Fission in component-based phonology

Jørgen Staun

ms.

Published in: *Language Sciences* 40 (2013), 123-147.

Fission in component-based phonology

Jørgen Staun

Department of English, Germanic and Romance Studies, University of Copenhagen,
Njalsgade 120, DK 2300 Copenhagen S, Denmark
E-mail address: staun@hum.ku.dk

ABSTRACT

This paper advances a novel view of the interrelatedness of the ultimate phonological components. Accepting that these are unary, the paper hypothesises that the phonological components in the three segmental gestures, articulation, categorisation and initiation, can be seen as modulations of basic pulmonic pressure. The modulation is viewed as a result of fission processes splitting nuclei into fragment nuclei which again can undergo further fission at the same time as the nuclei undergoing fission are preserved. The fragment components arising from fission exhibit greater phonetic sophistication than their mother nuclei, because they appear as a result of a demand for more detailed phonological differentiation. Fissional fragment components are developed for all three gestures and the paper deals with a variety of phonological contrasts and attempts to calculate the markedness value of representations.

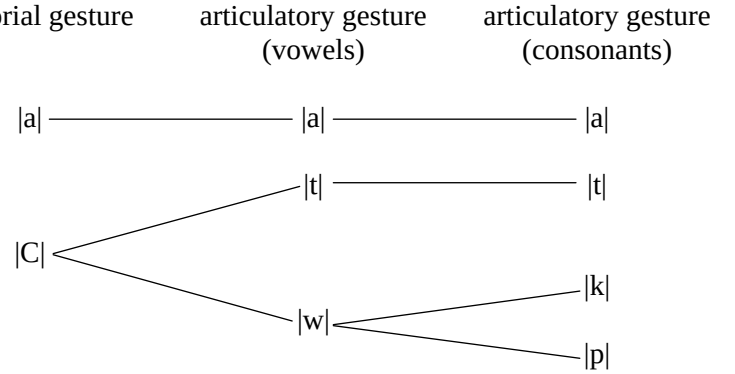
1. Preamble

Dependency/government phonology in its standard form builds on two well-substantiated assumptions about the internal structure of phonological segments (see Anderson and Ewen, 1987; Lass and Anderson, 1975; Lass, 1976; Ewen and van der Hulst, 2001). The first assumption involves the claim that phonological segments are organised in three phonetically and phonologically motivated gestures (sub-segments), each of which typically describes the initiation, the categorisation and the place of articulation of speech sounds. The second assumption involves the contention that the phonological primes used to specify the internal structure of each of these gestures constitute a restricted set of unary components which typically interact in dependency/government relations, the type and number of which depend on the multitude and character of the phonological contrasts that require differentiation and on the definition and nature of the unary components used to represent such contrasts (see Anderson and Jones, 1974, 1977; Anderson, 1980; Anderson and Ewen, 1987; van der Hulst, 1989, 1994, 1995). The description of phonological constituents to be presented in this paper is founded on both these views about the architecture of phonological segments and the constituents used to describe them. But where dependency/government models normally fail to express in any very explicit way that the phonological components of individual gestures are inter-related or that the number of components is not random, the present proposal contends that the basic components make up a restricted but non-arbitrary and phonetically inter-connected system. The phonetic inter-connectedness and non-arbitrariness of these components, not only gesture-internally but also cross-gesturally, follows from a fundamental hypothesis of this system. This hypothesis is that principally all components are viewed as products of basically the same kind of process. The process is instrumental in the creation of all the ultimate phonological components used to describe the internal structure of the three gestures. This process splits or propagates a nucleus component into one or more fragment components, at the same time as the mother nucleus of this expansion continues to exist independently. Fission, as this process will be referred to, is induced by gestural domain, in particular by the number of phonological contrasts requiring differentiation in each gestural domain, but all fission of nuclei involves copying and refinement of the phonetic properties of the mother nuclei so any new fragments resulting from fission of a nucleus share some phonetic material with their mother nuclei, at the same time as they differ from them and in case of binary splitting from one another in terms of phonetic sophistication. The duplication and refinement involved in fission mean that the components of such a system as will be presented below not only remain unary, since all fissionable nuclei are unary, but also that its components make up a set which is phonetically inter-connected such that gestures, albeit discrete, also share properties thanks to the components' common phonetic core.

Fission is commonly associated with the natural sciences. The term is adopted here because fission in both nuclear physics and biology resembles fission as this term is defined here (see Cottingham and Greenwood, 2001; Carter et al., 2005). As in nuclear physics, phonological fission splits a nucleus into fragment components, but unlike in nuclear physics phonological fission is without by-products such as damaging gamma ray-like entities, and without the loss of the nucleus undergoing fission. On the other hand, induced fission, despite its negative implications as the driving force of nuclear weapons, has a parallel in phonology. Phonological fission is also non-spontaneous, generated in particular by the need for phonological differentiation. In biology, phonological fission is paralleled by the binary replication found in cell duplicating mitosis and the division that prokaryote cells without a nucleus undergo. Both biological processes involve the generation of two equal or nearly equal daughter cells as a result of binary fission. But again, as in nuclear physics, the parent nucleus ceases to exist after biological fission, whereas in phonology the nuclei undergoing fission continue to exist because contrast differentiation drives the fission process, and both parent and daughter components are needed for the characterisation of phonological distinctions. Probably biological gemmation more closely resembles phonological fission without being completely the same. As a result of gemmation, a bud-like cell separates from a parent and begins an independent existence, but although the parent is preserved, sophistication in the new fragment is negligible, if at all observable. Finer details aside, phonological fission thus bears some resemblance to elemental transmutations in the natural sciences, but phonological fission also differs in important ways from them, notably in the preservation of the fissioning nuclei and in the sophistication of the copy fragment components, just as it remains to be seen whether it is only in phonology and not in nuclear physics and biology that fragments enter into government/dependency relationships. In fact, phonological fission differs in one more and important way from natural elemental transmutations found in nuclear physics and biology. In phonology some fission processes presuppose other fission processes. Therefore in phonology fission, as it is understood here, is seen as a series of interconnected binary divisions or sophisticating unary transformations and the term is intended to cover either in the following. The components resulting from fission also make up a phonetically coherent system of entities which allow for contrasting speech sounds. A similar coherence exists in the system proposed by Chomsky and Halle (1968), the features of which are held together by being articulatorily defined, and in the system of Jakobson et al. (1951) which exclusively consists of acoustically defined features. But in neither system does coherence entail systematic organisation of matrices in gestures just as features, be they articulatory or acoustic, are not interpreted as instances of refinement or sophistication of a core common to all primes. In the model to be proposed here such a common core assumption is basic and coherence is obtained because fission has to start where such coherence can be ensured. One plausible starting point is fundamental pulmonic egressive compression, an initiation type used in all languages.

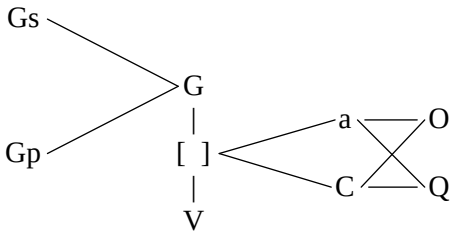
The hypothesis is therefore that the basic fission process, basic because its fission products feed other fissions, involves the bifurcation of pulmonic egressive initiation. This initiation type is thus seen as the 'epicentre' of phonological component formation, being the phonetic pulse always used in a language. Initially, fission involves the splitting of this fundamental nucleus into the fragments consonantality and vocalicness. Its universally stable and balanced status opts for an interpretation of this basic nucleus as unary in line with much work in dependency/government phonology. Thus the fission of this nucleus as well as the fission or transformation of its fragments and its fragments' fragments will result in components which are also unary. At the same time, because it is induced by the need for phonological differentiation, fission as a process involving successive binary replication results in increasing sophistication of components and thus more generally creates a phonetically coherent system of phonological components. The most basic fission process splitting pulmonic egressive initiation into vocalicness and consonantality provides the components |a| and |C| respectively. As unary and as always present entities, these components may fission into three or more fragment components. Fission of the basic two categorial components, |a| and |C| is characteristic of specifically the articulatory gesture, whereas the categorial gesture, hosting the two basic components, exhibits fission internally if phonological differentiation in the form of phonologically relevant laryngeal settings requires it. As supplier of componential energy, the initiatory gesture typically is unspecified, but phonologically relevant suction and glottalic pressure mechanisms, when these relatively rare mechanisms are used, require individual components and thus presuppose initiatory fission other than splitting into basic |C| and |a|. Fission of these basic two into three components is always found in the articulatory gesture of vowels, since most if not all languages minimally have three (peripheral) vowels. Similarly, fission is also found in the articulatory gesture of consonants which typically requires fission into four components, given that the number of consonant place contrasts rarely is less than four. The following diagram shows the system of components and the fission paths that exist between the categorial and the articulatory gestures:

(1)



Although they are all the results of fission, components do not automatically undergo further fission in any gesture. Depending on a component's phonetic complexity, in particular its ability to distinguish phonetic subtleties, will prevent fission and the less radical transformation involving a single refined replica occurs. This 'uni-fissional' transformation characterises in particular |a| and |t| in the articulatory gesture. The absence of parallel paths for |a| and |C| is then a result of these components' articulatory potentialities, for example how non-low vowels are the consonantal properties of vowels and |a| then fails to fission in the articulatory gesture (whereas it naturally fissions in the categorial gesture). (1) does not show the fission path that exists between the categorial and the initiatory gestures. Because the initiatory gesture is the source of phonological component energy, this gesture feeds the other gestures by the fission of unspecified initiation into categorial |a| and |C|. In the unmarked case, initiation energy is pulmonic egressive compression (indicated by [ ] in (2) below). In addition to providing other gestures with phonological components, [ ] also is the nucleus of the initiatory component specifying velaric suction initiation, |V|, and glottalic pressure/suction initiation, |G|, the latter fissionable into |Gs| and |Gp|, glottalic suction and pressure respectively, all of which sophistications of initiation. Internally within the categorial gesture, |a| may further fission into |O|, glottal opening, and |C| into |Q|, glottal closure, if more glottal states than two require phonological differentiation. Thus the fission paths existing between the intiatory and the categorial gestures and internally within either gesture have the forms shown in (2):

(2) initiatory gesture categorial gesture



Section 2 will deal in detail with the definition of the components shown both in (2) and in (1), just as it will be shown when fission into fragment components is needed phonologically. Basically, all three gestures are specified in any language, but componential sophistication in each gesture as a result of fission depends on the phonological contrasts requiring differentiation. Thus in Koisan !Xoo (Maddieson, 1992) which has close to 100 click and non-click consonant phonemes will display an extended gestural representation, whilst a language like East Papuan Rotokas with six contrasting consonant and four contrasting vowel phonemes (Maddieson, 1992) requires a much less complex gestural specification. But the three gestures are always invoked no matter how many or how few contrasting phonemes a language has. Equally, since a component-

based description with a limited number of unary primes, as proposed here, clearly involves considerable reduction in the descriptive apparatus, an important element of such a descriptive model must be to compensate for this reductionist view elsewhere. This compensation, which is necessary to allow for a variety of phonological contrasts, is part of the second assumption on which this study is founded and which was stated at the beginning of this section. The compensation involves the invocation of relations between components, specifically relations in which components interact in government/ dependency combinations.

In particular, following the tradition of government/dependency phonology, such government/dependency relations can be asymmetric and unidirectional or symmetric and bidirectional (see Anderson and Jones, 1977; Anderson and Ewen, 1987). Taking |x| and |y| as examples of two unary components, an asymmetric relation is one in which |x| governs |y| (or vice versa) or |y| is dependent on |x| (or vice versa). A one-headed arrow usually expresses this relationship. So in |x→y| (|x;y| is also used to express the relationship) the direction of the arrow indicates the direction of government or that |x| is governor and preponderant and |y| dependent and subordinate. In a symmetric relationship |x| governs |y| and |y| governs |x|. A double-headed arrow expresses that |x| and |y| are equally strong, so |x↔y| (or |x:y|) represents the bidirectional (rather than unidirectional) government property of this kind of relation. A government/dependency relation may also be more complex and involve more than two components as in the relations just illustrated. For example, |x;y| may enter into a relation with a third component |z| such that |x;y| together governs |z| or such that |z| governs |x;y| collectively. The exact number of possibilities of such complex relationships will depend on the system of contrasts they are proposed to account for. In addition, to symmetric and asymmetric a third insymmetric relation will be invoked. Insymmetry involves one component at the time and raises the quality of a component to an *n*th degree. Intensity and depth are then the key words to describe this relation.

Besides such government/dependency relations associated with the relative value of some specific phonetic parameter, there exists a hierarchical or structural presupposition relation between components. In general, all articulatory components depend on the presence of fundamental |a| and |C| unless a language has only consonants and no vowels or only vowels and no consonants. Presupposition also applies gesture-internally. For example, |O| and |Q| in the categorial gesture are invoked only if |a| and |C| are also present, just like |p| and |k| presuppose |w| in the articulatory gesture. Such structural presupposition relations are closely linked with markedness and the expression of the relative complexity of phonological parameters. In component-based phonology, the relative complexity or markedness of phonological segments has so far been expressed in terms of the number of components, including zero, used to represent a segment so unmarked never involves more components than marked (see Anderson and Ewen, 1987; Anderson and Durand, 1988; Allan and Bauer, 1989; Anderson, 1997 and de Lacy, 2006a for a critique). Following these specialists, let us term such a phonological approach to markedness a representational markedness model. Thus in such a model, the two basic

categorial components |a| and |C| reflect the fundamental status of vowels and voiceless (aspirated) stop consonants across languages. Similarly, the three basic components, |a|, |t| and |w|, characteristic of the articulatory gesture of vowels, reflect the almost universal occurrence of /a/, /i/ and /u/ in languages and the equally fundamental status of the places of articulation, labial, coronal and dorsal among consonants. In the same vein, the apparently never absent pulmonic egressive airstream is conveyed by the empty nucleus specification in the initiatory gesture. Conversely, sound types such as those utilising a glottalic airstream or those involving glottal stricture other and more than classic pulmonic egressive voiced versus (aspirated) voiceless typically will be assigned relatively more complex (or at least not simpler) representations on the assumption that they presuppose classic pulmonic egression. The underlying assumption of representational markedness models is then that relative complexity is universally fixed. But inventory structure implications have not acted as the sole valid markedness diagnostics in the component-based representational markedness models. As acknowledgment of the invalidity of using frequency and implication alone, diagnostics like ease of articulation or perceptual saliency have been incorporated too. Recently, frequency and saliency, but not inventory structure implication, have been rejected as valid markedness diagnostics (Rice, 1999a,b; de Lacy, 2006a,b) in part because they represent E-language and not markedness-relevant I-language phenomena. Chomsky's E-language/I-language distinction is controversial (Chomsky, 1981, 1986 and for discussion Cook and Newson, 2007; Isac and Reiss, 2008), but invoking I-language only involves the rejection of diachronic evidence, language acquisition evidence as valid markedness diagnostics and the recognition of synchronic processual evidence as all that matters in markedness calculations. Jakobson (1941) and Blevins (2004), however, have shown how important both acquisition and diachronic evidence are for the understanding of markedness, so an exclusively I-language-based view on markedness will leave out crucial evidence and be considered too narrow here. A strict I-language view is also unfortunate because it rejects typological frequency as valid. Although it is controversial, typological frequency is one area where evolutionarily endowed knowledge shows through when high typological frequency coincides with high saliency, an interaction which can be no coincidence but must reflect a tendency in language evolution to select units with maximal communicative effect. However despite the relevance of diachronic and acquisitional evidence, not all Chomskyan E-language evidence should be regarded as valid as when one group of language users exerts extensive influence on another group in an immigratory or imperial context, or when communication break-down occurs as a result of, say, an extensive vowel shift. Such instances clearly disrupt the transparency of typological frequency and saliency or synchronically relevant markedness phenomena, but they are usually easily detectable by their context and, arguably, do not disturb the overall general picture of markedness and what diagnostics are relevant.

