[Article on a Specified Topic]

REPRESENTING PHONOLOGY WITHOUT PRECEDENCE RELATIONS

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In the pursuit of a strictly monostratal model of phonology, syllable/prosodic structure is fully specified in lexical representations. Accordingly, information relating to the linear order of segments is redundant in representations: dependency relations holding between syllabic categories are sufficient to account for phonological phenomena. This paper therefore investigates the possibility of omitting from phonological representations all precedence relations between units, which would allow positional precedence to be viewed merely as a by-product of phonetic interpretation relevant to the sensorimotor systems. As such, the division between phonology and its external systems would parallel the division between syntax and performance systems.*

Keywords: *precedence*, *dependency*, *monostratalism*, *lexical specification*, *directionality*

1. Introduction

In the theory of syntax, precedence relations between the terminal nodes (words) of hierarchical structure are not encoded in formal representations. Precedence relations are generally viewed as a by-product of linearisation, a process which maps the hierarchical structure on to a left-to-right linear string at a point after the last operation is applied in the overt syntax and before the sentence is submitted to Spell-Out (Kural (2005: 367–368), cf. Chomsky (1981, 1995), Kayne (1994)).

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In contrast, phonology requires the encoding of precedence or ordering relations in representations, which sets it apart from syntax (and also other linguistic modules). This idea is mainly attributed to the widespread view that precedence relations between segments must be lexically specified in order to allow hierarchical (syllable) structure to be constructed—assuming that hierarchical structure is either unspecified (Bromberger and Halle (1989)) or partially/minimally specified (McCarthy and Prince (1986)) in lexical representations.

There is surprisingly little discussion in the literature which offers any serious challenge to this view, and which, like syntax, tries to eliminate the need for precedence relations in phonological representations.[1] To my knowledge, questions concerning the formal status of precedence relations are to be found only in Anderson (1987), Nasukawa (1999) and Takahashi (2004). Referring to some of their arguments, this paper will address this issue by evaluating two different relational properties—precedence and dependency—currently used in linguistic representations, and then attempting to collapse these into a single notion of dependency. It will then be argued that precedence is merely the natural result of computing and interpreting the dependency relations which hold between units in a structure. By adopting this approach, the competence side of the language faculty (which includes intra-segmental structure) gains the advantage of being able to maintain a greater degree of representational coherence throughout derivation, right up to the level at which it interfaces with the articulatory-perceptual systems. This does not undermine the discussion given in Shiobara (this volume) where linear information is significant in "prosodically-constrained" (stress-pattern-sensitive) syntax since linear information used for structure construction is considered to be a (phonetic) outcome of the linearisation process (stress and intonation patterns are regarded as by-products of the computing of hierarchical structure, as discussed in Liberman and Prince (1977), Scheer and Szigetvári (2005)). This is compatible with the position adopted here.

[1] Prosodic structure naturally divides into two parts, morpheme-internal and morpheme-external, the former being associated with the lexicon and the latter with morpho-syntactic operations. The present study focuses on the former and eliminates precedence relations between phonological categories. The latter, morpheme-external prosodic structure, lies beyond the scope of this paper, since it is constructed by referring to morpho-syntactic operations rather than to structures unique to phonology such as phonological words, phrases and intonational phrases.

This paper, which is the first formal attempt to describe phonology without any reference to formal properties of precedence, is structured as follows. Section 2 presents an overview of how linear information is represented in phonological theories. Section 3 discusses some disputed points about the formal status of precedence relations in phonology. Section 4 attempts to eliminate precedence from representations since it is redundant under a monostratal approach to phonology, and section 5 claims that precedence is a product derived from the interpretation of dependency relations. Section 6 describes a case study in which two types of assimilation, leftward place assimilation and rightward postnasal voicing are analysed comparatively without reference to precedence relations in the internal grammar. Section 7 presents conclusions.

2. Precedence in Phonology

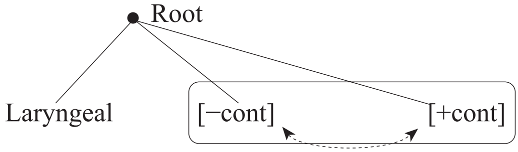
2.1. Formal Properties in Phonology

Phonological representations generally employ two types of formal properties: categorical and relational. Categorical properties refer to units such as melodic features, feature nodes, prosodic positions (e.g. C/V positions, skeletal positions) and prosodic constituents (e.g. syllable, onset, rhyme, nucleus, mora) while relational properties hold between these categories. Relational properties further divide into two kinds, precedence and dependency: precedence is typically encoded at the interface between prosody (suprasegmental structure) and melody (intrasegmental structure), which involves phonological units such as CVs, Xs and Root nodes; on the other hand, dependency is typically encoded between syllabic constituents. In some theoretical frameworks dependency also operates within melodic structure, where the internal structure of a segment is represented through dependency relations between intra-segmental units (McCarthy (1988), Anderson and Ewen (1987), Harris (1994), Clements and Hume (1995), Nasukawa and Backley (2005)). A point which is often overlooked, however, is the fact that the term "dependency" actually defines a more general structural property which is present in other modules of the grammar too. So rather than dependency, this section focuses on the notion of precedence and reviews how it is encoded in phonological representations.

