Chapter 9 Prosodic Representations

Section on Prosodic structure, constituents and their implementation*

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Handbook of Laboratory Phonology,
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9.3.1. Introduction

After three decades of literature focusing on prosodic structure, the view that prosodic structure has a role to play as the organizing framework of speech is well established. This structure consists of the grouping of chunks of speech into prosodic constituents arranged according to a hierarchy, delimited by prosodic boundaries or edges and with prominences or heads at the various levels. Prominence strength and boundary strength reflect the hierarchy. Prosodic domains are marked by constellations of cues, which stand as the major empirical evidence for prosodic structure and the constituents it comprises. These cues have been shown to be used in lexical processing, in the disambiguation of syntax, or in the identification of morpho-syntactic units (as in bootstrapping).

Laboratory phonology approaches to the study of speech have been instrumental in the discovering and discussion of cues to prosodic structure, in the shaping of the essential questions that need to be accounted for and of the challenges for future research if we are to sharpen and deepen our understanding of prosodic constituency across languages. In this chapter we provide an overview of the contribution of work in laboratory phonology to the present knowledge of prosodic structure, prosodic constituents and their implementation. Illustration of the already considerable amount of research is provided on the basis of selected examples. In sections 1 and 2 we deal with two essential questions on the nature of prosodic structure, namely whether there are different kinds of such structures or instead a unique

representation, and how a prosodic constituent is defined and whether levels of constituency and of phrasing are equivalent. In section 3 we examine the implementation of prosodic structure across languages. In section 4 we highlight recent developments and explorations in research on prosodic structure.

9.3.2. On the nature of prosodic structure: is one enough?

Different views of prosodic structure have been proposed both in the general literature on prosody and in the laboratory phonology literature. Research on phonological rules has successfully shown that morpho-syntactic structure influences prosodic structure, so that syntactic constraints, together with phonological constraints, yield the constituent structure that accounts for contextual segmental rules (Nespor & Vogel 1986, Selkirk 1984, 1986, 2000, 2005, Truckenbrodt 1999, inter alia). Parallel to rule-based structure, research on intonation has posited an intonation-based structure that has been shown to describe the intonation of several languages (Beckman & Pierrehumbert 1986, Pierrehumbert & Beckman 1988, Jun 2005a, among others). A prominence-based structure has also been proposed, where levels of constituency correspond to levels of prominence seen as stress and/or accent manifestations with no direct relation to 'other' prosodic constituency (e.g. Beckman & Edwards 1990, 1994). The different views cannot be reduced to grid versus tree-based models of representation of prosodic structure. Instead, they seem to emerge from independent research traditions and/or angles of approaching prosodic structure: phonological rules, intonation, and prominence. Some researchers have assumed an integrated view and set out to empirical test the hypothesis that phrasal rules, intonation and prominence phenomena all refer to the same structure of prosodic constituents (Hayes & Lahiri 1991, Frota 2000, Hellmuth 2007). In this section we briefly review and compare these approaches.

The hierarchies given in (1) capture the main aspects of the different approaches.[1] They all share three basic observations about prosodic structure: prosodic constituency is non-isomorphic to morpho-syntactic constituency and thus is properly phonological; prosodic constituents are metrical constituents of some sort that are hierarchically structured; the limits of higher constituents are also the limits of lower level constituents.

(1)

a. Rule-based	**b. Intonation-based**	**c. Prominence-based**
Intonational Phrase (IP)	IP	Nuclear accent
Phonological / Major Phrase (PhP)	Intermediate Phrase	
Clitic Group/Minor Phrase/Prosodic Word Group	Accentual Phrase	Accent
Prosodic Word (PW)	PW	Stress
Foot	Foot	Full vowel
Syllable	Syllable	Syllable
Mora	Mora	