Although the position taken here that relative or zero markedness representations are universally fixed as predicted by a representational markedness model, fixed should not be taken to mean completely invariable. Not only are features ordered on a markedness

scale so if an unmarked feature, say glottal, is unavailable in an inventory the next least marked feature, coronal typically, will emerge as unmarked, but the phonetic detail required and the number and types of contrasts in a particular inventory also affect the complexity of representations in a representational model (for inventory structure and markedness, see Rice, 1999a,b, 2006; Causley, 1999). But the representation of one property never fluctuates more than markedness distinctions will be maintained. To sum up:

a. Not only purported processional synchronic I-language phenomena will be taken as valid markedness diagnostics; diachronic evidence, inventory typology and saliency will also count as valid diagnostics when mutually supportive
b. As a representational markedness model, the present proposal assumes that zero or more or less complex specifications are universally fixed
c. Universally fixed is subject to modification depending on the contrasts of a given phoneme inventory

A further and more general assumption is that markedness does not always involve a pressure to reduce or eliminate marked and promote unmarked elements. Markedness may also show through by giving special protection to and preserving marked elements. Both views go hand in hand with a representational markedness model. A problem listed as fatal for a representational markedness model that it cannot with its universalist assumption allow for conflicting markedness hierarchies is also not borne out. The structure of phonological segments in such a model with substantial hierarchical sub-structure is well designed to handle cases where there exists markedness conflict, as markedness hierarchies can apply to different subparts of phonological segments. Finally, it should be pointed out that a statement like feature x is more marked than feature y is better expressed as ‘feature y is never more marked than feature x’. This negative formulation confirms the cautious approach to representational markedness which characterised the earliest descriptions of government/dependency in which a unmarked feature never involved more features than a marked one (Anderson and Ewen, 1987; Anderson and Durand, 1988). Regrettably, there is no guarantee that a representational markedness model will cover all phonological markedness phenomena, but considerable progress can be achieved towards integrating this notion in a component-based phonological representation if these assumptions are kept in mind and adhered to.

The structure of the following will be as follows. Section 2 will outline the system of components and provide definitions as well as describe when fission is in order. Subsequently, Section 3 will review the fission/fragmentation necessary in the initiatory gesture, outlining the representation of a variety of glottal and velaric contrast types. Section 4 will focus on the categorial gesture and the fission necessary internally within this gesture, as well as describe the fission paths that link the categorial and the initiatory gestures. Finally, Section 5 reviews how fission refines the system of components so it also allows for the place of articulation contrasts.

The legitimacy of gestural and componential assumptions underlying this study will not be motivated further. Ample motivation has been adduced in the literature referred to above. The fission hypothesis is inspired in part by the work of van der Hulst who has shown how a bi-componential assumption is viable in the description of the internal structure of segments (see van der Hulst, 1994, 1995) and in part by work within feature geometry see, inter alii, McCarthy (1988), Staun (2003, 2005) in which the mutual relations between features are expressed in terms of organisational and superordinate nodes which can be seen as the precursors of fission nodes from which new components are created by a process of copying and sophistication. As for the calculation of markedness and this notion's interpretation in the most recent decades, the reader is referred to the works listed earlier, most notably the recent and comprehensive account by de Lacy (2006a,b) although he rejects representational markedness and the present proposal thus contests some of his claims. Since no further motivations for the underlying assumptions will be given, the following section will pursue the goal of outlining the internal structure of the three gestures on the assumption that in the description of this internal structure only two basic components suffice, viz. categorial |a| and categorial |C|, both of which are formed as a result of fissioning fundamental nuclear pulmonic egressive initiation.

2. The basic components

The phonetic energy of phonological segments is the flow of either ingoing or outgoing air. The latter is by far the most common, but the former is also used although no known language uses ingoing air only. The preponderance of outgoing, in particular such as has a lung-based pulse, determines that this is regarded as the source of component energy and the nucleus of the fission paths. The empty specification representing initiatory nuclear componentiality is then defined as follows (cf. Catford, 1977):

[ ] positive value for volume decrease as a result of a pulmonic pressure

Negative values for volume decrease as a result of ingoing air are also found but comparatively rarer, being characteristic of glottalic (implosives) as well as velaric suction (clicks). Such suction is sometimes the sole initiation of segments, sometimes both suction and pulmonic pressure are phonologically relevant in the same language, even sometimes characteristic of the same phoneme. Phonologically, velaric suction is represented in terms of the component |V| and since only one type of nonglottalic suction is used phonologically, |V| is defined as follows:

|V| negative value for volume decrease as a result of rarefying velaric suction

The lungs are the preponderant location of the outgoing pulse. The location can also be glottalic in which the speaker either pulls the closed glottis upwards producing oral compression before a simultaneous oral occlusion resulting in an ejective, or the speaker pulls the glottis downwards creating glottalically based rarefying suction. In the present

description, glottalic initiation is captured in terms of the component |G|, which is defined as follows:

|G| positive/negative value for volume decrease as a result of glottalic pressure or suction

The division is here between velaric and glottalic rather than between suction and pressure, because with a segment-internal division in which initiation is regarded as fundamental, fission is determined by the location of the speech source rather than by the direction of the air-stream. The internal supposition relation between initiatory [ ], |V| and |G| is determined by whether languages have ejectives or implosives or both without also having common or garden pulmonic egressive consonants. From 10 to 20 percent of the world's languages use glottallic ejective or suction mechanisms and according to Maddieson (1992) no language which requires |V| or |G| specifications seems to lack ordinary pulmonic consonants. That pulmonic egressive initiation occurs by default and as such can be considered a never absent airstream is then reflected by the empty initiatory specification. By contrast, the glottalic airstreams and the velaric suction mechanism are both specified, signalling their structurally dependent use, i.e. that they presuppose the use of pulmonic egression. These frequency-based and typological markedness observations are supported by phonological behaviour. In (Southern Amerindian) Cuzco Quechua (see Parker, 1997; Parker and Weber, 1996), ejectives, for example, are subject to heavy positional constraints, occurring syllable-initially in root onsets only. Outside these position – as well as in these positions naturally – voiced and voiceless stops crop up. The emergence of voiced and voiceless or the elimination of ejectives in roots and outside is a phonological indication of the more marked status of the latter. Similarly, for implosives the tendency in, for example, Afro-Asiatic Hausa to simplify sequences of implosive plus non-implosive obstruent to two non-implosive obstruents (Newman, 1987) and the repair operation in Niger-Congo Fula (Paradis, 1992) which restores an implosive plus non-implosive stop combination as a geminate non-implosive stop series suggests that implosives also are marked phonologically. The conclusion drawn by Clements and Osu (2002) that implosives come off phonologically as a class which is neither completely like that of obstruents nor completely like that of sonorants further supports the divergent status of implosives and thus the propriety of regarding this class as relatively more marked and hence represent this status in the initiatory gesture.

When glottalic suction and pressure require differentiation as when a language utilises both mechanisms phonologically, |G| fissions into |Gs| and |Gp|, two further fragment components defined as follows which, as they presuppose |G|, are never less marked than that |G|:

|Gs| negative value for volume decrease as a result of rarefying glottalic suction

|Gp| positive value for volume decrease as a result of a glottalic pressure

Whether these initiatory components also interact in government/dependency relationships because there exist, or it can be argued that there exist, phonologically relevant gradual relationships between initiation types, as has been claimed by, among others, Anderson and Ewen (1987), is a question which will be addressed in Section 3.

By its presence, |V|, the other fission product occurring in the initiatory gesture, also indicates marked status for velaric suction. As pointed out above, comparatively few languages make use of this suction mechanism, clicks being mainly restricted to languages of Southern Africa. Articulatorily, clicks are quite complex involving always two closures and a sequence of articulatory movements which are quite unique (see e.g. Ladefoged and Maddieson, 1996). Phonologically, the occurrence of clicks seems also to be constrained. In Niger-Kordofanian Zulu and Xhosa, for example, clicks never occur in affixes but appear in roots only (Beckmann, 1998). Such defective distribution and the emergence of non-click consonants in roots and affixes alike support the impression established by frequency and articulatory complexity that the click consonants are not less marked than non-click consonants.

An important tenet of fission, as it is understood here, is that the componential expansion following from this process involves copying and sophistication. Both |V| and |G|, as well as |Gs| and |Gp|, satisfy this requirement. Not only |V| but also |G| specify initiation, just as they differ from their fission nucleus in terms of the more exact location of this initiation. Similarly, |Gs| and |Gp| are fission products sharing glottalic initiation with |G|, their fission nucleus, at the same time as they individually specify opposite directions of the air-stream.

Turning to the categorial gesture, the components |a| and |C| always fill this gesture. |a| and |C| are the fission products of fundamental, (‘epi-central’) lung-based egressive initiation. Fission of [ ] is then manifested differently in the categorial gesture. As a domain specifying segment type and laryngeal setting, fission in this gesture produces components which primarily characterise consonants and vowels and sound types generally differing with respect to manner of articulation. The emanation of categorial components from the pulmonic egressive nucleus does not entail that the categorial components are incompatible with other initiatory specifications like |V| or |G|. Fission can be gesture-internal in the initiatory gesture and at the same time form new components on the segment stem in other gestures and these components, although emanating from [ ], are compatible with, say, |V| and |G| because the latter presuppose [ ]. Since no language seems to have only consonants and no vowels or only vowels and no consonants, the categorial gesture contains both |a| and |C|. Their apparent indispensability is signalled by specifying each type with one component. The question is what type of vowel and what type of consonant |a| and |C| represent individually. The following definitions should hint at the possible segment categories encompassed by the two components (cf. Anderson and Ewen, 1987):

|a| maximal openness and periodicity

|C| maximal stricture and zero output

These definitions, as required, reflect the nuclear origin of both fragment components. Simultaneous openness and periodicity are possible refinements of lung-based initiation, just like stricture combined with no outgoing energy production is a possible quality of the same lung-based pulse. Such opposite modifications of basic [ ] clearly must represent correspondingly opposite segment categories. Openness and periodicity evidently represent vowels, specifically as will become clear once the articulatory gesture is considered, some open unrounded version of /a/. Stricture and no output, on the other hand, characterise obstruent consonants. |C| in particular must represent some stop type and so far it has been assumed that this stop is the voiceless unaspirated stop. That it stands for a voiceless stop is indisputable given the specifications stricture and zero output. Whether it is aspirated or unaspirated is an issue which will be taken up later, but for now it will be assumed that it can represent either. In the categorial gesture, |a| and |C| interact in dependency/government relations and different constellations allow for manner types like fricative, sonorant, and nasal (see Anderson and Jones, 1977; Anderson and Ewen, 1987). Phonological clines as evidenced by lenition or fortition, sometimes following the full path from stop to vowel (see Rischel, 1970), thus receive an obvious description in the categorial gesture with |a| at the one end, |C| at the other end. The definitions of |a| and |C| allow no link to a contrastively significant feature like syllabicity in the categorial gesture. Syllabicity concerns the phonological function of segments and does not describe a clearly definable phonetic property. But it is obvious that |a| is associated with syllabic peaks and |C| characteristic of syllabic margins, at least in stressed syllables, but such properties cannot be part of the fission process proposed to be central here as this involves copying and sophistication of phonetically based properties.

|a| and |C| always occur in the categorial gesture. Arguably, like fundamental lung-based egressive initiation, |a| and |C| need then not be specified categorially, since, universally, vowels do not occur without consonants and consonants always coexist with vowels. But phonological inventories typically contain more than the two sound types, obstruent consonant and vowel (in a languages with this typology |a| and |C| would suffice actually, possibly even redundantly), and even a language like, for example, Indo-Pacific Rotokas (Maddieson, 1992) with no more than 10 contrasting phonemes requires more than just |a| or |C| to describe its typology. Structured combinations of |a| and |C| involving government/dependency appear to be necessary in any language in fact, and since the exact type of combination is never fully predictable, unspecified categorial gesture is not a viable option. But unspecified |a| and |C| would also involve the hypothesis that fission has a vacuous result in the categorial gesture. This would complicate the tenability of the further fission process purported to occur within this gesture.