2.2. Linear Ordering of Phonological Units

It has traditionally been assumed that precedence relations are expressed typically at two distinct levels: (i) within segments and (ii) between segments. Regarding (i), Sagey (1986), for example, proposes the representation in (1) for affricates, where the ordering of [−cont] and [+cont] reflects the order in which these feature values are phonetically interpreted.

(1) Linear Ordering of Features within a Segment

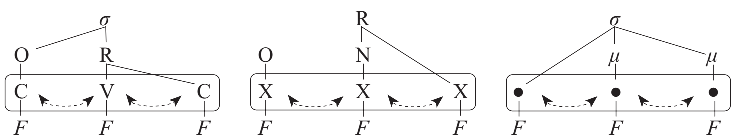


Precedence relations =

As for (ii), Clements and Keyser (1983) employ C/V slots which themselves occupy the terminal nodes of syllabic (prosodic) structure, which makes it possible to express a direct connection between consonantal/vocalic properties and particular positions within syllable structure. In this model, linear ordering is represented by the left-to-right arrangement of CV strings, as depicted in (2a).

(2) Linear Ordering between Segments

a. CV-tier model b. X-tier model c. Mora-based model



C/V = C/V position X = skeletal position ● = Root node

F = feature O = onset R = rhyme N = nucleus μ = mora

Precedence relations =

Dependency relations =

In a later development the units of the CV tier were redefined as bare timing units which are often called skeletal positions and represented by Xs (Kaye and Lowenstamm (1981, 1986), Levin (1985), Harris (1994)). As shown in (2b), their left-to-right arrangement represents precedence relations. The skeletal tier had the advantage of giving the prosodic structure sole responsibility for differentiating between consonantal and vocalic expressions.

An alternative model of syllable structure developed by McCarthy and Prince (1986) excluded from syllable structure all timing units such as Xs as well as syllable categories such as onsets and nuclei. Instead, the authors adopted the category mora μ. In this model (2c), the only unit relevant to linear ordering is the Root node of Feature Geometry which is specified as part of melodic structure rather than prosodic structure. In this model, the formation of syllable structure is based on lexically encoded precedence relations holding between Root nodes in the string.

Representational precedence is an important element in principles/constraints, which often refer to 'directionality' and 'locality.' In rule-based frameworks, for example, rules for describing assimilation processes (e.g. Spread right/left) typically refer to directionality in a given domain. Some recent phonological analyses of assimilation have departed from the sequential spreading processes, but still refer to right/left (e.g. Align right/left) which is determined by precedence relations at the interface level between prosody and melody. As for locality, which in most phonological theories prescribes a domain for phonological processes and syllable formation, this notion is based on adjacency at a certain level of representation: for example, the distinction between foot-initial and foot-final is primarily attributed to positional adjacency in phonology. In precise terms, then locality in phonology is different from locality in other linguistic components such as syntax.

3. Questioning the Formal Status of Precedence Relations in Phonology

3.1. No Precedence Relations in Contour Expressions

During the last decade, however, the formal status of contour expressions has been called into question by Lombardi (1990), Schafer (1995), Scobbie (1997), Scheer (2003), Nasukawa (2005), Nasukawa and Backley (2008) and others, who dispute a number of points concerning precedence relations between intra-segmental categories such as features. First, it is hard to provide an explanation for why affricate contours defy typical edge effects (Lombardi (1990)). Second, there are no clear reasons why the two features in a contour (e.g. [ʤ]) never appear in the reverse order (e.g. *[ʒd]). And third, there is nothing to account for the fact that the number of sub-segmental timing slots in an affricate is always two. Phonological theory is required to explain why contours do not contain three slots or more; allowing an upper limit of two slots is essentially an arbitrary restriction.

In response to these points, there is now a growing literature in support of the view that the precedence relations observed in contour segments are not attributable to any sequential ordering of features in representations. Rather, they are recognized as being the result of staggering the realisation of a single segmental structure. For example, Lombardi (1990) proposes a representation (based on Feature Geometry) which contains the two unordered privative stricture features [cont] and [stop]; she claims that these two features belong to separate autosegmental tiers and display a symmetric dependency relation. Meanwhile Schafer (1995) accommodates Lombardi's proposal and claims that there exists an asymmetric dependency relation between [stop] and [cont]. These and other similar proposals all dispense with formal precedence relations between the relevant segmental features. It emerges that there is insufficient phonological evidence to support any segment-internal ordering of features.

Accepting the view that affricates are not contour segments, Nasukawa and Backley (2008) also recognize no phonological difference between plain stops and affricate stops; affrication itself is taken to be entirely a matter of phonetic realisation. In addition, they provide a perception-oriented explanation of why some stops are produced as contours. Their claim is that affrication is regarded as a performance device for improving the perceptibility of complex-resonance stops by making multiple place cues more accessible to listeners; this is achieved by enhancing the portion of the speech signal containing aperiodic noise energy, which is relatively rich in place cues. In contrast, plain stops with a single resonance prime exhibit a less complex and less intense acoustic pattern, which can be recovered from a non-affricated (i.e. simultaneous or non-staggered) realisation of the stop.

