2005) and references cited there). However, such vowels are argued to occur contrastively in Turkana (Dimmendaal 1983, Gordon 1998). Vowels can also have breathy or creaky voice contrastively (Maddieson 1984: 132ff).[51] We are not sure that this requires a phonation interpretation of their laryngeal node, which, then, would exclude tonal interpretations.

5.2.4 Vowels with special manner

A final type of complexity in vowels occurs in vowels that have consonantal aspects of articulation. An example here would be "fricated vowels", which have been found in African languages and also in various Chinese dialects (Ladefoged & Maddieson (1996: 313), Wiese (1997), Connell (2007), Lee-Kim (2014), Sloos, Ran & van de Weijer (submitted)). These vowels (which are typically high, just like the voiceless vowels in § 5.2.3) have clear indications of frication in their waveform and formant structure (see references cited above for discussion and illustration).

Rhotacized schwa of course occurs in American English. Just like rhotacized vowels (and later centering diphthongs) resulted from r-loss in British English (*carve* →

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[50] Sonorant consonants can carry contrastive phonation properties such as aspiration (see (19), so technically they could also be specified as voiced or fortis.
[51] Maddieson (1984: 132ff.) also mentions 'pharyngealization' on vowels which lends some support to the idea that pharyngealization is different from place of articulation (see above).

[ka:v]), sometimes "lateralized" vowels are posited as a historical stage in English l-loss (*half* → ha:f) (Pilch 1997). However, it is hard to say what the latter type of vowels should phonetically correspond to.[52]

Potentially, all these kinds of vowels could be represented as two-root segments; as discussed in the next section.

6. Branching syllabic constituents and 'two-root structures'

Since our view on syllable structures allows branching onsets (and branching rhymes), we accept that the traditional view on the structure of prevocalic (and tautosyllabic) /kl/, /br/ etc. in language such as English as branching onsets. In some approaches, branching onsets (or any branching syllabic units) have been banned.[53] Here we do not make a comparison between such approach and our syllable theory; see van der Hulst (in prep.).

Another theoretical possibility that could be explored is whether certain complex events can be analysed as **two-root structures**. This theoretical option is explored by van de Weijer (1996), where it is suggested that clicks have two independent root nodes. While we do not, perhaps, need this option for clicks (for which we have suggested compound place structures of non-sister places), van de Weijer points that out multi-root representation may also be useful in other cases. For example, nasalization on vowels may have a different status in different languages, referring to Polish (Rowicka & van de Weijer 1992), where nasalization may involve a two-root structure resulting from compression of independent segments. While perhaps no language will distinguish two types of nasal vowels (but see Ladefoged (1971: 35) for a possible case in point), it may be 'realistic' to allow representation that reflects different degrees of intimacy between the vowel and the nasal element. What this would mean is that although the criterion of being contrastive in a single language is the main criterion for proposing structure, it need not be the only criterion.

An additional usage of double root structure could lie in providing an account for 'improper' onsets such as /pt/ (if not analysable as compound structure with two non-

52 Rhotic vowels and rhotic harmony occurs in Yurok; see Smith, de Wit & Noske (1988).

53 Lowenstamm's strict CV approach bans all branching units, allowing CV as the only syllable structure (Lowenstamm 1996). Alleged branching onsets as either analysed as two onsets with an intervening empty nucleus or as complex segments, which could be analysed as /p^{r}/. Duanmu (2011), who suggests CVX is the universal syllable structure, proposes to analyse all alleged branching onsets as complex segments.

sister places) or, for that matter, initial ‘onsets’ that as Dutch /kn/ or /xn/, or any instance of improper onsets (i.e. onset that do not consist of an obstruent and sonorant), including all /s+C/ clusters. If thus used, we could perhaps do away with initial adjunction. We leave the exploration of the potential usage of double root segments, which would then also have to be explored for vowels in nuclear position (giving us another window on short diphthongs) for another occasion.

7. Conclusion

In this chapter, we have offered an RcvP perspective on relative complexity. We have outlined the architecture of Radical CV Phonology, a model that reduces all phonological distinctions to structures that contain maximally two element, C and V. While an unconstrained combinatory system would produce an infinite set of structure, ranging from simple to increasing degrees of complexity, we have proposed that the generative engine is curtailed by a principle of binarity. In various instances, we have shown that the adoption of head/dependency relations allows us to make sense, not only of which categories can occur, but also of various kinds of asymmetries in phonological representations. Using the formal apparatus of RcvP, we have argued segmental complexity is a relative property and that there thus is no coherent notion of ‘complex segment’, showing that the members of this traditional class display complexity at different levels of structure. Whereas affricates result from a combination within the primary manner class, several other cases involve some type of secondary structure. Still different are multiple articulated consonants and clicks for which we have proposed compound structures (i.e. a combination of two head class structure in the place class).

We have related segmental complexity to markedness: whereas a one-to-one relation between a higher (class) node and a content unit (element) is unmarked (at the segmental level), a divergence from this results in markedness: either ‘undershoot’ (zero elements) or ‘overshoot’ (i.e. complexity, branching: two elements) results in marked structures. However, matters are complicated by the fact that minimality requirements cause some structures, being complex, to be less marked than simpler structure which are ‘incomplete’ (such as an onsetless syllable or a place segment).

We finally discussed theories that ban complex onsets, resulting in syllable-initial consonant ‘clusters’ being analysed as complex segments (or two onsets with an intervening empty nucleus). The motivation for such proposals seems to be reductionist (it turns all syllables into CV(X). Although this is an interesting line of research, we have been ‘conservative’ in making a difference between segmental structure and syllabic structure. Only in the context of a complete proposal for *both* can we evaluate the relation between (complex) syllabic units and (complex) segments. While providing such a complete proposal was the goal of this article, we admit that much work needs to be done in order to make comparisons of the formal and substantive content (in terms of phonetic interpretation and empirical coverage of contrast).

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