The categorial gesture, it was suggested in Section 1, also hosts two further components, viz. the component |O| which specifies glottal opening, and the component |Q| specifying glottal closure. The gestural domain and general presupposition status of |O| and |Q| in relation to other categorial components is somewhat controversial, as will be discussed in Section 3. What is important to note at this point is that the categorial gesture phonologically serves two functions: it specifies manner types like stop, fricative, sonorant, vowel and at the same time it is the gesture hosting specifications for phonologically relevant laryngeal settings such as voiced, voiceless, aspiration, creaky and breathy voice. This double role is a challenge for any description of this gesture, but the challenge can be met if |a| and |C| are supplemented with the two fragment components, both of which are fragments following from the further fission of |C| and |a|. They are simply defined as follows:

|O| glottal opening

|Q| glottal closure

|O| and |Q| presuppose |C| and |a|. Two hypotheses regarding markedness follow from this presupposition assumption. Firstly, that the opposition types regarding laryngeal setting expressed by means of |C| and |a| are generally unmarked. As will be discussed in Section 4, both voiced versus unaspirated voiceless and voiceless unaspirated versus voiceless aspirated will be characterised in terms of |C;a| as opposed to |C|. These VOT oppositions, as they are often referred to (VOT = voice onset time), then fall under the heading generally unmarked, although not all equally unmarked probably (see Vaux and Samuels, 2005). Secondly, that other than VOT contrasts involving laryngeal setting will generally not be considered less marked. These laryngeal settings include creaky and breathy voice as well as contrastive glottal closure. Glottal stops aside, Maddieson (1992) provides some support for this division into VOT, on the one hand, and other laryngeal setting on the other. In the data base only about 10% of the languages have more than two series among stops involving non-VOT laryngeal setting and these even include types which in the present account are characterised as initiatory rather than categorial such as ejectives. The architecture of fricative series points in the same direction. There are about six languages in the sample that employ another type of laryngeal setting than voiced versus voiceless among their fricatives (in all cases creaky voice, see Section 4). Although two thirds of these utilise this kind of laryngeal setting instead of ordinary voice, the fact that so few languages in the sample use creak must be taken as indicative of its status as not more marked. Studies of intensity also support the view that creaky and breathy voice behave differently than other states. Thus in Mon-Khmer Chong (Thongkum, 1987) and Amerindian Hupa (Gordon, 1998), both creaky and breathy voiced vowels are characterised by overall less intensity. As such their saliency is lower than that of ordinary voiced vowels. In other gestures such as the articulatory gesture (Staun, 1996) low saliency coincides with marked status. Phonological evidence supporting marked status for non-VOT is not so easy to come by. Assuming that they are

breathy voiced stops, although this is controversial (cf. e.g., Bomhard, 1984, 2008; Hopper, 1973), Indo-European breathy voiced stops (written *bh*, *dh*, *gh* in the literature, see e.g. Lass, 1987; Lass and Anderson, 1975) and their behaviour provide some support, appearing subsequently as one or the other VOT type of stops in Slavic (/b, d, g/), Greek (aspirated /p, t, k/) and Germanic (/β, ð, ɣ/ subsequently /b, d, g/). As is well-known, breathy voiced stops did not disappear from the Indo-Aryan languages like, for example, (standard) Hindi and Gujarati, (this assumes that they are analysed as single segments and not sequences of two consonants, the latter analysis would minimise the problem substantially although not affect creaky voice sounds). Although firmly established in many Indo-Aryan languages, breathy voiced consonants nevertheless can be said to exhibit a declining tendency in some languages of this family. The breathy voiced stop series is absent in Punjabi and Kashmiri and occur only in Rajasthani initially (Masica, 1991). Sinhalese and Maldivian have lost phonemic aspiration entirely, whereas other languages belonging to this group tend to replace the aspirated stops with fricatives (Masica op.cit.). Although there is also evidence of aspiration and hence of breathy voice spreading, specifically to other sound types like nasals and laterals, the evidence suggests quite robust change towards VOT types of consonants when change is seen, and spreading to other sound types occurs when breathy voice already is phonological among the obstruents. The most obvious interpretation of this reduction tendency is to place non-VOT breathy voice setting among the marked ones.

It is more difficult to adduce phonological evidence supporting marked status for creaky voice. What can be adduced is closely linked to saliency, in particular the low saliency of the non-VOT types mentioned above. As a result of low saliency, languages tend to construct their phonologies with little use of creaky (and breathy) voice. Its distribution is often restricted occurring next to glottalised consonants, or it can be manifested synchronically as tone. In Amerindian Jalapa Mazatec, creaky voiced vowels are much longer than ordinarily voiced vowels, but the creaky quality yields to voice resulting in a vowel which is also voiced. Such distributional restrictions motivated by lack of saliency strongly suggest marked status for creaky voice, specifically when elsewhere high saliency can be shown to coincide with unmarked. To return to the components |O| and |Q|, marked status is then much more obvious for these two than for |C| and |a|. In one instance fission is then noncanonical. As is apparent from (1) and (2), both the categorial fragment component |C| and the categorial component |a| splits into two further but identical fragments. Not only |a| but also |C| bifurcates into |O| and |Q| because both consonants and vowels exhibit contrastive non-VOT types.

One issue still remains. Glottal stops were deliberately not included in the above discussion of markedness and the categorial components. But the glottal stop has long been considered an unmarked candidate because it emerges in epenthesis (see e.g. Lombardi, 2003) as well as being the product of consonant neutralisation (de Lacy, 2006a,b; Wells, 1982). |Q|, however, specifies glottal closure and as such should be categorised as unmarked given the phonological behaviour of glottal stops. Thus a characterisation in terms of single |Q| contradicts its unmarked status. But |Q| will not be

required to specify glottal stops phonologically. Only along with another component does it have phonological function. The need for phonetic detail, in particular when the glottal stop enters into a gradual relationship with other non-VOT categories can also represent an appropriate |Q|-context. However for all phonological occurrences of glottal stops, the placeless and categorial single |C| representation suffices, allowing for the unmarked status in epenthesis just as it can serve as phonologically sufficient in a language like Austro-Tai Gimi (Section 4). So the glottal stop is a default consonant, a consonant which is marked as obstruent but otherwise its articulatory specification is irrelevant and it is not one thing when it is the result of epenthesis and another when phonologically contrastive. The need for phonetic detail does not prevent it to be specified in terms of |Q|, when this use makes the interaction of glottal stops with other phonological contrasts more obvious.

As fission products of more basic |C| and |a|, |O| and |Q| also exhibit greater phonetic sophistication as required of components within the same gestural domain. Whilst |C| signals general presence of occlusion and stricture, |Q| specifically denotes a closed glottis. In the same way, |O| specifies an open glottis which is an extension of the moderate opening of the glottis and the general periodicity found in voicing, properties which |a| allows for in the categorial gesture. Outside the categorial gesture, |a| and |C| do not follow exactly parallel paths. As just pointed out, |a| does not undergo further fission although it reoccurs in the articulatory gesture as a result of a transformation involving a single refined replica.

|C|, by contrast, allows for articulatory sophistication fissioning into |t| and |w| in the articulatory gesture relevant for the place description of vowels, and |w| undergoes further fission and splits into the fragment components |k| and |p| characteristic of the articulatory gesture of consonants. This organisation of fission paths can be seen in (1). It remains now to define these further fragment components as well as |a| which not only is categorial but also articulatory. In the articulatory gesture, |a|, |t| and |w| have the following definitions:

|t| maximal degree of coronal stricture compatible with the categorial properties of the segment in question

|w| gravity and such maximal degree of non-coronal stricture as is compatible with the categorial properties of the segment in question

|a| maximal aperture and periodicity compatible with the categorial properties of the segment in question

And the fission products resulting from the bifurcation of |w|, i.e. |k| and |p|, specify the following properties:

|k| such post-coronal constriction as is compatible with the categorial properties of the segment in question

|p| such pre-coronal constriction as is compatible with the categorial properties in question

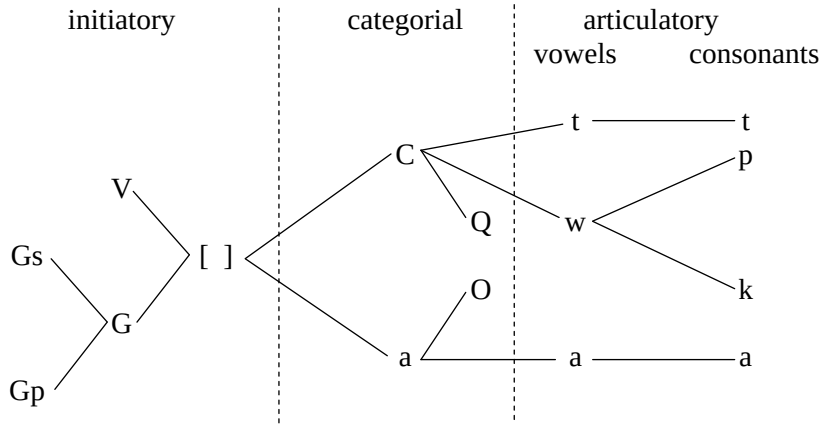
The definitions of articulatory (fragment) components are necessarily rather general and associated with a compatibility constraint because they serve, with the exception of |k| and |p|, as descriptors of both vocalic and consonantal place. The articulatory (phonetic) basis of these definitions is neither completely passive nor completely active. Instead the assumption is that displaced articulations are not the norm. Thus the definitions reflect that phonological contrasts in the alveolar region involve the coronal active articulator, that contrasts in the velar region involve the dorsal active articulator and that contrasts in the labial region involve the lower lip and so on. It is true that the definitions are very crude, but subtle phonetic differences are far from always utilised phonologically and if they are, then the fact that the components may interact in government/dependency relations and that contrasts may be expressed categorially too will compensate for the lack of such phonologically relevant distinctions.

Although general and crude, the definitions nonetheless increase in sophistication as required by the fission hypothesis, so fragment components exhibit greater phonetic detail than their mother nuclei. Thus while |C| refers to stricture, |t| and |w|, which are fragment sister components of |C|, refer to more specific coronal and non-coronal strictures respectively. Similarly, |p| and |k|, resulting from fission of |w|, define pre-and post-coronal constrictions, both more sophisticated forms of constriction than specified by |w| with its general element of gravity. As among initiatory components, there exist presupposition relations between the articulatory components too. |p| and |k| are only relevant for consonants. They presuppose |w| and all of |t|, |k| and |p| presuppose |C|. In a representational markedness model, single occurrence of a component in a specification is significant with respect to markedness, just as an empty initiatory specification represents a potentially less marked sound category. When single component specifications co-occur, say articulatorily, markedness distinctions are not lost, but signalled directly elsewhere. In such cases, fission paths or the general gestural architecture of phonological segments help identify the least complex specification and sound type, either in terms of fission nodes or number of gestures invoked. This and the general markedness calculation will be taken up in later sections.

The chief points of the fission hypothesis are then that the pulmonic egressive pulse constitutes the initiatory nucleus of speech and that from this nucleus unary components, categorial, intiatory and articulatory, emanate through processes of fission involving bifurcation of the basic nucleus as well as bifurcation of the fragment components resulting from fission. The organisation of the components (fragmentary or not) in the initiatory, categorial and articulatory gestures is as outlined in the following diagram showing all proposed components. In the articulatory gesture a special relation exists:

although |p| and |k| are fission products of |w|, the existence of consonants does not depend on the existence of vowels. Articulatorily, both sound types make use of |t| and |a|, depend on either so to speak, but interpret |w| in a more or less sophisticated way as expressed in the possible fission of |w|:

(3)



3. Initiatory contrasts

Few if any languages have velaric or glottalic contrasts without also having ordinary pulmonic egressive sounds. This section explores how velaric and glottalic contrasts are expressed on the assumption that pulmonic egressive is the unmarked basic initiatory pulse.

The glottalic airstream mechanism, as pointed out earlier, can involve either upward or downward movement of the (usually closed) glottis. Upward movement creates pressure between the closed glottis and the concomitant oral closure or stricture, the location of which varies. These sounds are known as ejectives. Downward movement of the (not always closed) glottis causes air to be sucked in creating what is known as implosives. Languages utilising either of these mechanisms require as a minimum the component |G| phonologically in the initiatory gesture, unless phonetic detail dictates that further specification is necessary in which case |Gs| or |Gp| will be used. By contrast, languages in which both mechanisms are contrastive need both components phonologically, |Gs| for implosives and |Gp| for ejectives. Thus in Armenian (cf. Maddieson, 1992) which has both pulmonic and ejective bilabial, dento-alveolar and velar stops but no implosives, the phonological initiatory representations shown below suffice:

(4)	pulmonic stops	p	t	k
	intiatory gesture	| |	| |	| |
	ejectives	p’	t’	k’
	initiatory gesture	|G|	|G|	|G|

whereas, for example, to describe Nilo-Saharan Maasai, which contrasts pulmonic and implosive stops but lacks ejectives, the following initiatory representations are sufficient

(5)	pulmonic stops	p	t	k
	initiatory gesture	| |	| |	| |
	implosives	ɓ	ɗ	ɠ
	initiatory gesture	|G|	|G|	|G|

In many languages ejectives and implosives contrast, well-known examples being Afro-Asiatic Hamer and Afro-Asiatic Hausa. (6) lists another example, viz. Nilo-Saharan Koma (cf. Maddieson, 1992), which has quite a neat stop system:

(6)	pulmonic stops	p/b	t/d	k/g
	initiatory gesture	| |	| |	| |
	ejectives	p’	t’	k’
	initiatory gesture	|Gp|	|Gp|	|Gp|
	implosives	ɓ	ɗ	
	initiatory gesture	|Gs|	|Gs|	

In a language like Koma the two airstream mechanisms, ejective and implosive, must be distinguished in the phonological representation specifying initiation. Demand for phonetic detail phonologically can also mean that other than simple |G|, specifying one or the other glottal airstream mechanism, is needed in the representations for Armenian and Maasai systems in (4) and (5).

Turning to the velaric airstream mechanism, this suction type demands an independent component phonologically because it is non-pulmonic ingressive and does not involve movement of the glottis. |V|, the component specifying clicks, is thus necessary to characterise the following contrasts found in Koisan !Xu, ((7) contains just a small subset of the click contrasts found in this language (see Maddieson, 1992; Ladefoged, 2001; Ladefoged and Maddieson, 1996):

(7)		alveolar	categorial gesture	initiatory gesture
	voiceless plosive	t	|C|	| |
	voiceless click	ɬ	|C|	|V|
	voiced plosive	d	|C;a|	| |
	voiced click	gɬ	|C;a|	|V|

But although they represent only an extract, the contrasts illustrate that for phonological differentiation clicks require a unique initiatory representation.

Clicks are always articulated with an anterior (bilabial, dental, alveolar, lateral) closure and a posterior velar or sometimes uvular closure. The anterior closure names the click type and organises clicks in locational families. In the present account the anterior property of a click will be described primarily in the articulatory gesture. The posterior closure can also vary not with respect to location but by being accompanied by nasal airflow, laryngeal setting or extra intiatory activity. The latter is relevant in a discussion dealing with the phonological characterisation of airstream mechanisms. According to Ladefoged and Maddieson (1996), Koisan Zhu|hoasi has contrasting clicks, one of which is a voiceless affricated velar ejective and another is a voiceless affricated velar plosive. Clearly, these two clicks will not be distinguished by just using |V| in the inititory gesture. Specification of the extra airstream mechanism is needed, so the ejective click is different. Consequently, not only |V| but also |G| or |Gp|, depending on phonetic accuracy, specify the ejective click as shown in (8):

(8)		vl velar ejective click	vl velar click
	intiatory gesture	|V, Gp|	|V|

If implosive clicks are found, a specification involving |Gs| will be called on too in combination with |V| in the initatory gesture. Although it is quite easy to produce glottal suction along with a click and comparatively easier than to produce an ejective click (cf. Ladefoged and Maddieson, 1996), the former possibility has so far not been encountered in any language. For the time being, |G| and |V| then combine in this one instance.

Glottalic and velaric airstream mechanisms as comparatively rare articulations then receive a more marked description than simple pulmonic egressive activity. |G| specifies glottalic, |V| specifies velaric, and as is inherent in the fission hypothesis each refines their initiatory nuclear source, unspecified |[ ]|. |G| refines the source of the airstream to being glottal pulse and |V| restricts the source of speech energy to velar suction. So far components function independently or in combination. Use of structured dependency relations between components does not apply in the initiatory gesture. As such the present account deviates somewhat from classic descriptions like that of Anderson and Ewen (1987) in which extensive dependency relations are proposed to exist in order to capture both laryngeal setting and initiation types. Let us then briefly consider their and other accounts of initiation types.