3.2. Lexical Specification of Precedence

Having argued for the elimination of linear ordering in contour segments, I now turn to the question of precedence relations between skeletal positions at the structural level. Since segmental precedence is relevant to the amount of information which is specified lexically, let us examine the kinds of properties which are given in the lexicon. For example, allowing for differences in terminology used by different theoretical models, rule-based multistratal approaches do not specify syllable structure in lexical representations: instead, based on lexically-specified precedence relations between skeletal positions, syllabification takes place through the serial application of extrinsically ordered rules during the course of derivation (Bromberger and Halle (1989), Keating (1990), Bickmore (2007)).

In McCarthy and Prince (1986), although there is little explicit discussion, some syllable categories (morae) are lexically given, but other aspects of syllable structure are assigned during the course of derivation. This also requires information regarding precedence relations between Root nodes (of Feature Geometry) for the assignment of syllable structure. This type of representation is generally seen as having the advantage of excluding representational redundancy in derivations. Here, a lexical representation consisting of a string of segments and the partial specification of morae together comprise the minimal amount of information necessary for building syllable structure.

This kind of representational mismatch between lexical and non-lexical characteristics of multistratal approaches is based upon the following statements of lexical and derived representations.

(3) a. Lexical representations (sometimes dubbed primary or underlying representations) contain the minimal information necessary for exhibiting lexical contrasts, and serve the functions of memory and lexical storage.

b. Derived representations (sometimes dubbed categorical or systematic phonetic representations) contain more physical, concrete or precise information, and serve as the input to auditory processing and motor programming.

In this approach, the decision to not specify syllable structure lexically may be viewed as a type of archiving programme which compresses information for compact storage. Motivation for this type of lexical representation in generative phonology seems to have come from the assumption that long-term memory constraints prompt speakers to limit storage to idiosyncratic information and maximize the computing of predictable information. However, this view has never been seriously defended in the psycholinguistics literature (for a detailed discussion of intra-segmental representations, see Harris and Lindsey (1995)). If underspecification of syllable structure is not justified by storage considerations, then the view in (3) is brought into question. The more economical a lexical specification is, the heavier the computational burden of the grammar must be before a phonological outcome can be achieved.

In fact, this argument for the underspecification or minimal specification of syllable information in lexical structures is circular, because the opposite treatment may also be theoretically possible. That is, syllable structure is assigned lexically, and this then allows us to generate syllabic constituents and distribute segments. In principle, therefore, there is no decisive way of choosing between the underspecification of syllable structure or the full specification of syllable structure. The choice of information (either linear or prosodic) to be lexically specified is determined by the overall design of the cognitive system. If the competence side of the language faculty retains representationally coherent characteristics throughout the derivation, then the units of phonological representation must resemble those units found within other grammar-internal components: the syntactic structures of phonological units (= prosody) must feature in any kind of phonological representation. Under this view, which follows the same line of argument found in syntactic theories (Chomsky (1981, 1995), Kayne (1994), Kural (2005)), the sequential ordering of phonological units is viewed as the phonetic outcome of computing hierarchical structure.

Monostratal approaches to phonology (Government Phonology: Kaye, Lowenstamm and Vergnaud (1990), Harris (1997)) also raise serious doubts about the validity of the underlying-surface distinction. For example, Kaye (1995: 320) makes the point that syllable structure (prosodic properties) cannot be stripped away in lexical representations since it is sometimes required for the purposes of encoding lexical contrasts.

> "… Consider French *watt* 'watt' and *oiseau* 'bird'. Their initial portion is pronounced identically, [wa]. If claim (a) ['The phonological surface representation must encode how a word is pronounced.'] is applied to French then their initial portion ought to have the same syllable structure. It does not, cf. *le watt* vs. *l'oiseau* and *les watts* vs. *les oiseaux*. Consider also Italian pairs such as *fato* 'fate' vs. *fatto* 'fact'. Both contain the sounds 'f', 'a', 't', and 'o'. The first syllable of *fato* is open, while that of *fatto* is closed. Such examples could be easily multiplied."

Following this argument, consider one version of the Licensing/government-based framework of phonology (LGP) (Harris (2004), Takahashi (2004), Nasukawa (2005, 2010)). Unlike standard multistratal models, this monostratal approach permits the specification of syllable structure in lexical representations. In this framework, the only syllable properties deemed necessary are those which play a role in deriving lexical contrasts. This is due to the assumption that computation becomes overly burdened if any syllable structure that is necessary at the phonology-phonetics interface is assigned unnecessarily at non-lexical levels of derivation.

With regard to sequential ordering, even in this monostratal model precedence is indispensable in lexical representations for the purpose of evaluating structural well-formedness. In LGP, as in most other theories, phonological structures are defined by dependency relations between units. In this framework, such relations are described under the term "licensing," which controls phonological structure as follows.

(4) Phonological Licensing (Harris (1994: 156), Kaye (1990: 306))
   a. Within a domain, all phonological units must be licensed save one, the head of that domain.
   b. Licensing relations are local and directional.

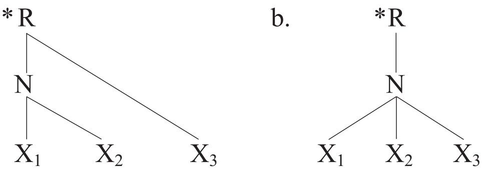
Takahashi (2004: 45–47) classifies descriptive variations of the principle in (4b), as found in (5).

(5) a. Locality
The head must be adjacent to its dependent.
b. Directionality
The head and its dependent assume a unidirectional precedence.

Locality ensures that a dependency (or 'p-licensing') relation cannot bypass a position, while Directionality requires that the head occupies one edge of a dependency-formed domain. With recourse to the two principles, we naturally derive the Binary Theorem which declares all syllable constituents to be maximally binary.

Given these principles, the theory claims that a branching rhyme, for example, cannot dominate a branching nucleus.

(6) a. b.



In the configuration (6a), the head X_1 fails to license the rhyme dependent X_3 in accordance with Locality (cf. Kaye (1990: 303), Kaye, Lowenstamm and Vergnaud (1990: 200)). A structure with three positions under a single constituent node in (6b) may satisfy Locality, since the head X_2 licenses its dependents X_1 and X_3 which are both adjacent to X_2 at the skeletal level. However, (6b) violates Directionality since head X_2 licenses X_1 and X_3 in a different direction. In LGP, only syllable structures which conform to principles/constraints such as these are well-formed.

According to the description of LGP just given, it would seem that this approach must also make reference to precedence relations between skeletal positions in the evaluation of structural well-formedness. However, in what follows I shall dig deeper into the monostratal theory of LGP and discuss the possibility of eliminating the formal notion of precedence from phonological representations.

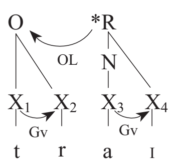
4. Precedence as a Redundant Property in Monostratal Phonology

As discussed in the previous section, syllable structure in LGP is fully specified in lexical representations. The theory treats syllable structure as an idiosyncratic, unpredictable property.[2] Given that lexical representations are fully syllabified and that this syllabification cannot be altered, as dictated by Structure Preservation, it is unnecessary to assume any precedence relation (e.g., x_i precedes x_j) independently of the head-dependent relation holding between x_i and x_j. In this paper, therefore, I investigate the possibility of omitting from phonological representations all precedence relations between units. Instead, I treat positional precedence as the natural result of performance systems interpreting the hierarchical structure present in phonological representations. This renders the division between phonology and its external systems similar to the division between syntax and performance systems. (No precedence relations are employed in syntactic representations; rather, processes which linearise syntactic properties are carried out by its outer systems via dependency relations between syntactic units.) The elimination of precedence from phonology implies that phonology is a phon-syntax.

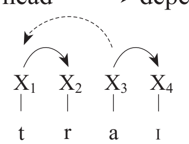
If we omit the notion of precedence from representations, principles/constraints such as Locality and Directionality which refer to positional precedence also need to be reconsidered. Now I argue for representations that exclude precedence properties within LGP and then demonstrate how Locality and Directionality are derived effects of phonetic interpretation.

First, let me give an example of syllable structure in LGP.

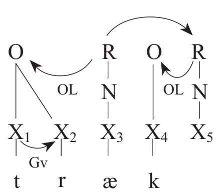
(7) a. *try*



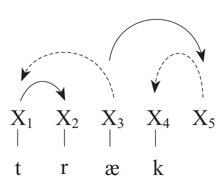
b. dependent ←------ head *Exocentric*
head ⟶ dependent *Endocentric*



c. *track*



d. dependent ←------ head *Exocentric*
head ⟶ dependent *Endocentric*



[2] Takahashi (2004) claims that syllable structure should be fully specified in lexical representations even in the framework of classical Optimality Theory (OT). This is because an empirically impossible evaluation may be selected if syllable structure is not specified at the input level in OT. Further arguments in favour of the lexical specification of syllable (hierarchical) structure even in OT are found in Golston (1996) and Nasukawa (2010).

In this theory, dependency relations at the skeletal level are formed by government (Gv), and the two instances in (7a)—X_1 licenses X_2 in an onset and X_3 licenses X_4 in a nucleus—are head-initial. On the other hand, a head-final dependency relation holds between an onset constituent and rhyme constituent in accordance with ONSET LICENSING (OL) (Harris (1994: 160)): an onset head must be licensed by the following nucleus head. It should be noted that this framework departs from traditional representational approaches by claiming that morphemes/words ending phonetically in a consonant do not end representationally in a coda; instead, this consonant is assumed to occupy an onset which is followed by an empty nucleus (see Harris and Gussmann (1998, 2002) for a detailed discussion to support the empty-nucleus-final structure). An example is given in (7c) which also involves both head-initial and head-final dependency relations: the former holds between skeletal positions within an onset and the latter between an onset and a rhyme.