Anderson and Ewen (1987), following Ewen (1980), propose that that both laryngeal settings and initiation types be characterised in terms of dependency relations between the initiatory and categorial gestures. As part of this proposal, their component |O|, glottal opening, also is initiatory rather than categorial as suggested above and discussed below in Section 4. But both the inter-gestural interaction hypothesis and the claim that |O| is initiatory are odd and unjustified. As will appear from Section 4, |O| serves to characterise

laryngeal settings, indeed interacts with other categorial components in dependency relationships, to characterise glottal states at same time as it specifies the pulmonic initiatory pulse. That gestures interact in dependency relationships is difficult to justify when the introduction of gestures precisely serves the purpose of organising phonetic properties in phonologically relevant discrete bundles, and letting |O| characterise initiatory pulmonic pulse when it refers to a glottal state is equally odd, in particular when it far from always is present in a representation. Davenport and Staun (1986) have pointed to these unfortunate areas in Anderson and Ewen's representational system and suggested some changes to amend the problems. First they reassign |O| to the categorial gesture and reject the counterintuitive idea that gestures interact in dependency relations. This amendment is only partly relevant here but will be taken up later in Section 4. Second they propose an alternative account of initiation, notably of velaric and glottalic initiation types but also of basic pulmonic egression. This is relevant when the topic is the phonological characterisation of initiation. In their account, the initiation types are described in terms of three components (Davenport and Staun op.cit.):

(9) |K|: velaric initiation
|G|: glottalic initiation
|I|: initiator velocity

With these three components they characterise implosives, ejectives and clicks in terms of the following dependency relationships:

(10)

initiatory gesture	/p'/	/ɓ/	/ɻ/	/ʔ/
	|I;G|	|G;I|	|K;I|	|I|

|I| is also used about basic pulmonic lung-based initiation, hence the glottal stop in (10) is specified for single |I|.

Davenport and Staun's account bears some resemblance to the present proposal. As in the present description, they introduce two components identifying glottalic and velaric initiation types and as in the present description they presuppose that velaric and glottalic do not exist without basic pulmonic initiation. The latter structural dependency is not directly apparent but it emerges, so Davenport and Staun claim, from the single use of |I| to describe pulmonic initiation and dominant |I| in ejectives which, like pulmonic initiation, use an outgoing airstream. But Davenport and Staun's account is also burdened by some arbitrariness. It is not obvious that |I| is needed, if at all appropriate to characterise such suction mechanisms as are found in implosives and clicks. These sound types involve only ingoing airstream mechanisms and the presence of |I| seems more to be dictated by a desire to employ dependency representations. However, use of dependency relations requires gradual steps in a phonetic or phonological continuum, but this continuum is not obvious here. Similarly, the absence of |K;I| also makes |K;I| less convincing. As for the alleged basicness of |I|, the component representing universal pulmonic egressive lung-based air, this claim makes good sense. But why specify this basic universal property when the degree of a property's universality is proportional with

its representational simplicity in the phonological representation? Observe that if all |I| are removed in (10) and pulmonic egressive airstream is vacuously represented, i.e. as |[ ]|, then we have a representation for these contrast types which matches closely the system proposed in this section and summarised in (3), except that |K| in (9) and (10) is |V| in the present description (see again (3)) and what in (10) is specified as |G| is listed as |Gp| (/p'/) and |Gs| (/ɓ/) in the present description unless ejectives and implosives do not contrast within the same language in which case unmodified |G| suffices, a possibility which is the norm since, although they are found, contrasting ejectives and implosives do not occur very often.

Both the good and the less fortunate or bad parts of Davenport and Stauns's account thus support what has been proposed in this section. The good parts have been adopted and the bad ones dropped and replaced by better solutions. One good part appearing inadvertently from Davenport and Staun's analysis is the propriety of an empty nuclear (universal) representation. Combined with the fission hypothesis, this nuclear representation results in a viable description through specialisation and refinement of ejective, implosive and click consonants. The components resulting from fissional refinement and specialisation are unary and as such subject to mutual dependency/government interaction. Such interaction is not contemplated for the initiatory gesture for want of obvious continuum evidence. However, such evidence is available among properties described in the categorial gesture. These properties consequently will be the topic of the following section.

4. Laryngeal settings and the categorial gesture

Drawing the dividing line between the initiatory and categorial gestures has been a controversial issue from the time the notion of gesture was first introduced (see Lass and Anderson, 1975; Anderson and Jones, 1977; Lass, 1976; Ewen, 1980). The controversy has centred on the status of the phonological primes (features or components) referring to specifically voiced/voiceless and more generally laryngeal setting. First laryngeal setting, including voiced/voiceless, was assumed to be categorial. Later it was seen as initiatory, but such that it could undergo 'gesture shift' and appear in the categorial gesture when phonologically appropriate. Ewen and later Anderson and Ewen's response to 'gesture shift' (Ewen, 1980; Anderson and Ewen, 1987) was to propose that the categorial and initiatory gestures interact in dependency relationships. As pointed out in Section 3, this option has been criticised (Davenport and Staun, 1986) and as a result the characterisation of all types of laryngeal setting is regarded in the present article as belonging within the domain of the categorial gesture. The characterisation of manner of articulation also falls within the domain of the categorial gesture, and the gestural domain of manner never has been the topic of dispute unlike laryngeal setting. Nor has manner of articulation involved gestural interaction but instead it has always been characterised in terms of the two basic categorial components, |a| and |C| (|V| and |C| in most other accounts), in particular dependency combinations of these two components. There exists no uniform categorial

account of laryngeal settings, one that as a starting point regards such contrasts as categorial in domain. This section pursues how laryngeal setting should be characterised given the components outlined in Sections 1 and 2 on the assumption that it is categorial only. Since there is general consensus on how the components |C| and |a| are used to describe manner of articulation, an account of this categorial domain will not be discussed in detail, see instead Anderson and Ewen (1987) for discussion.

Laryngeal setting encloses the phonological contrasts produced on a pulmonic airstream which involve different states of the glottis such as voiced, voiceless, aspiration, breathy voice, creaky voice. Classic component-based accounts such as Ewen (1980) and Anderson and Ewen (1987) argue that to allow for these differences phonologically it is necessary to let the initiatory component |O|, defined as glottal opening, interact in dependency relationships with categorial |C| and |V| (corresponding to |C| and |a| in the present system). Because |O| belongs in the initiatory gesture, this interaction involves dependency/government relationships between gestures and not between components directly. As pointed out above (cf. Davenport and Staun, 1986), it is odd, indeed counter-intuitive, first to argue for the division of initiatory, categorial and articulatory gestures and then subsequently introduce inter-gestural relations because the proposed gestural division fails to express the desired phonological contrasts. This problem is a result of interpreting |O| as initiatory. For this reason |O| is regarded as categorial and not initiatory in the present proposal.

The question which gesture |O| should be assigned to naturally belongs in a discussion of what types of laryngeal setting require phonological differentiation. One well known and very frequent contrast is voiced versus voiceless. Given the system outlined in (3), this contrast as manifested, for example, in the English pairs /t/–/d/ and /s/–/z/ is represented in the following way in the categorial gesture (cf. Anderson and Ewen, 1987), i.e. with the voiced member involving an extra dependent |a|:

(11)

	/t/	/d/	/s/	/z/
categorial gesture	|C|	|C;a|	|C:a|	|C:a;a|

Some languages (probably many more than normally assumed) also make a two-way contrast between two types of a voiceless stop consonants involving variation along what is frequently referred to as the VOT continuum (see Section 3). Thus the difference in Danish (see Harris, 1997) between the pairs of plosives such as /p/–/b/, /t/–/d/, /k/–/g/ is one of aspirated voiceless versus plain voiceless. This contrast serves the same systemic function as that between plain voiced and voiceless in English (the latter member of the English contrast also involves a good deal of aspiration in fact) and a host of other languages. But the Danish stop contrast has not been characterised as suggested in (11) for English voiceless versus voiced plosives. Phonetic detail, in particular the wide open glottis in the voiceless aspirated series, has dictated that |O| be invoked. This phonetically motivated solution has been adopted by Davenport and Staun (1986) and used among others as an argument for assigning |O| to the categorial gesture. Phonologically,

however, there is nothing to prevent a characterisation involving just |C| and |a| so voiceless aspirated is |C| and voiceless unaspirated becomes |C;a| in the categorial gesture. Choosing this phonological representation for other privative contrasts than just ordinary voiced versus voiceless has the advantage of invoking |O| and |Q| only when three or more laryngeal settings are phonological. Statistically, contrasts involving more than two laryngeal settings are rare and since the invocation of |O| and |Q| adds considerable complexity to the categorial representation, having to occur alongside with |C| and |a|, it makes good sense to opt |O| and |Q| out except in what seems to be marked contrasts involving at least three glottal contrasts. But characterising the privative voiceless unaspirated versus voiceless aspirated minimally as the voiced versus (aspirated) voiceless contrast also goes well in hand with the conclusions drawn by Vaux and Samuels (2005) about laryngeal markedness in stop series, specifically their claim that the unmarked privative laryngeal contrast among stops is not voiced versus voiceless unaspirated but unaspirated voiceless versus aspirated voiceless.

Among laryngeal settings, the contention is then that |a| and |C| serve to characterise privative laryngeal contrasts only. It is left open which two-way contrast that |a| and |C| describe is best seen as unmarked. Vaux and Samuels' interpretation (op.cit), although convincing for stops does not include fricatives, so a conclusion regarding this issue must await further investigation. The contention is also that more than two contrasts require extra components, in particular |O| and |Q|. There is a drastic drop in languages utilising breathy and creaky voice along with one or more other classic |a|–|C| depictable contrasts. This drop justifies marked status for three or more contrasts and hence marked status for |O| and |Q|, in particular when |O|–|Q| depictable contrasts presuppose |a|–|C| contrast types. Other than categorial status for |O|, despite Anderson and Ewen (1987), is then also difficult to maintain, unless violation of otherwise well-motivated gestural borders is in order. How should |O| and |Q| then be used in the categorial gesture? Various laryngeal settings constitute a phonetic continuum with glottal closure at one end and a glottal state with vocal cords wide apart as in aspiration at the other end. Such a scale of openings invites the use of graded dependency relationships. Thus while privative contrasts will involve just |a| and |C|, just like |a| and |C| continue to characterise manner types, in a language like Eastern Armenian with three laryngeal contrasts, voiced, voiceless unaspirated and voiceless aspirated (cf. Ladefoged and Maddieson, 1996), |O| and |Q| serve to capture this extra property in terms of dependency relationships as shown below. As fission products of basic categorial |a| and |C|, |O| and |Q| may co-occur with the former, but when they do so |O| and |Q| add complexity to the representation. The appropriate |a| and |C| representations are then assumed to coexist with the specifications involving |O| and |Q| in (12) and all following categorial representations:

(12)	*Armenian*	voiced	voiceless unaspirated	voiceless aspirated
		/b/	/p/	/pʰ/
	categorial gesture	|Q;O|	|Q:O|	|O; Q|

Dominant |Q| signals least glottal opening in voiced sounds, whilst conversely the wide open glottis in voiceless aspirated sounds is reflected by dominant |O|. Voiceless unaspirated represents a state in between these two extremes and hence exhibits equally dominant |Q| and |O|. Contrasts involving more than three glottal states such as that found in Hindi which has four laryngeal contrasts and which differs from the Armenian system by also having a breathy voiced stop series, will involve the following dependency interaction of |O| and |Q| (in addition to |a|, |C| configurations):

(13)	*Hindi*	voiced	breathy voiced	voiceless unaspirated	voiceless aspirated
	categorial gesture	/b/ |Q;O|	/b^{h}/ ||Q;O|:O||	/p/ |O:Q|	/p^{h}/ |O; Q|

The exact choice of phonological representation will vary depending on whether phonological contrast or phonetic detail is emphasised. Also one laryngeal type does not necessarily get assigned the same phonological specification at any time. The phonological system that a particular sound type is part of will often affect its phonological depiction. But in (13) the general and natural mutually dependent |Q:|O| structure of (12) for non-peripheral values is preserved with the |Q| of breathy voiced governing an extra |O| to allow for the characteristics of this laryngeal type. Alternatively, breathy voiced and voiceless stops in Hindi could be identified phonologically as ||Q;O|;Q|| and |O;Q|;O|| respectively which would preserve their mutual differences on a scale, but not express so well the affinity between the Hindi and the Armenian sounds nor the non-peripheral values of breathy voiced and voiceless aspirated.

No matter which of these alternatives is chosen, markedness will not be violated by the proposed representation. Among the Armenian contrasts, all three types appear equally complex in accordance with the fact that no potentially more marked contrasting category has fewer components assigned to it. Among the Hindi set, the breathy voiced stop type appears the most complex. Presupposition evidence supports this status as does the phonological behaviour of this sound type as discussed above in Section 2. Among the Armenian set, |Q:O| is not a sign of representational unmarkedness, as it involves mutual dependency and not absence of dependency.

How laryngeal sound types get assigned different phonological representations is also apparent from the characterisation of systems involving creaky rather than breathy voice. As a laryngeal setting which is near to the closure end of the scale, creaky voice should involve relatively high predominance of |Q| in its categorial representation which also involves |O|. Languages using creak do not seem to make more than three laryngeal contrasts, but creaky voice contrasts with both voiced, aspirated voiceless and unaspirated voiceless. Thus (Afro-Asiatic) Hausa is one type of example and (Austro-Tai) Lakkia a slightly different type with, unlike Hausa, no voiced member contrasting with creaky voice (cf. Ladefoged and Maddieson, 1996):

(14)	*Hausa*	voiceless	voiced	creaky voice
		/s/	/z/	/s̰/
	categorial gesture	|O; Q|	|Q:O|	|Q;O|
	Lakkia	aspirated	unaspirated voiceless	creaky voice voiceless
		/pʰ/	/p/	/p̰/
	categorial gesture	|O; Q|	|Q:O|	|Q̃;O|

As in the representations listed in (13), the Hausa and Lakkia contrasts are specified for |a| and |C| too in the categorial gesture: the Hausa fricatives involve |C:a| and ||C:a|;a||, whereas Lakkia stops require |C|. Arguably, three-way contrasts as these need not be specified for |O| and |Q| in all three sound types. It could be left to |O| and |Q| to identify creaky voice and let |a| and |C| handle other members of the systems. In this way, voiced fricatives and unaspirated voiceless stops would not be identically specified for |Q| and |O|. But failing to maintain |Q| and |C| everywhere would disguise the phonetic properties of the contrasts and particularly in the tree-way stop series it would not reveal how aspiration interacts closely with voiceless and voiced. Here a solution emphasising phonetic detail and the expression of phonological markedness of the entire series rather than just one member of the series is preferred, but obviously the representational system proposed here allows for a more narrow specification too. Markedness is allowed for by marked categories not appearing representationally less complex as demanded by representational markedness.