Looking beyond syllable constituents, we may classify these dependency relations into two types: head-initial and head-final. Head-initial licensing holds between melodic expressions of the same type, consonantal or vocalic. By contrast, head-final licensing involves melodic expressions which are different in type, e.g., a nucleus licenses an onset. Under this view, we no longer need to refer to notions such as 'initial' and 'final.' As I will demonstrate later, we can account for phonological phenomena just by referring to types of dependency rather than to terms based on positional precedence. As we find in syntax, the two types of dependency may be defined as follows.

(8) Types of Dependency
  a. Endocentric Dependency
     If the dependent is of the same type as its head, this is endocentric dependency.
  b. Exocentric Dependency
     If the dependent is of a different type from its head, this is exocentric dependency.

A similar argument is developed in Takahashi (2004), where the mapping between dependency relations and their phonetic manifestation is defined in terms of linearisation.

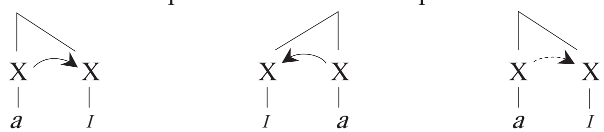
(9) Takahashi (2004: 172)
  a. Endocentric Dependency: if $\alpha \rightrightarrows \beta$, then $\alpha \ll \beta$
     In endocentric dependency wherein α and β are the head and the dependent position, respectively, α strictly and immedi-

ately precedes β in phonetic interpretation.

b. Exocentric Dependency: if $\alpha \rightarrow \beta$, then $\alpha > \beta$
In exocentric dependency wherein α and β are the head and the dependent position, respectively, α strictly but not necessarily immediately follows β in phonetic interpretation.

According to this view, the representations in (10a) and (10b), which display endocentric dependency, have the same phonetic manifestation. On the other hand, since (10c) is formed by exocentric dependency, the structure phonetically manifests itself as *ja* rather than *aɪ*.

(10) a. Endocentric dep b. Endocentric dep c. Exocentric dep



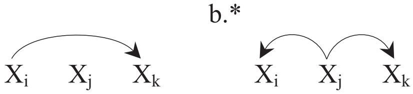
As Takahashi (2004: 175) argues, these two types of dependency can offer a redundancy-free mode of representation. Given the restrictive nature of the proposed model, the Directionality constraint is no longer necessary. Consider the ternary structures in (11), where a position with a dependent on each side is regarded as the head of two independent domains $X_j \rightarrow X_i$ and $X_j \rightrightarrows X_k$.

(11) a. b.

The Directionality constraint is required in order to eliminate the ternary structure in (6b) and leave dependency relations strictly binary. However, in the present theory, Directionality is dispensable.

Another constraint relying on precedence relations is Locality, which disallows structures like (12a) where X_i skips the adjacent position X_j to license X_k.

(12) a. b.*



Unlike standard GP, the proposed model does not treat this configuration as being ill-formed. The representation simply tells us that the skipped position X_j, which is not licensed, is not phonetically interpreted. Its presence is highly questionable in the first place. Therefore, configurations such as (12a) do not amount to a Locality violation. In the proposed theory, the arbitrariness of (12b) renders it phonetically ambiguous and thus ill-formed: it is not clear whether the structure should be interpreted as $X_j < X_i < X_k$ or as

$X_j<X_k<X_i$. Its violation is explained in terms of Unique Path.

(13) Unique Path (Takahashi (2004: 184))
Let α and β be positions. A dependency path from α to β must be unique within a domain.

In (12b) two paths of endocentric dependency extend from the same position X_j. This constraint bans such a structure at the syllable level.

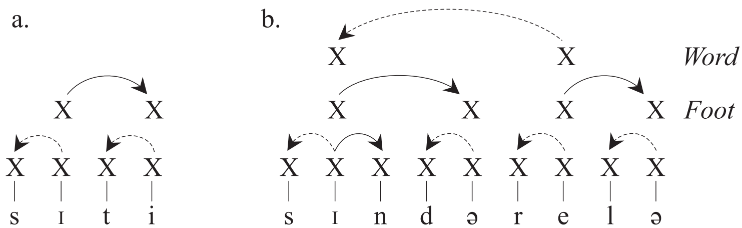
Thus, well-formed representations comprise positions entering into endocentric/exocentric dependency relations in compliance with UNIQUE PATH.

5. Linearisation of Phonological Structure

Thus far, I have eliminated precedence relations both from intra-segmental structures and syllabic positions, and have claimed that precedence is a product derived from the interpretation of dependency relations by the sensorimotor systems. My arguments follow the widely accepted view that structures in generative grammar are generally formed by dependency relations in syntax and morphology, where the process of producing strings from trees is generally seen as a trivial matter (Chomsky (1995)). It is normally considered that categories in these components are linearised by their corresponding external systems (Kural (2005), cf. Kayne (1994)).

Returning to phonology, it is clearly not ideal that levels above the syllable should be analysed in a unique way. For this reason, I shall extend the entocentric/exocentric dependency model to higher levels of prosodic structure.

(14) a. b.



First, like relations found in X-bar syntax but unlike syllable-internal relations, I shall assume that exocentric- and endocentric-dependency relations above the syllable level involve relations between a spec and its head, and between a head and its complement, respectively.

In (14a), the projected positions enter into an endocentric dependency relation, this configuration being phonetically interpreted as a head preceding its dependent along the time axis. At the syllable level, two exocentric dependency relations are formed and they are phonetically manifest as a dependent preceding its head. Like the syntactic-tree-traversal algorithms in Kural (2005), this mapping process first takes place at the highest dependency level, then moves down successively to the lower levels in a structure. In this way the linear ordering of segments is established. Although the representation in (14b) is more complex than that in (14a), the mapping strategy is identical.

From these representations, we may follow (7) in assuming that the kinds of dependency relation operating at the syllabic level are universally fixed: the dependency relation between an onset and a nucleus is exocentric, while that between two onsets/nuclei is endocentric. On the other hand, above the level of the syllable, the type of dependency relation varies from language to language. It is through the observation of prosodic phenomena that we are led to recognize parametric variation of this kind.

6. An Analysis of Phonological Processes without Reference to Precedence Relations

6.1. A Case Study: Postnasal Voicing Assimilation

Traditionally, precedence relations between units are considered to be indispensable in the analysis of certain phonological phenomena such as long-distance and local feature-agreement processes. Here I shall focus on the latter type and analyse it without referring to precedence relations. Note that several studies (Piggott and van der Hulst (1997), Nasukawa (2005) and others) have already proposed analyses of the former type by referring to the interplay between prosodic/syllable structure and particular melodic primes—crucially, without employing sequential ordering.

The local agreement process we examine here is postnasal obstruent voicing assimilation, which is usually found in true voicing languages such as Japanese and Zoque and is typically analysed by referring to precedence relations at the segmental level (i.e. positions such as CVs, Xs and Root nodes).

(15) Postnasal Obstruent Voicing Assimilation

a. Yamato Japanese (Nasukawa (2005))

šin + te (gerundive)	→	*ši**nd**e*	'die' (gerundive)
kam + te	→	*ka**nd**e*	'chew' (gerundive)
šin + ta (past indic.)	→	*ši**nd**a*	'died'
kam + ta	→	*ka**nd**a*	'chewed'

b. Zoque (Wonderly (1946, 1951), Padgett (1994))

min-pa	→	*mi**mb**a*	'he comes'
min-ta	→	*mi**nd**amʌ*	'compel (pl.)'
pʌn-čʌki	→	*pʌ**ɲǰ**ʌki*	'figure of a man'
pʌn-ksi	→	*pʌ**ŋg**ʌsi*	'on a man'

This process typically involves two types of assimilation: as the name implies, one is postnasal voicing which is triggered by a nasal and changes a *following* segment into voiced one (16a); the other is place assimilation which is triggered by the obstruent in a nasal-obstruent (NC) sequence and usually affects a *preceding* segment (16b).

(16) Two Types of Assimilation in Postnasal Obstruent Voicing Assimilation

a. Postnasal Voicing $\ldots\ C_{Nas} \longrightarrow C_{Obs}\quad V\ \ldots$

b. Place Assimilation $\ldots\ C_{Nas} \longleftarrow C_{Obs}\quad V\ \ldots$

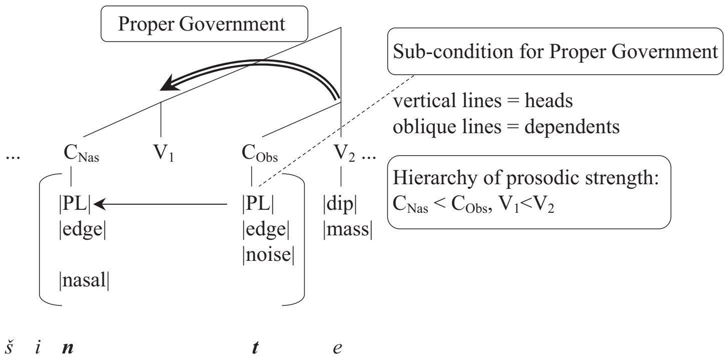
The difference in directionality between these two assimilation processes is usually stated directly in the phonological formalism, rather than explained in any reasoned way. For example, we find statements such a 'Spread [α] rightwards/leftwards' (Cho (1990), et passim) and 'Align(α, right)' and 'Align(α, left)'(McCarthy and Prince (1993), et passim). However, it is possible to account for place assimilation in (16b) just by referring to dependency, rather than to precedence relations. This is explained in the following section. (The postnasal voicing assimilation process shown in (16a) will be described in section 6.3.)