In creaky voice the vocal cords reach a mode of close constriction. One step further along the continuum of laryngeal setting is completely closed glottis. Glottal stops are well-known in predominantly British varieties of English and should be distinguished from ejectives in which a closed glottis act as initiator (see Section 3 for discussion). In English varieties glottal closure does not function phonologically. Instead it is a free variant reinforcing or replacing voiceless plosives, in particular / t/. Complete substitution has been seen as supporting the gestural division of segments involving the deletion of all articulatory material so a glottal stop is specified categorially only. Thus final /t/ of what assumes the following form after glottalising illustrating how organised and non-discrete components (or features) express the dearticulation succinctly:

(15)	articulatory gesture	(a)	[ ]	*or*	(b)	[ ]
	categorial gesture		[|Q|]			[|C|]

|Q| as specifier of glottal closure, captures the phonetic properties involved in English whereas its fission source |C| is sufficient phonologically but devoid of phonetic detail. However, there are languages in which (non-ejective) glottal stops contrast with consonants also specified in the articlatory gesture and which exhibit another laryngeal activity than closure. Thus in Hawaiian, a glottal stop with no simultaneous oral closure

contrasts with /p/ and /k/. Categorially, the glottal stop differs from the oral stops as follows:

(16)		oral /p/, /k/	glottal stop
	categorial gesture	|C|	|Q|

where the glottal stop could be specified also as single categorial |C| but, unlike /p/ and /k/, with unspecified articulatory gesture. Some languages are reported to have what is referred to as voiced glottal stops (see Ladefoged and Maddieson, 1996). Probably these physiologically impossible sounds involve a kind of creaky voice as pointed out by Ladefoged and Maddieson. Thus a potential description of (Austro-Tai) Gimi (cf. Ladefoged and Maddieson op.cit.), which has voiced and voiceless unaspirated stops as well these two types of glottal stops, would look as follows:

(17)	(*Austro-Tai*) *Gimi*	asp. voiceless	unasp. voiceless	voiced glottal stop	glottal stop
	categorial gesture	|O|	|O; Q|	|Q;O|	|Q|

The fact that the glottal stop is phonological in this language and naturally captured in terms of single |Q| invites the opposite end of the laryngeal continuum to be represented in terms of single |O|. Either specification makes good phonetic sense and with the extreme ends of the continuum described by single component representations, the path is open for graded representations between |O| and |Q| to express the two intermediate points on the continuum such that |O| is dominant in unaspirated voiceless stops and |Q| dominant in the alleged voiced glottal stops. Using |Q| for the latter two stop types captures better a categorial continuum than if it was left to single |C| which, albeit a fully valid alternative representation, also requires an empty articulatory specification.

Glottal stops emerge as neutralisation products. Glottal as a value therefore is diagnosed as unmarked (see Lombardi, 2003; Rice, 1999a,b; de Lacy, 2006a among others), but it still remains to be seen if in the few languages which have them as phonemes, like Gimi, glottal stops also exhibit unmarked behaviour as outputs of neutralisation. In a representational markedness system, like the one proposed here, unmarked glottal behaviour therefore becomes a problem if contrastive glottals are specified |Q| phonologically. Arguably, the problem is made worse by the existence of languages in which both glottals and coronals emerge as neutralisation products (de Lacy, 2006a). When coronals, like glottals, behave as unmarked they become potentially indistinguishable from glottals in a representational markedness model. There is a resolution to both these problems. As is clear from the proposed |Q|-representation, these are phonetically motivated, proposed to enhance phonetic detail. But the phonological representation originally proposed and mentioned in connection with (15) characterising glottal stops as single |C| categorially and with empty articulatory specifications are fully available and in fact suffice. The use of |Q|, which as a fission product of |C| links the phonologically sufficient with the phonetically detailed representation, emphasises the

phonetic continua glottal stops enter into when contrastive. The availability of single categorial |C| and empty articulatory gesture also solves the second problem, the model's contended inability to distinguish unmarked coronal from unmarked glottal. Coronality is an articulatory property, whilst glottal is specified in the categorial gesture and as such they belong to discrete representational domains. Even if they did belong to the same domain (as claimed by e.g. Lombardi, 2003; Rice, 1999a,b; de Lacy, 2006a), the more richly hierarchised system proposed here with its built-in presupposition relations and assumption that marked never is representationally less complex than unmarked would still be able to capture how they differ with respect to markedness. To return to the system of contrasts in (17), the prediction is then that the contrastive glottal stop clusters with common or garden voiceless tops. Given the rare occurrence of inventories with contrastive glottal stops, inventory presupposition evidence indicating markedness status is hard to come by. But allowing for the option to represent glottal stops minimally both categorially and articulatorily ensures the unmarked status of this category elsewhere.

The previous discussion of glottals and their representation, including their markedness status, constitutes an appropriate prelude to the following section. When glottal is not seen as a place property what is then articulatory? And when coronal is a place property and unmarked and unmarked not necessarily involves placeless specification how is coronal then represented in the articulatory gesture? These and similar questions regarding the way the fission components outlined so far, but extendable to place of articulation, interact with one another to capture place contrasts among consonants and place contrasts among vowels will be the topic of the two following sections.

5. The articulatory gesture and vowels

In the articulatory gesture, which specifies the locational or place of articulation properties of a phonological segment, the components developed as a result of fission amount to minimally three and maximally four. As in much component-based phonology (see e.g. Anderson and Jones, 1977; Anderson and Ewen, 1987; Ewen and van der Hulst, 2001), three components suffice in the articulatory gesture of vowels. The relevant three components are |t| and |w|, the fission fragment products of splitting |C|, and |a|, the non-binary propagation of categorial |a|. The definition of these components when articulatory is (cf. Section 2) maximal coronal stricture (|t|), gravity and non-coronal stricture (|w|), and maximal aperture (|a|). In classic component-based phonology, such as Anderson and Jones, 1977; Anderson and Ewen, 1987, these components appear in the form |i|, |u| and |a| which individually characterise the three widely attested vowels /i u a/. In the present account, in which |t w a| respectively represent /i u a/, front vowels are interpreted as government/dependency combinations of |t| and |a| and back vowels as government/dependency combinations of |w| and |a| (see Anderson and Ewen, 1987; van der Hulst, 1994; Durand, 2003; Staun, 2005 among others). This triangular interpretation of the vowel space raises a number of questions. How does it relate to the markedness of

vowels? How do the three basic components allow for other than classic front unrounded and back rounded vowels? How is it possible to express classes of vowels in such a system? Is it appropriate to say that |t| represents /i/, |w| represents /u/ and |a| represents /a/?

Let us first point out that a triangular system whose extreme points may interact with one another in government/dependency relationships in principle allows for this interaction to be the same between all three components. In reality, however, the interaction between |a|, on the one hand, and |t| and |w|, on the other, is the basic pattern rather than between |t| and |a|/| w| or between |w| and |a|/|t| (see van der Hulst, 1989 for discussion). In so far as |t| and |w| are both fission fragment components of categorial |C| and articulatory |a| is the propagation of categorial |a|, the present system predicts the |a| versus |t|/| w| pattern. The assumption that |a| versus |t|/|w| or |~a| (non |a|, see Anderson, 1980; Anderson and Ewen, 1987 for this notation) is basic illustrates the relevance of the high/low distinction in particular as manifested in stepwise vowel height contrasts (see Durand, 2003) and chain shifts along this dimension (Anderson, 1980). This does not mean that the front back distinction is ignored or left unexpressed. Instead it is not viewed as central whether the front-back distinction is high or low, whilst it is regarded as relevant whether high versus low is in the front or in the back position. Because they are non-low, |t| and |w| have been seen as inaccurate descriptors of /i/ and /u/ individually, specifying high vowels but not specifically high front and high back respectively. The bifurcation of categorial |C| as a result of fission into articulatory |t| and |w| is not susceptible to this kind of critique. The fissional sophistication leading to |t| and |w| allows both for the stricture, position and rounding of /i/ to be identified with |t| and /u/ with |w|. |t| specifies maximal coronal stricture and |w| maximal grave noncoronal stricture when combined with a categorial vowel representation. Both theses descriptions are sufficiently precise to single out /i/ and /u/.

Whilst the issue of what the three basic components represent individually and how they are organised internally is fairly straightforward, it is much more difficult to establish how the triangular system expresses the markedness properties of vowels. When |t a w| individually represent /i a u/ then, given that in a representational markedness model simplicity of representation corresponds, ceteris paribus, with unmarked status, any vowel requiring more than one component in its representations cannot be less marked than /i a u/. The questions asked above how front rounded and back unrounded and central vowels should be represented are then closely linked with the issue of how to express markedness. In former component-based descriptions, these vowels have been argued to require sometimes three components phonologically (Anderson and Ewen, 1987). But even frequent members of vowel systems like /e, æ/ and /o, ɔ/, the former requiring structured combinations of |i| and |a|, the latter combinations of |u| and |a|, will then be assigned marked status. Clearly it is difficult to maintain that high and low vowels but not non-high/low vowels are unmarked. Markedness and its expression within the |t a w|-based system is clearly far from straightforward.

Actually, when |t a w| are the basic components not only the individual vowels /i a u/, but also vowels involving |t a w| combinations which agree with the internal organisation following from the binary fission of |C| rather than |a| candidate as unmarked entities. Originally, one motivation for proposing the /i a u/-triangle as basic is the very frequent appearance of this set in vowel inventories. In Maddieson, 1992 this pattern is obvious. 80% or more of the languages in this sample have these three vowels. The sample also provides support for |t a| vowels (front unrounded) and |w a| (back rounded) vowels as very frequent, with some variation depending on height, at the same time as it illustrates that front rounded and back unrounded, both of which types require more than |t a| and |w a|, follow a much less frequent pattern. Although in the early days of component-based vowel description they would have been taken as indicative of unmarked status of the dispersed /i a u/ vowel system and the core status of the components |t a w|, such frequency figures cannot solely support unmarked status. Some vowels have high frequency but nevertheless get interpreted as marked (central /ə/) in a componential |t a w|-based type of system (but see van der Hulst, 1989), and as has been pointed out by de Lacy (2006a,b), Lombardi (2003), among others, the behaviour of vowels as outputs of epenthesis, neutralisation and in prosodically determined hierarchies varies so much that the dispersed system /i a u/ does not always appear as the least marked.

The conflicting evidence prevents a clear answer to the question of which vowels are marked and which are unmarked. With respect to epenthesis, the work of Lombardi suggests that both low and high vowels candidate as unmarked with /a ɨ ə/ as the most typical and /ɨ/ the least marked among the non-low candidates. The work of de Lacy (2006a,b) restricts this set to non-back high and low vowels (Lombardi (2003) characterises /ɨ ə/ as back), so according to him epenthetic vowels are always unrounded and non-back. Neutralisation evidence is discussed extensively by de Lacy (2006a,b). As with epenthesis, neutralisation provides only limited insight into vowel markedness and does not single out one particular set as potentially least marked. The dispersed /i a u/ set does not always appear as the output of neutralisation. Probably /a/ is a good candidate as it regularly is the output of neutralisation of system-contiguous vowels in the absence of /ə/, as seen in both Belarusan and Berguener Romansh, two languages cited by de Lacy (2006a). This status fits in nicely with its role in the system developed here where the component representing /a/ occupies a basic role as the one fundamental component of fission. /i/ and / u/ are less obviously unmarked candidates. But neutralisation outputs (/ə/ again excluded) which involve /i/ and /u/ are seen and involve contiguous front and back vowels respectively (Berguener Romansh, de Lacy (2006a)). Alternations moving towards these high vowels is also characteristic of languages such as Sri Lankan Portuguese Creole (de Lacy op.cit.). On the other hand, there are also languages in which high dispersed /i, u/ become mid vowels. The same direction is exemplified in part by the centralisation seen in English in which both high, mid and low vowels merge in /ə/ in unstressed position (see e.g. Cruttenden, 2001).

Evidence from epenthesis and neutralisation appears then somewhat inconclusive. There seems to be evidence supporting low, in particular /a/ as unmarked, a status

congruent with the basic role of |a| proposed here. The conflict seems to concern central versus dispersed among non low vowels. But actually if two simple assumptions are made about the vowels space, viz. that dispersed vowels are important in order to maintain distinctiveness (de Boer, 2000) and that distinctiveness figures less prominently in unstressed syllables, the |t a w|-based system can capture some vowel markedness properties. Given that |t w| are fragments of |C| and vocalic |a| the articulatory continuation of categorial |a|, the triangular set expresses that |t a| and |w a| combinations are the norms, as pointed out earlier. The fact that combinations of |t a| and |w a| also represent unmarked candidates, albeit less obviously than /a/, entails that the combinations front rounded and back unrounded are marked. The former involve combinations of |t (a) w| but such that 'roundness' (|w|) is an added and hence dependent feature, whereas in the latter absence of roundness (|t|) always is dependent. Both front rounded and back unrounded vowels will then have fairly similar representations but the former always with the recurrent structure |t;w| and the latter always with the recurrent structure |w;t|. A hypothetical vowel system like /y ø œ ɯ ɣ ʌ/ would then get represented as follows depending on the amount of phonetic detail required:

(18)

y |t;w|	ɯ |w;t|
ø ||t;w|;a|	ɣ ||w;t|; a|
œ |a;|t;w||	ʌ |a;||w;t||′

Markedness of front rounded and back unrounded vowels appears then directly from most of (18), as four vowels involve three components in their representation. /y/ and /ɯ/ are exceptions, but given the structural properties expressed in the vowel triangle with the basic categorial |a| unfissioned, because height distinctions in different places are seen as more basic than front-back distinctions at different heights, combinations of only |w| and |t| arguably exhibit markedness inherently.

But if there is a way, as suggested here, to express markedness so that classic front unrounded and back rounded vowels appear as unmarked, how can the apparently unmarked central /ə ɨ/ be associated with a representation showing this status? Clearly, it is difficult to align either vowel with any of |t a w| when each component represents the corners of the dispersed system. But in those cases where the emergence of the unmarked is a central vowel like schwa in English, this vowel also often does not contrast with other vowels in stressed syllables. Its contrastive phonological function is marginal. Instead it serves the function of filling lexically less significant or predictable material such as for example grammatical form words. As the potential neutralisation product of all English vowels, schwa in English resembles the English glottal stop which is a reduction product of not specific vowels but of specific stop consonants. When the glottal stop has this function it is represented as devoid of articulatory properties. When it functions as the reduction product of vowels, schwa is then also represented with an empty articulatory gesture to capture its default status in neutralisation outputs. van der Hulst (1989) has proposed a similar interpretation, but unfortunately operates with two types of empty representations to account for the difference between central and back unrounded vowels.

In the present fission-based system only the first central category is empty in the articulatory gesture.

As a representational markedness model, the present system of fission-generated components is liable to the criticism that empty articulatory representations fail to allow for empirical facts like e.g. dissimilation, triggering (see Section 6 for discussion) and conflation. Among vowels, the empty articulatory gesture poses a potential problem with respect to capturing conflation typology. As pointed out by de Lacy (2006a,b), an empty schwa representation predicts that when schwa forms a class with other vowels which avoids stress, these other vowels must also be feature- or componentless in the articulatory gesture. But in a fission-based representational markedness model both absence of fission, i.e. empty specification, and the three basic dispersed corner components count as unmarked, albeit probably hierarchically different just as glottal and coronal differ among consonants, the former as empty and the latter as plain articulatory |t| (see Section 6). Thus in Gujarati (see de Lacy op.cit., Hayes, 1995) in which both /a/ and schwa avoid stress, this is predicted by dispersed |a| which represents /a/ and empty schwa, because simple structure or absence of structure signals unmarked. As a result, a conflation class need not consist of zero-specified vowels only. However, it remains to be seen whether stress repellence is a valid synchronic processual diagnostics that belongs to I-language.