6.2. Place Assimilation

The prosodic context where these phenomena take place can be stated as in (17). The LGP literature (Nasukawa (2005, 2010)) typically employs a strict CVCV structure for systems referred to as CV languages. These are assumed to have neither codas nor consonant clusters: the prosodic structure is assumed to be strictly CVCV, which rules out any branching constituents. In this paper it will be assumed that this structure also applies to Japanese, which gives priority to the CV-dichotomy.[3]

[3] In this framework, geminate consonants are not analysed as coda-onset sequences; instead, they are treated as sequences consisting of an empty nucleus flanked by two identical consonants. Additionally, C*j* is not analysed as a consonant cluster; instead, the *j* is syllabified in a nucleus rather than in the second slot of a CC cluster (Nasukawa (2005, 2010)).

(17) The Prosodic Context of an NC Sequence
šinde ‘die’ (gerundive) (Yamato Japanese)



The melodic representations employed here are based on the version of Element Theory described in Nasukawa and Backley (2008) and Backley and Nasukawa (2009, 2010). In this approach, each phonological feature (element) is monovalent (single-valued) and therefore creates privative oppositions; each is also fully interpretable on its own, and as such, does not require support from other features (elements). The set of elements is listed below, showing their principal phonetic properties.

(18) Elements

		onset	*nucleus*
|dip|	(|I|)	coronal: dental, palatal POA	front vowels
|rump|	(|U|)	dorsal: labial, velar POA	rounded vowels
|mass|	(|A|)	guttural: uvular, pharyngeal POA	non-high vowels
|edge|	(|ʔ|)	oral or glottal occlusion	creaky voice (laryngealised vowels)
|noise|	(|H|)	aspiration, voicelessness	high tone
|nasal|	(|N|)	nasality, obstruent voicing	nasality, low tone

Elements are not tied to particular syllabic positions—in principle, any element can appear in any position. However, the same element can display different phonetic properties according to the position where it appears. In nuclear positions, for example, |dip| |rump| |mass| (|I U A|) have the correlates in the top three lines in (18) and are associated with the peripheral vowels [i u a] ([e] and [o] are the phonetic manifestation of a compound expression |I A| and |U A| respectively). On the other hand, in non-nuclear positions |dip| |rump| |mass| contribute consonantal place properties.

Let us now turn to the so-called consonant elements |edge| |noise| |nasal|

(|ʔ H N|). The |edge| element provides the stopness or occlusion which characterises oral and nasal stops. And when no other elements are present, it is interpreted in an onset as [ʔ]. In some languages it can also appear in nuclei, where it creates a laryngealised vowel to give the effect of creaky voice. The remaining consonant elements |H| and |N| can also appear in either consonants or vowels—that is, they also display consonant-vowel unity. In onsets, these two elements provide laryngeal properties such as aspiration and (true) voicing in obstruents, while in nuclei they create tonal distinctions on vowels. Note that Element Theory does not recognize any independent element corresponding to the feature [voice]; instead, |nasal| is phonetically interpreted as true voicing when it appears together with |noise| (Nasukawa (2005)).

We now turn to prosodic structure. As (17) shows, an NC sequence is formed by two Cs flanking a nucleus that has no melodic material. In this structure, the melodically empty nucleus V_1 is the head of a head-dependent domain, its dependent being the preceding position containing the nasal. Then in turn, the empty nucleus is itself a dependent of the following melodically-filled nucleus V_2.[4] The filled nucleus V_2 is also the head of another head-dependent domain, its dependent being the obstruent in the NC sequence. Now, the empty nucleus is licensed to be phonetically silent by its head vowel V_2, but this can only happen if V_2 contains melodic material. In LGP and related theories, this kind of dependency relation is called Proper Government. It is defined as in (19):

(19) Proper Government (cf. Kaye (1990), Harris (1994), Charette (1998), Nasukawa (2010))[5]
An empty position can be licensed to be phonetically silent by virtue of being prosodically dependent on a melodically filled nucleus.

[4] This dependency relation is based on an analysis of Japanese morpho-syntax developed by Tonoike (1990, 1991, 1995) and Fukui and Takano (1998) where the case-marking particle is the head of a given phrase.

[5] A different version of Proper Government is found in Kaye (1990: 314) and Harris (1994: 191), where Proper Government applies if a structure meets all the conditions below.

Proper Government:
A nucleus α properly governs an empty nucleus β if and only if
a. α and β are adjacent on the relevant nuclear projection,
b. α is not itself p-licensed, and
c. no governing domain separates α from β.

In Japanese, Proper Government takes place only if the nasal (the dependent of V_1) and the obstruent (the dependent of V_2 which is the head of V_1) share the same place features. In other words, the nasal and the obstruent form a domain and their shared place feature (represented by |PL| in (17)) becomes a property of the whole domain. When this happens, the shared place feature is the one belonging to the obstruent position, since the obstruent position is prosodically stronger than the nasal position. Here, strength is defined by dependency relations: the obstruent is strong because it is a direct dependent of the head V_2, whereas the nasal is weaker because it is only an indirect dependent of V_2.

The situation just described for NC sequences also applies to other phenomena in Japanese, such as the suppression of vowels between consonants.