In Nganasan (de Lacy, 2006a,b), allegedly schwa forms a class with /i y u ɨ/. Apparently, all these vowels repel stress in this language and as such must be conflatable and stress repellence ascribable to (un)markedness. Clearly, if it is a valid diagnostics and the evidence from this Uralic language is not linked with vowel harmony, this prosodic phenomenon poses a problem to a representational markedness model as /y/ and /ɨ/ would feature as unmarked. Either stress repellence is invalid or the gestural structure of phonological segments is insufficient to account for the distribution of a prosodic phenomenon.

To sum up the vowel description, the continuation of fundamental |a| and the fission of |C| create a triangular vowel space with |a| and the fission fragments |t| and |w| as the basic dispersed elements. Individually, the three components represent /a/, /i/ and /u/ highlighting the importance of distinctiveness (de Boor, 2000). Other vowel qualities appear from structured dependency/government combinations of these components. The fission paths predict that these combinations involve |a| plus either |t| or |w| so height distinctions at different places are seen as more fundamental than front-back distinctions at different heights. Absence of components or no fission fragments in the articulatory gesture of vowels is also a possible option. In a representational markedness model, no or little structure matches unmarked. For vowels this approach to markedness predicts that empty representations and the unfissioned continuation of categorial |a| are unmarked candidates, something which is supported by the evidence that schwa and /a/ appear as neutralisation outputs. The structure of the fission paths is such that fragments of |C| are the only other options in the articulatory gesture of vowels. Thus, combinations of |C| fragments, i.e. |t| and |w|, and |a| also represent unmarked albeit less unmarked than a

single |a| specification let alone an empty specification. Front rounded vowels and back unrounded vowels then figure highest on a markedness scale as they get represented with more than three components. The system of fission components then allow for a hierarchy of markedness with an empty vowel specification as the least marked candidate. Phonetically, this hierarchy is closely linked with sonority: the closer a vowel is to the unmarked end of the hierarchy the more sonorant it is.

6. The articulatory gesture of consonants

A description of articulatory place in consonants must first identify which properties belong and require representation in the articulatory gesture. Following common practice, labial, coronal and dorsal are relevant locational properties of such a description, where labial covers bilabial and labiodental, coronal stands for inter-dental, dental, alveolar and palato-alveolar and dorsal refers to velar and uvular. Glottal is commonly regarded as a place too (de Lacy, 2006a among others) as is sometimes pharyngeal (see McCarthy, 1994). As discussed briefly in Section 4, glottal is here specified in the categorial gesture only and left empty in the articulatory gesture (similar analyses are found in feature geometry, cf. Clements and Hume, 1995, Kenstowicz, 1994). Interpreting glottal as an empty place of articulation so both [h] and [ʔ] receive categorial specifications but are unspecified articulatorily has a long history (Lass and Anderson, 1975; Anderson and Ewen, 1987; Archangeli, 1988; McCarthy, 1988). Much recent work has established glottal as unmarked (see de Lacy, 2006a and the references cited there). This status then goes well in hand with the present description's assumption that glottal is associated with an empty representation. However, de Lacy (op.cit.) argues that in representational markedness models the empty glottal representation is unfortunate because it prevents the expression of the equally well-established unmarked value of coronal. Glottal and coronal cannot both be unspecified or left empty to signal unmarked values as this would disguise their mutual markedness relation as well as their phonological dissimilarity. Also glottal as zero-specified cannot trigger processes. Criticism like this fails to observe that in representational markedness models, the use of both tri-gestural representations and relative componential and other structural complexity allow for markedness, just as underspecification does not entail complete absence of features. With these options, glottal simply belongs to a non-locational hierarchy without being completely unspecified. And more importantly as a non-locational property, glottal is also irrelevant in a discussion of consonantal place. Instead the focus of attention can be directed towards the central primary articulatory properties, labial, coronal and velar and perhaps pharyngeal. Finer distinctions like labio-dental, dental, palatal, uvular will also be dealt with in the following, but they depend on primary places of articulation.

Given the properties ascribed to articulatory |t, k, p| (cf. Section 2) following from the fission of categorial |C|, labial, coronal and velar will be represented as follows:

(19) labial coronal velar
|p| |t| |k|

Accepting a somewhat restricted locational view of consonant contrasts, one which follows, say, a crude reading of the IPA chart ignoring and disregarding apical/laminal distinctions and differences relating to stridency or delayed/abrupt delivery which arguably are non-locational, a simple consonant system like /p t k b d g/, will look as follows in the articulatory gesture where the voiced/voiceless distinction is expressed in the categorial gesture:

(20) /p b/ /t d/ /k g/
|p| |t| |k|

Adding the phoneme pairs /f v/, /s z/ will not necessarily add complexity to the articulatory representation. The former pair will also be represented as |p| articulatorily and the latter as |t| in the articulatory gesture, whilst the categorial gesture specifies the distinction between stop and fricative. However, extending the phoneme system so it includes also /ɵ ð/ and /ʃ ʒ/, as in most varieties of English, complicates the picture. As dental fricatives, /ɵ ð/ will be described in terms of |t| in the articulatory gesture like /t d/ but distinguished from the latter in the categorial gesture. But as |t|-specified fricatives they become identical to /s z/ which are also fricatives. Similarly, /ʃ ʒ/ create the problem that as coronal fricatives they will be indistinguishable from /s z/, if just specified as |t|. The finer locational phonetic details between, on the one hand, /ɵ ð/ and /s z/ and, on the other, between /ʃ ʒ/ and /s z/ must then decide what representation is appropriate. In particular, /ʃ ʒ/ are further back than /s z/, what is typically referred to as palato-alveolar, a term reflecting both a larger contact area and a more retracted place of articulation. The locationally more retracted articulation of /ʃ ʒ/ can be shown by combining |t| and |k| as in the articulatory specification in (21). On the other hand, the more forward articulation of /ɵ ð/ can be represented by combining |t| and |p|:

(21) /ɵ ð/ /s z/ /ʃ ʒ/
|t,p| |t| |t,k|

The combination of |t, k| interprets /ʃ ʒ/ as a blend of coronality and velarity, whereas /ɵ ð/ get interpreted as a combination of labiality and coronality. Labiodentals could also be specified as a combination of labiality and coronality. This would result in more structured representations involving asymmetric government/dependency relations:

(22) /f v/ /ɵ ð/ /s z/ /ʃ ʒ/
|p;t| |t;p| |t| |t,k|

where the governing |p| reflects the greater labiality of /f v/ and the governing |t| exposes the stronger presence of coronality in /ɵ ð/. The choice of specification for labiodentals depends largely on the phonetic detail required, as well as on the types of phonological

contrast otherwise found in the language in question. For example, it is possible to represent /f v/ simply in terms of |p| and leave it to the categorial gesture to distinguish them from /p b/ as discussed in connection with (20). But the representation in (22) is equally possible and a representation involving both |p| and |t| is a prerequisite if /f v/ occur in an inventory which also contains bilabial /ɸ β/. Similarly, the representation for palatoalveolars may vary depending on whether the language also contains phonemic palatals. In such a case, insistence on expressing phonetic detail would result in structured combinations of |t| and |k|, as shown below:

(23) /ʃ ʒ/ /j/
|t;k| |k;t|

in which |t| in governing position in /ʃ ʒ/ reflects the dominance of coronality in these consonants, whilst |t|'s dependent status in /j/ signals less prominence of coronality and the comparatively stronger presence of velarity in palatals. However, the representation for /ʃ ʒ/ in (21) would also suffice as long as the categorial gesture keeps fricative and vocoid distinct.

In the consonantal place description, the component |a| also has a function which varies depending on whether it is in governing or in dependent position. The use of governing |a| signals a slightly wider definition of |a| than summarised by the specification [-ATR] (see Laver, 1994). In particular, it signals an articulation which is more retracted than velarity. Thus uvulars and pharyngeals both involve |a| which can be put to use as shown in (24a), or alternatively as in (24b), the latter reflecting the gradual intensity of the retraction/lowness component.

(24) uvulars pharyngeals
(a) |k,a| |a|
(b) |k;a| |a;k|

It is possible that epiglottals will also be described in terms of |a|, but this issue will be left open here.

So far this section has outlined the potential representations of some common place types among consonants. The sophistication resulting from fission of specifically fundamental |C| provides the primary properties of consonantal place: coronal stricture, on the one hand, and con-coronal labial and dorsal strictures on the other. Invocation of government relations between components allows for further phonetic detail. Many phonemic distinctions still remain to be accounted for, something that the following sections will look into. At this point a few remarks regarding markedness are in order. As should have become clear, markedness values appear from the representation proposed here so in general unmarked is not more representationally complex than marked in accordance with the predictions of a representational markedness theory. The widespread and common primary places labial, coronal and dorsal thus appear with one component

each in the articulatory gesture. Arguably this does not show their mutual position on the markedness hierarchy, in particular that coronal has been shown to be the least marked (Paradis and Prunet, 1991; Prince and Smolensky, 2004; de Lacy, 2006a,b among others). Another problem is that |a| singles out a place type, pharyngeal, which is not typically regarded as unmarked, (but see Lombardi, 2002), even though it is represented in terms of one component. But the special status of both |a| and |t|, although special in different ways, appears from the diagram in (1). |a| constitutes its own subsystem of which no other component is a part. As such it falls outside the markedness calculations applicable to the system resulting from the fission of |C|. Among the fission products of |C|, however, |t| occupies a special position too because, unlike |p| and |k|, it is the only component which at the same time is terminal and the direct fission product of |C|. The other two terminal components in the articulatory gesture for consonants constitute a subsystem which is fissional sophistication of |w| which again is a product of the splitting of |C|. This difference is evidence of a more basic status and less marked value of |t| and consequently of coronality.

Another structural property which distinguishes |t| from |p| and |k| is this component's greater combinatorial flexibility. While |p| and |k|, the fissional fragments of |w|, are unable to combine with one another except in instances of double articulation (cf. /kp/, /gb/), |t| can combine with both |p| and |k.|. Such flexibility supports the view of assigning coronal special status. As more flexible and more able to interact with other components, |t|'s coronality is more readily susceptible to reduction, which otherwise is a sign of unmarked value. Among labiality and dorsality, the present representation contends no internal markedness hierarchy. Evidence from phonological behaviour is not unambiguous. Rice (1999a,b) provides evidence of dorsal being least marked, whilst Hume (2003) and Hume and Tserdanelis (2002) argue that labial is least marked. The fact that labial, coronal and dorsal are the most frequent (Maddieson, 1992) and the most salient places of articulation (Stevens and Keyser, 1989), a concurrence which here is interpreted as no coincidence but an evolutionary endowment accessible by I-language signalling unmarked, does not single out one place type as unmarked. Instead it stresses the primary status of these three consonantal place types and phonological evidence as pointed out above (cf. in particular Paradis and Prunet, 1991) helps identify coronal as the least marked of the three. Unlike in de Lacy (2006a) and in the works of the other specialists referred to in this paragraph, the relative markedness status of labial and dorsal is then considered an open question here.

The more subtle phonetic distinctions within specifically labial and coronal such as labiodental, dental or palatal can also be expressed if necessary phonologically in the articulatory gesture. On the assumption that they presuppose that the primary places in the relevant area have been utilised (see Maddieson, 1992), such distinctions entail more than one component phonologically and thus get interpreted as more marked. Before discussing what evidence exists for this more marked status, let us consider such less common but more subtle phonological contrasts. The most challenging of these contrasts concern those which occur within the same series, i.e. classes of sounds whose members

share the same categorial features and the categorial gesture therefore cannot be invoked. Examples do not abound but two well-known examples are voiceless stops in Australian Aranda and nasals in Dravidian Malayalam (Ladefoged and Maddieson, 1996; Maddieson, 1992). (25) shows the structure of the Arandan system:

(25)	*Aranda*	bilabials	dentals	alveolars	post-alveolars	palato alveolars	velars
		/p/	/t̪/	/t/	/t̠/	/ʈ/	/k/
		|p|	/t,p/	|t|	|t;k|	|k;t|	

Componentially, this series of stops poses no problems. Combinations of |t| and |p| suffice to distinguish dentals phonologically, whereas structured asymmetric combinations of |t| and |k| maintain the distinction between postalveolars and palatoalveolars so the greater preponderance of |t| in the former and the correspondingly greater preponderance of |k| in the latter reflect these two sound types' relative locational position between alveolars and velars. The examples of contrast from Malayalam nasals appear from (26):

(26)	*Malayalam*	bilabials	dentals	alveolars	post-alveolars	sub-apicals	palatals	velars
		/m/	/n̪/	/n/	/n̠/	/ɳ/	/ɲ/	/ŋ/
		|p|	|p,t|	|t|	|t;k|	|t:k|	|k;t|	|k|

Representationally, this series is somewhat more complicated involving three places between classic alveolar (coronal) and velar (dorsal). But invocation of an extra symmetric dependency structure for the intermediate category, sub-alveolar, ensures that contrasts in the alveolar-to-velar region differ phonologically.

But are all these subtle contrast types also more marked as their two-component representations predict? Evidence exists for the markedness value of labial, coronal and dorsal (see references above). But what sound types in (25) and (26) get interpreted as labial, coronal and dorsal? Whereas for labial this is straightforward in the absence in these two systems of contrasts of labio-dentals, it is less obvious if coronal is alveolar, dental or post-alveolar. Ceteris paribus, the assumption here will be that in nasal and stop series coronal corresponds to alveolar, labial to bilabial and dorsal to velar in the event of several locational candidates. The implication of this is that dental, postalveolar and palatal, for example, are more marked place types. Unfortunately, little phonological evidence supports this exactly because coronal is a very wide category embracing a variety of place types in this part of the mouth and because the use of such a wide array of place types within one series is rare. Inventory structure implications can support some of these markedness categories. Palatal, and sub-apical probably, among nasals presuppose the existence of labial, alveolar and very often velar and so get interpreted as marked. Such neutralisation evidence among nasals as seen in some Spanish dialects (Trigo, 1988) in which labial, coronal become [N], a nasal interpreted as glottal here, highlights their unmarked status as they are the last steps on the place scale before a placeless structure

materialises. General frequency as apparent from Maddieson (1992) points to labial, alveolar and velar as the most frequently used places of articulation. As an inspection of saliency (Stevens and Keyser, 1989; Staun, 1996) also singles out these places as unmarked and since intuitively they are the most obvious options, dentals, postalveolars, subapicals, alveopalatals get assigned more marked representations with more than one component. But it must be emphasised that real hard-core evidence pointing to which is marked and which is unmarked is difficult to come by and requires further investigation (but see Hansson, 2007 for an enlightening discussion of this issue).

Contrasts among fricatives can in some more difficult cases pose a challenge to the present representational system both with respect to expressing phonological distinctions and capturing markedness. Ewe is an example often cited (Ladefoged and Maddieson, 1996; Brown and Ogilvie, 2009) because it is a language with bilabial, labiodental and alveolar fricatives. Given the components available here, these fricative contrasts would be represented as follows:

(27)	*Ewe*	bilabial	labiodental	alveolar
		ɸ/β	f/v	s/z
		|p;t|	|t;p|	|t|

Above the presence of bilabial and labio-dental fricatives in the same inventory was said to generate a bi-componential representation involving |p| and |t| for either place type. In bilabials, |p| is preponderant and |t| dependent, whereas in labio-dentals |p| it is dependent and |t| preponderant, relations which reflect the comparative contributions of labiality and coronality in the two place types. The suggested representations are neutral with respect to markedness. As instances of labial consonants, they are more marked than coronal, but evidence justifying how they differ from one another with respect to markedness is not obvious. Frequency and inventory presupposition relations may favour labio-dental (Staun, 1996) but this does not conflict with the representations in (27) as long as labio-dental is not more complex, i.e. involves no more components, than bilabial.

Caucasian Kabardian with a total number of 22 contrasting fricatives is a test too. Within one series, voiceless fricatives, seven places of articulation, if counting glottal, are made use of. Six contrasts are shown in (28):

(28)	*Kabardian*	labio-dental	alveolar	palato-alveolar	velar	uvular	pharyngeal
		/f/	/s/	/ʃ/	/x/	/χ/	/ħ/
		|p|	|t|	|t,k|	|k|	|k;a|	|a;k|

The full variety of fission components available in the articulatory gesture serve to keep these contrasts distinct. The representational markedness property of the present proposal also makes it possible to express markedness. In particular, (28) highlights that labial, coronal and dorsal (disguised as labio-dental, alveolar and velar) are the unmarked categories also among fricatives each being represented in terms of one component only.

The representation of, say labio-dentals, fluctuates in the above lists of phoneme contrasts. In (22), labio-dentals get assigned the representation |p;t|, but could also be |p| if there is no demand for phonetic detail and in (27) they appear as |t;p|. This raises the more general questions: how can this phonological fluctuation represent one phonetic category and how is it compatible with the hypothesis that in a representational markedness model representations are 'universally fixed'? Phonetic realisation can be insured because all representations at least contain |p| and a representation for a fricative in the categorial gesture. In those cases where there is more than one segment meeting these requirements, extra conditions restrict the realisation rules. A regards universally fixed, this prediction does not make any representation completely invariable. A representation can vary depending on what other contrasts in an inventory it co-occurs with on condition this variation does not violate the expression of markedness. In all the representations above, labiodentals never appear componentially less marked than potentially unmarked labial categories they co-occur with. In a representational markedness model, variation in representational complexity is then acceptable when an unmarked category never involves more components than a marked one.

The fission-based components thus account for the common place types and a selection of more subtle differences among consonants. The fission of |C| not only produces basic and unmarked coronality via a single fission path, but it also generates via |w|, and following further sophistication, unmarked but in relation to |t| more complex |p| and |k|. To test the validity of this representational system with respect to both articulatory distinctions and its capacity for expressing relative markedness another consonant type not yet considered must be included and analysed. This type is what will be subsumed under the category, laterals and rhotics.

7. Laterals and rhotics

Of these two sound types laterals are considered first. The assumption is that laterals require an articulatory representation. Arguably, this assumption conflicts with laterality involving constriction centrally and aperture on one or both sides of this stricture, an articulation which many have interpreted as more manner than place. On the other hand, the distribution that not only approximants but also fricatives and affricates can be lateral supports a unique articulatory representation, just like the potential confusion of /r/ and /l/ in the categorial gesture demands an articulatory specification. The predominant evidence then speaks in favour of a unique articulatory representation for laterality (for further discussion, see Rice and Avery, 1991; Anderson and Ewen, 1987; Staun, 1996).

Within the present framework aperture and constriction are expressed in terms of |a| and |C|, the basic components resulting from fission of fundamental pulmonic pressure. Articulatorily, laterals will then be specified as a collective |a,C|representation subjoined to the otherwise relevant articulatory representation. The categorial representations vary depending on sound type as described in detail in Anderson and Ewen (1987) whose description has been adjusted to the system developed here. These options are illustrated

in the following diagram, showing contrasts in Welsh and Papuan Mid-Waghi (cf. Ladefoged and Maddieson, 1996):

(29)

Welsh	voiceless fricative	voiced approximant	voiceless approximant
	/ɬ/	/l/	/l̥/
articulatory gesture	|t| | |C,a|	|t| | |C,a|	|t| | |C,a|
categorial gesture	|C:a|	|a| | |a;C|	|a| | |a;C| | |C|

Mid-Waghi	laminal dental	apical alveolar	velar
	/l/	/l̥/	/ʟ/
articulatory gesture	|t,p| | |C,a|	|t| | |C,a|	|k| | |C,a|
categorial gesture	|a| | |a;C| | |C|	|a| | |a;C|	|a| | |a;C|

Laterality is then characterised in very general terms in the articulatory gesture. |C| and |a| refer to two fundamental properties of articulation: obstruction and free air passage. Nonetheless, this very general characterisation is appropriate for quite a unique sound type, because it is possible to add |C,a| to very different consonant types because the composition of the internal structure of segments assumed here allows for a property to be subjoined directly to the (primary) articulatory specification.

The markedness prediction of these representations follows from the representational markedness values of the articulatory gesture. Coronal as least marked among other sound categories also makes classic alveolar /l/ potentially least marked in e.g. Mid-Waghi. To be true, /l̥/ is also coronal but phonologically distinct from /l/ because it is dental and voiceless. If phonetic detail is the main concern, |t,p| stressing the forward articulation of /l̥/ is appropriate, but if only sufficient phonological indication is required no more than an extra categorial specification suffices (extra subjoined |C|). Either way, /l̥/ appears more marked than alveolar /l/ in agreement with inventory structure implications that /l̥/ presupposes /l/ among this consonant category.

So much for laterals. Rhotics constitute the other group of liquids to be considered in this section. By rhotics is meant the heterogeneous class of liquids which includes approximant *r*'s, trills, retroflex *r*'s as well as taps and flaps. The class comprises consonants, both sonorant and fricative, produced at very different places of articulation. Despite the common name, the members of this class share no single phonetic or phonological property in the articulatory gesture except that the 'basic' r-sound is probably alveolar. Probably, as pointed out by Ladefoged and Maddieson (1996), the single unifying property is that they are spelled with the letter 'r' (and even this description is probably not exhaustive). In the categorial gesture, on the other hand, the class of rhotics is characterised by predominance of |a|. As pointed out in Anderson and Ewen (1987), members of the class which they term /r/-types all have two |a|-nodes in their representation (|V|-nodes in their terminology), one of which enters into either an asymmetric or a symmetric relationship with a |a:C| configuration. This configuration does not align rhotics with a unique categorial representation, as it also includes the lateral liquids. The assumption is then that rhotics will also have to be specified in the articulatory gesture and rhotics in single rhotic languages follow the pattern of representations found in languages with more than one contrasting rhotic.

Let us begin with a consideration of languages with more than one contrasting r-type. Ladefoged and Maddieson (1996) list Hausa, an often used example, as one language whose speakers contrast between an alveolar trill and a postalveolar flap or approximant. Australian languages are also reported to have two or three rhotic contrasts. Ladefoged and Maddieson mention Arrernte as a language which contrasts between an alveolar tap or trill and a postalveolar approximant and Warlpiri as a language with a three-way contrast between approximant, trill and flap. Three-way contrasts are also found in Edoid Edo, which distinguishes between voiceless fricative, closed approximant and open approximant (the latter two are listed as voiceless fricative and voiced fricative, cf. Ladefoged and Maddieson, 1996).

An account of such rhotics may appropriately begin with the trills. Crudely speaking, trills may be described as repetitive stop contacts between two articulators, one of which has a small mass such as the tip or the uvular. Given this and the fact that they derive historically in some languages from a sequence of two consonants, trills could be represented in terms of two dependent |C|-components which are sequentially ordered within the articulatory gesture and subjoined to the primary place specification. But the use of sequential order implies that something which is phonologically non-sequential and componential is turned into something which is phonologically segmental. This may be appropriate for some sound types such as affricates consisting of separate phonetic gestures (Davenport and Staun, 1986). There is just no obvious argument supporting the proposal that trills be interpreted as border-line cases of segmenthood in the way that affricates are and thus potentially sequential segment-internally. Repetitive use of |C| would also require that the relationship between the components be neither symmetric nor asymmetric. Instead what is needed is an intensification of a single component. Insymmetric will be the term used to described this process (see also Schane, 1984 for a

similar proposal) which affects a single component and raises it to an *n*th power, i.e. $|C^n|$. The use of $|C^n|$ reflects the repetitive phonetic character of trills, |C| that trills involve closures and the subjunction of $|C^n|$ that trills may occur at different locational specifications. The fact that flaps/taps, which do not need to be phonologically distinguished, are closely related to trills as single trill occurrences, i.e. just one flick of the active articulator, is also expressed by the use of |C|, as the representation which appropriately characterises the tap/flap class of rhotics is single subjoined |C|. Thus the Hausa contrast will be represented as shown in (30):

(30)	*Hausa*	trill	flap/approximant
		/r/	/ɽ/
	articulatory gesture	|t|	|t|
		|	|
		$\|C^n\|$	|C|

With trills and flapped rhotics represented in this way, the Warlpiri system with contrasting trills, retroflex approximants and flaps is also accounted for except for the approximant rhotic. Given that the latter /r/-type involves approximation of the two articulators, subjoined |C| is again appropriate for this /r/-type. But since there is no stop contact, |a| combines with |C| in this r-type. The representation for approximant rhotics will then involve a combination of subjoined |a| and |C| where |a| signals incomplete contact and |C| close approximation, but because there is no contact, unlike in laterals, |a| governs |C| in this combination. The tree-way Warlpiri contrast is shown in (31):

(31)	*Warlpiri*	trill	retroflex approximant	flap
		/r/	/ɹ/	/ɽ/
	articulatory gesture	|t|	|t|	|t|
		|	|	|
		$\|C^n\|$	|a;C|	|C|

It was pointed out above that single rhotics are assumed to be specified like the rhotics in the languages whose speakers make a contrast between two or more /r/-types. Thus English approximant /ɹ/, as found in RP, will be specified as Warlpiri /ɹ/ in the articulatory gesture, although it does not contrast with any other rhotic in this language. Similarly, the trill found in Nyangumata Kunjen and numerous other languages will be specified as Warlpiri /r/, although they do not contrast with other rhotics either.

The rhotics of Edo poses a slightly different problem. This language is different because its rhotics are described by Ladefoged and Maddieson (1996) both as fricatives, either voiced or voiceless, and as liquids. Therefore the option exists that the three Edo rhotics be distinguished solely in the categorial gesture. Unfortunately, this possibility will lead to confusion of rhotic and lateral liquids. Instead the following articulatory

entries are appropriate phonologically in which only the voiceless fricative has a unique /ɹ̥/ categorial representation:

(32)

Edo	voiceless fricative	closed approximant	open approximant
	/ɹ̥/	/ɹ̝/	/ɹ/
articulatory gesture	|t| | |a;C|	|t| | |C;a|	|t| | |a;C|
categorial gesture	|a| | |a;C| | |C|	|a| | |a;C|	|a| | |a;C|

where the greater openness of /ɹ/ is reflected by the greater prominence of |a| in the articulatory gesture (dominant and not dependent).

To summarise: in the view adopted here laterals and rhotics essentially require artiulatory specifications. The system of components resulting from fission of fundamental pulmonic egression allows for these specifications. The classic places of articulation like coronal, labial and velar are covered by the articulatory fission products of |C|, i.e. |t|, |p| and |k|, whereas the other extra articulatory activity, what leads many specialists to interpret rhotics and laterals as an amalgam of manner and place, is captured by subjoined categorial |a| and |C|. The proposed representations for rhotics and laterals also contain markedness implications as predicted by a representational markedness model. In general, laterals and rhotics are represented as more marked than obstruent consonants thanks to the extra articulatory |C| or |a| or both subjoined to the basic labial, coronal and dorsal specifications. The general structure of inventories supports this markedness calculation as sonorant consonants presuppose obstruent consonants such that no inventory has only sonorant but not obstruent consonants (Maddieson, 1992). One type of rhotic appears less marked than other rhotics and laterals. Flaps/taps have only one subjoined |C| in the articulatory gesture. In a representational markedness model flaps/taps then get interpreted as less marked. This status is supported by neutralisation outputs. In varieties of English, notably American English (see Wells, 1982; Staun, 2010), the /t/–/d/ contrast neutralises to the flap. This is the process known as *t*-voicing which occurs in unstressed intervocalic position. Working class London English shows a similar development (Wells, 1982). Intervocalic /t/ in this variety is in among other positions frequently debuccalised to [ʔ] but a less ‘broad’ or moderate output is a flapped/*t*-voiced pronunciation. This behaviour in these two English varieties agrees well with flaps/taps being represented as least complex among the rhotic vocoids.

8. Concluding remarks

Fission in phonology as it is presented and developed here bifurcates phonologically atomic units such that each splitting involves refinement and sophistication of the nuclear component which undergoes fission. Assuming that phonological segments consist of the three discrete gestures (hierarchies), initiation, categorisation and articulation, fission starts from basic pulmonic initiation and provides the individual gestures with their phonologically atomic categories. Unlike fission in the natural sciences, phonological fission copies and transforms nuclei at the same time as these nuclei remain intact. Typically, each fission process splits a nucleus into two fragment components, but simple propagation is also a possible option by duplicating and adding phonetic and phonological refinement to one new component, just like multiple fission occurs when this process creates both gesture-internal and gesture-external fragments. By feeding all segmental gestures with phonological material, fission modulates the basic initiatory pulse into a variety of components allowing for phonologically relevant parameters such as glottal and velaric mechanisms in the initiatory gesture, major class and glottal state properties in the categorial gesture and a variety of places of articulation including vowel space distinctions in the articulatory gesture. As it emanates from one nucleus and applies to all three gestures, the fission hypothesis asserts that basically all components are phonetically connected as transformed constituents of basic pulmonic egression. Connectedness also surfaces in the preservation of the fissioned nuclei, the continued existence of which not only underpins how categorisation presupposes initiation and categorisation in turn is a prerequisite for articulatory structure, but also emphasises why any phonological inventory always utilises all three gestural hierarchies.