(20) Vowel suppression between consonants

a. *hašir* + *-anai* (negative) > *haši**ran**ai* > *haši**nn**ai*
‘run’ (negative)

b. *koku* ‘nation’ + *ki* ‘flag’ > *ko**kk**i*
‘national flag’

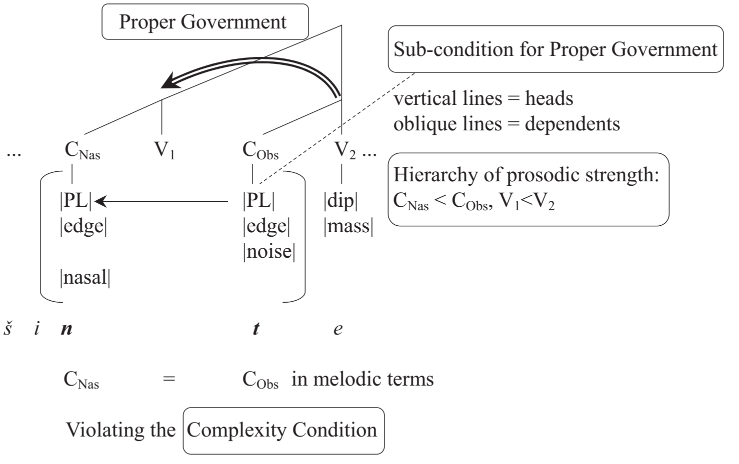
6.3. Postnasal Obstruent Voicing

We now move on to postnasal voicing assimilation. This takes place in the same context as place assimilation, but it actually operates in the opposite direction. It is assumed that this also concerns the interplay between prosodic strength and melodic organisation. In particular, I propose that it involves a constraint called the Complexity Condition.

(21) Complexity Condition (cf. Harris (1994), Nasukawa (2005))
A prosodically strong position must be melodically more complex than a prosodically weak position.

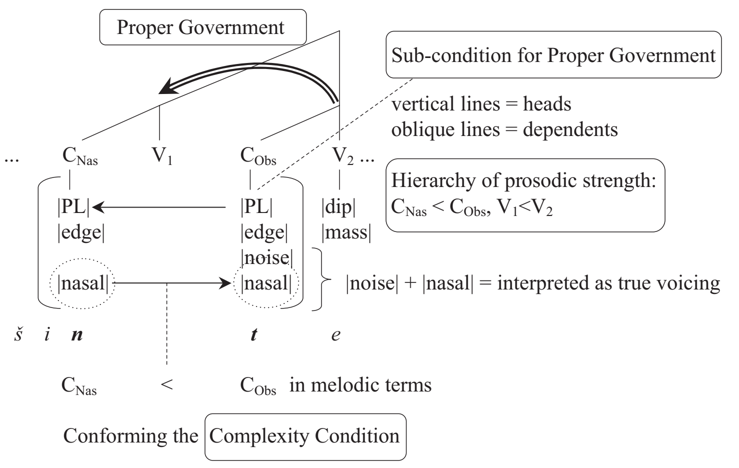
In order to calculate the complexity of a segment, we simply count the number of melodic elements in its representation. So when we compare the melodic complexity of the nasal and the obstruent, we find they are equal—and this violates the Complexty Condition in (21). As (22) shows, in order to conform to the condition, the stronger obstruent position must be more complex than the weaker nasal position.

(22) *šinde* 'die' (gerundive) (Yamato Japanese)



In voicing languages such as Yamato Japanese, the element |nasal| becomes a property of the domain formed by the two consonant positions. We saw exactly the same thing in the case of place assimilation. This means that |nasal| in the nasal position is shared with the obstruent position. This is illustrated in (23).

(23) *šinde* 'die' (gerundive) (Yamato Japanese)



When this happens, the structure in (23) conforms to the Complexity Condition because the obstruent has gained an element and has become melodically more complex than the nasal.

Thus, although postnasal voicing and place assimilation are processes which apparently operate in opposite directions, we can analyse them in parallel by employing two very general structural effects, Proper Government and the Complexity Condition. Both of these refer to strength relations in prosodically-defined dependency structure rather than to precedence relations. As noted earlier, similar approaches are also found for analysing opacity and transparency effects in long-distance feature-agreement processes by referring to the interaction between prosodic dependency relations and melodic complexity (Nasukawa (2005)).

7. Conclusion

This paper has described an approach to phonological representations which make no reference to precedence relations, arguing that precedence is merely the natural result of computing and interpreting the dependency relations that hold between units in hierarchical phonological structure. Employing this dependency-based structure, I have also shown how we can account for the apparent directionality bias in two types of assimilation, leftward place assimilation and rightward postnasal voicing. Although this difference in directionality is traditionally handled by simply stipulating "right" or "left" as a variable, I have demonstrated that the apparent direction is determined by the relation between structural strength in prosody and structural complexity in melody. In this way, the competence side of the language faculty can maintain a greater degree of representational coherence throughout the derivation, right up to the interface with the articulatory-perceptual systems. Further research will be needed in order to investigate whether other phonological phenomena can be analysed according to the same mechanism of prosody-melody interaction rather by referring to precedence relations.

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