Fission as a process of refinement and sophistication presupposes a stable and balanced nucleus with one bond to a phonetic value only. Bondage to one value characterises monovalency. Fission therefore is directly associable with government/ dependency-based phonological models in which the ultimate phonological constituents are monovalent or unary rather than binary or polyvalent. With dependency/government phonology the fission-based model also shares the hypothesis that markedness directly appears from the phonological representations or the fission paths associated with the components that constitute these representations. The (for some phonologists) controversial representational markedness hypothesis is then revived in fission-based phonology and supported by markedness diagnostics like epenthesis, neutralisation outputs and typological inventory presupposition and sometimes saliency. Three representational aspects play a central role in this revival and how it is supported. First, the segmental division into discrete gestures allows for extra representational options by being able to function independently of one another. Second, the possibility of leaving individual gesture empty and others fully specified adds more structural possibilities. Third and finally, the presence of clear fission paths and patterns which nuclei and fragments follow or enter into also provides an extra representational dimension. Together these three aspects present a considerably more refined and advanced mechanism than is otherwise available in feature-based models. The latter may or may not have discrete hierarchical

bundles or gestures. But even if they have, they usually reject empty representations because this option allegedly makes specific phonological categories indistinguishable. But because the three aspects are available in fission-based phonology, representational markedness with its built-in zero/empty category hypothesis is a legitimate way of expressing how phonological categories vary in markedness.

Fission as it is proposed in this article has two inter-related implications which have not been discussed so far but which require a brief mention here as they may lead to new insights in phonology. The first is that fission may offer a novel view of the evolutionary development of the basic speech elements, and the second, and related implication, that fission may cast a new and different light on the notion of phonologicalisation. If the evolution of speech, as some have claimed (cf. Fitch, 2002), is closely linked with the presence of genes allowing for the potential descent of the larynx so humans unlike apes can possess a phonatory system next to the respiratory and articulatory systems, then one phonological interpretation of this anatomical development is a division into initiation, categorisation and articulation, the three gesture on which this study is founded. Fission as a process which starts with bifurcation of fundamental initiation could then be viewed as a first and natural step in the direction of speech development following from this possible descent, and the expansion of further nuclei resulting in a system capable of distinguishing phonological categories as the logical continuation of this evolutionary process. The inter-dependence of gestures emphasises the natural logic of this progress and is a sign of how the evolution of inventories is endowed with presupposition.

The evolution of such a system capable of describing inventories is connected with the second implication following from the present proposal, the implication that concerns phonologicalisation. When linked with the progressive fission processes, phonologicalisation becomes a process of systematisation which describes the development of a cognitive system of phonological primes, in particular a process whereby a sufficient amount of primes is created for an inventory to contain and distinguish a complete set of mutually presupposing contrasts. Viewed in this way, phonologicalisation does not presuppose phonemes and is not dependent on a specific allophonic typology nor associated with the creation of conventional contrasts in a process involving abduction as is the common interpretation of this notion and its parallel process in syntax, grammaticalisation (see Jakobson, 1931; Lass, 1984, 1997; Hopper and Traugott, 2003). Nor is phonologicalisation an initial step towards a proto but not fully developed inventory as this process has been called by some evolutionary scientists (Nowak and Krakauer, 1999). Instead phonologicalisation is the process, as just pointed out, by which fission creates a fully fledged set of primes capable of distinguishing a phoneme inventory or other phonological categories, and fission then supports the assumption of language evolutionists that language inventories only exist as complete structures. Needless to say, these implications are only speculative at this stage and their scope so comprehensive that they require to be treated in a separate study. But it is possible that as far as the segmental domain is concerned, fission is one transformational development that potentially helps us to understand the evolution of a system of primes. Interestingly,

Anderson (1997, 2006) envisages that specialisation splits also hold for grammatical categories, arguing that for example auxiliaries and determiners are developmental refinements of fundamental nouns and verbs.

References

Allan, S., Bauer, L., 1989. Review of John M. Anderson and Colin J. Ewen. 1987. Principles of Dependency Phonology. Cambridge: Cambridge University Press. *Australian Journal of Linguistics* 9, 347-355.

Anderson, J.M., 1980. On the internal structure of phonological segments: evidence from English and its history. *Folia Linguistica Historica* 1, 165-191.

Anderson, J.M., 1997. *A Notional Theory of Syntactic Categories*. Cambridge: Cambridge University Press.

Anderson, J.M., 2006. *Modern Grammars of Case*. Oxford: Oxford University Press.

Anderson, J.M., Durand, J., 1988. Underspecification in Dependency Phonology. In: Bertinetto, P., Loporcaro, M. (eds.), *Certamen Phonologicum* II. 1-36. Turin: Rosenberg and Sellier.

Anderson, J.M., Ewen, C., 1987. *Principles of Dependency Phonology*. Cambridge: Cambridge University Press.

Anderson, J.M., Jones, C., 1974. Three theses concerning phonological representations. *Journal of Linguistics* 10, 1-26.

Anderson, J.M., Jones, C., 1977. *Phonological Structure and the History of English*. Amsterdam: North Holland.

Archangeli, D., 1988. Aspects of underspecification theory. *Phonology* 5, 183-227.

Beckmann, J.N., 1998. *Positional Faithfulness*. Doctoral Dissertation. University of Massachusetts, Amherst.

Blevins, J., 2004. *Evolutionary Phonology*. Cambridge: Cambridge University Press.

Bomhard, A.R., 1984. *Toward Proto-Nostratic: A New Approach to the Comparison of Proto-Indo-European and Proto-Afroasiatic*. Amsterdam: John Benjamins.

Bomhard, A.R., 2008. *Reconstructing Proto-Nostratic: Comparative Phonology, Morphology, and Vocabulary*. Leiden: Brill.

Brown, R., Ogilvie, S., 2009. *Concise Encyclopedia of Languages of the World*. Oxford: Elsevier.

Carter, N., Celis, J.E., Small, J.V., Simons, K., Shotton, D.M., Hunter, T., Celis, J.E., 2005. *Cellular Biology*. Amsterdam: Academic Press.

Catford, J.C., 1977. *Fundamental Problems in Phonetics*. Edinburgh: Edinburgh University Press.

Causley, T., 1999. *Complexity and Markedness in Optimality Theory*. Doctoral dissertation. University of Toronto.

Chomsky, N., 1981. *Lectures on Government and Binding*. Dordrecht: Foris.

Chomsky, N., 1986. Knowledge of Language: Its Nature, Origin and Use. New York: Praeger.

Chomsky, N., Halle, M., 1968. *The Sound Pattern of English*. New York: Harper and Row.

Clements, G.N., Hume, E., 1995. The internal organisation of speech sounds. In: Goldsmith, J. (ed.), *The Handbook of Phonological Theory*. Oxford: Blackwell.

Clements, G.H., Osu, S., 2002. Explosives, implosives and nonexplosives: the linguistic function of air pressure differences in stops. *Laboratory Phonology*, vol. 7, 299-350. Berlin: Mouton de Gruyter.

Cook, V.J., Newson, M., 2007. *Chomsky's Universal Grammar*. Oxford: Blackwell.

Cottingham, W.N., Greenwood, D.A., 2001. *An Introduction to Nuclear Physics*. Cambridge: Cambridge University Press.

Cruttenden, A. (ed.), 2001. *Gimson's Pronunciation of English*. London: Hodder.

Davenport, M., Staun, J., 1986. Sequence, segment and configuration. In: Durand (ed.), *Dependency and Non-linear Phonology*. 135-161. London: Croom Helm.

de Boer, B., 2000. Self-Organisation in Vowel Systems. *Journal of Phonetics* 28, 441-465.

de Lacy, P., 2006a. *Markedness*. Cambridge: Cambridge University Press.

de Lacy, P. (ed.), 2006b. *The Cambridge Handbook of Phonology*. Cambridge: Cambridge University Press.

Durand, J., 2003. The vowel system of Danish and phonological theory. In: Galberg Jacobsen, H., Bleses, D., Madsen, T.O., Thomsen, P. (eds.). *Take Danish – for instance: Linguistic studies in honour of Hans Basbøll presented on the occasion of his 60th birthday*. 41-58. Odense: University Press of Southern Denmark.

Ewen, C.J., 1980. *Aspects of Phonological Structure with Particular Reference to English and Dutch*. PhD Thesis. University of Edinburgh.

Ewen, C.J., van der Hulst, L., 2001. *The Phonological Structure of Words*. Cambridge: Cambridge University Press.

Fitch, W.T., 2002. Comparative vocal production and the evolution of speech: reinterpreting the descent of the larynx. In: Wray, A. (ed.), *The Transition to Language*. 21-45. Oxford: Oxford University Press.

Gordon, M., 1998. Laryngeal timing and correspondence in Hupa. *UCLA Working Papers in Phonology* 2.

Hansson, G., 2007. On the evolution of consonant harmony: the case of secondary articulation agreement. *Phonology* 24.1, 77-120.

Harris, J., 1997. Licensing inheritance: an integrated theory of neutralisation. *Phonology* 14, 315-370.

Hayes, B., 1995. *Metrical Stress Theory: Principles and Case Studies*. Chicago: Chicago University Press.

Hopper, P.J., 1973. Glottalized and murmured occlusives in Indo-European. *Glotta* 7, 141-166.

Hopper, P., Traugott, E., 2003. *Grammaticalisation*. Cambridge: Cambridge University Press.

Hume, E., 2003. Language specific markedness: the case of place of articulation. *Studies in Phonetics, Phonology and Morphology* 9.2, 295-310.

Hume, E., Tserdanelis, G., 2002. Labial unmarkedness in Sri Lankan Portuguese Creole. *Phonology* 19, 441-458.

Isac, D., Reiss, C., 2008. *I-Language. Introduction to Linguistics as Cognitive Science*. Oxford: Oxford University Press.

Jakobson, R., 1931. Prinzipien der historischen Phonologie. *Travaux du Cercle Linguistique de Prague* IV, 247-267.

Jakobson, R., 1941. Kindersprache, Aphasie und algemeinte Lautgesetze. *Selected Writings*, vol. 1. 328-401. The Hague: Mouton.

Jakobson, R., Fant, G., Halle, M., 1951. *Preliminaries to Speech Analysis*. Cambridge, MA.: MIT Press.

Kenstowicz, M., 1994. *Phonology in Generative Grammar*. Oxford: Blackwell.

Ladefoged, P., 2001. *A Course in Phonetics*. [4th ed.] Boston: Heinle and Heinle

Ladefoged, P., Maddieson, I., 1996. *The Sounds of the World's Languages*. Oxford: Blackwell.

Lass, R., 1976. *Phonological Structure and the History of English*. Cambridge: Cambridge University Press.

Lass, R., 1984. *Phonology*. Cambridge: Cambridge University Press.

Lass, R., 1987. *The Shape of English*. London: Dent.

Lass, R., 1997. *Historical Linguistics and Language Change*. Cambridge: Cambridge University Press.

Lass, R., Anderson, J.M., 1975. *Old English Phonology*. Cambridge: Cambridge University Press.

Laver, J., 1994. *Principles of Phonetics*. Cambridge: Cambridge University Press.

Lombardi, L., 2002. Coronal epenthesis and markedness. *Phonology* 19.2, 219-251.

Lombardi, L., 2003. Markedness and the typology of epenthetic vowels. In: *Linguistics and Phonetics 2002 Proceedings: Prosody and Phonetics*.

Maddieson, I., 1992. *UCL Phonological Segment Inventory Database*. UCLA, Los Angeles.

Masica, C.P., 1991. *The Indo-Aryan Languages*. Cambridge: Cambridge University Press.

McCarthy, J., 1988. Feature geometry and dependency: a review. *Phonetica* 43, 84-108.

McCarthy, J., 1994. The emergence of the unmarked: optimality in prosodic in prosodic morphology. In: *Proceedings of NELS* 24, 333-379. Amherst, MA.: GLSA.

Newman, P., 1987. Hausa and the Chadic languages. In: Comrie (ed.), The *world's major languages*. 705-723. Oxford: Oxford University Press.

Nowak, M.A., Krakauer, D.C., 1999. The evolution of language. *Proceedings of the National Academy of Sciences* 96 (14), 8028-8033.

Paradis, C., 1992. *Lexical Phonology and Morphology: The Nominal Clauses in Fula*. New York: Garland.

Paradis, C., Prunet, J.F. (eds.), 1991. The Special Status of Coronals: Internal and External Evidence. *Phonetics and Phonology* 2. San Diego: Academic Press.

Parker, S., 1997. An OT Account of Laryngealization in Cuzco Quechua. Work Papers *of the Summer Institute of Linguistics*, vol. 41. University of North Dakota Session.

Parker, S., Weber, D., 1996. Glottalized and aspirated stops in Cuzco Quechua. *International Journal of American Linguistics* 62, 70-85.

Prince, A., Smolensky, P., 2004. *Optimality Theory*. Blackwell, Oxford.

Rice, K., 1999a. Featural markedness in phonology. Part I. *GLOT* 4.7, 3-6.

Rice, K., 1999b. Featural markedness in phonology. Part II. *GLOT* 4.8, 3-7.

Rice, K., 2006. Markedness. In: de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge: Cambridge University Press.

Rice, K., Avery, P., 1991. On the relationship between laterality and coronality. In: Paradis, C., Prunet, J.F., (eds.), The special status of coronals: internal and external evidence. *Phonetics and Phonology* 2. 101-123. San Diego: Academic Press.

Rischel, J., 1970. Consonant gradation: a problem in Danish phonology and morphology. In: Benediktsson, H. (ed.), *The Nordic Languages and Modern Linguistics*. 460-480. Reykjavik: Visindafelag Islendinga.

Schane, S., 1984. The fundamentals of particle phonology. *Phonology Yearbook* 1, 129-155.

Staun, J., 1996. On the Locational Description of Consonants. *Travaux du Cercle Linguistique de Copenhague* 24. København: Reitzel.

Staun, J., 2003. On vocalic feature hierarchisation. *Language Sciences* 25, 111-158.

Staun, J., 2005. Towards a taw-based phonological representation of place. In: Carr, P., Durand, J., Ewen, C. (eds.), *Headhood, Elements, Specification and Contrastivity*. 229-268. Amsterdam: John Benjamins.

Staun, J., 2010. *An Introduction to North American English Pronunciation*. Odense: University Press of Southern Denmark.

Stevens, K., Keyser, S.J., 1989. Primary features and their enhancement in consonants. *Language* 65, 81-106.

Thongkum, T., 1987. Phonation types in Mon-Khmer languages. *UCLA Working Papers in Phonetics* 67, 29-48.

Trigo Ferre, R. L., 1988. *On the phonological derivation and behaviour of nasal glides*. Doctoral dissertation. MIT.

van der Hulst, L., 1989. Atoms of segmental structure: components, gestures and dependency. *Phonology* 6, 253-477.

van der Hulst, L., 1994. Radical CV phonology: the locational gesture. *UCL Working Papers in Linguistics* 6, 439-478.

van der Hulst, L., 1995. Radical CV phonology: the categorial gesture. In: Durand, J., Katamba, F. (eds.), *Frontiers of Phonology: Atoms, Structures and Methods.* 80-116. London: Longman.

Vaux, B., Samuels, B., 2005. Laryngeal markedness and aspiration. *Phonology* 22.3, 395-437.

Wells, J., 1982. *Accents of English*. Vol. 1. Cambridge: Cambridge University Press.