However, the approaches differ in that they propose different principles of prosodic organization for the structure above the word level and, to some extent, different types of constituents. For (1a) prosodic constituency partially results from the interface of phonology with other components of grammar, and thus it bears some systematic relation to morpho-syntax. For example, Phonological Phrases (PhPs) relate to syntactic phrases (XPs) and Intonational Phrases (IPs) to syntactic clauses, but crucially it is not the case that all syntactic boundaries of a certain type must correspond to prosodic boundaries of a given type and vice-versa (Nespor & Vogel 1986, Selkirk 1986, 2000, Truckenbrodt 1999). The principles of syntax to phonology mapping are themselves partially responsible for this non-isomorphism,

by promoting the alignment of a specific pair of syntactic/prosodic constituent edge (left or right) or enforcing the inclusion of a morpho-syntactic phrase within a prosodic phrase. The combination of syntactic constraints on prosodic structure with wellformedness conditions on the size and eurhythmicity of prosodic constituents is a further factor behind the autonomy of prosodic structure (e.g. Ghini 1993, Selkirk 2000, Prieto 2005, Elordieta, Frota & Vigário 2005, Frota & Vigário 2007). For the approaches (1b) and (1c), by contrast, prosodic structure is intonation defined or prominence defined in the sense that prosodic constituents are posited (and labelled) with reference to the phenomena that characterize them (rather than to the morpho-syntactic constituents they relate to). Thus, for example, the presence of a nuclear accent and a boundary tone defines the IP, whereas the presence of a nuclear accent and a phrase accent defines the Intermediate Phrase (Beckman & Pierrehumbert 1986, and much subsequent work). In these approaches the highly variable character of prosodic structure is usually highlighted as a consequence of factors such as speaking rate, style, discourse structure, or rhythm.

Despite the clear differences in the underlying principles and definitions of the prosodic constituents, a closer inspection to the hierarchies in (1) reveals some striking similarities. In all cases, syllables, prosodic words (PWs), and IPs are constituents of the prosodic structure. Also in all cases, there seems to be variation in the number and/or type of constituents between the PW and the IP. Sources for this variation have been suggested in the literature: it may well be the case that certain levels of structure are language-specific (e.g. Selkirk 1990); it may also be the case that some of the variation is a side-effect of the specific approach to prosodic structure, and that, for example, PhPs and Intermediate Phrases represent the same type of constituent (an early suggestion in this direction can be found in Pierrehumbert & Beckman 1988), in the same way as the Clitic Group, the Minor Phrase, the Accentual Phrase and more recently the Prosodic Word Group (PWG) can be seen as

essentially equivalent (Selkirk, Shinya & Kawahara 2004, Vigário 2009). The question thus arises whether the hierarchies in (1) are not fundamentally versions of the same prosodic structure. This question has been empirically addressed in work where morpho-syntactic and phonological constraints on prosodic structure are assessed by more than one of the possible correlates of prosodic constituency, namely phonological rules together with intonational phenomena (and sometimes also relative prominence, rhythmic and lengthening phenomena). This research is crucially laboratory based, in that it requires the development of experimental paradigms that control and provide a test for the properties of prosodic structure. Illustrative examples of this line of research are described below.

In what is probably the first systematic empirical test to an integrated view of prosodic structure, Hayes & Lahiri (1991) have shown that in Bengali the distribution of boundary tones and the application of segmental phrasal rules of assimilation refer to the same prosodic hierarchy, which is defined on the basis of syntax to phonology mapping principles plus phonological constraints. In Frota (2000) a set of production experiments was designed to examine whether there is a match in European Portuguese among the phonological structures required to account for phrasal rules, the domains of rhythmic phenomena such as stress clashes, the distribution of intonational events, and the facts of boundary-related lengthening.[2] The findings show convergent results pointing to the same prosodic structure established on the basis of both syntactic and phonological conditions (namely on the size of prosodic phrases). In detailed production studies of prosodic phrasing in Egyptian Arabic, Hellmuth (2004, 2007) has inspected a range of post-lexical tonal phenomena, including pitch accent distribution, together with a syllable repair rule of epenthesis, and pause distribution. The phrasing patterns that emerge are, again, consistent with a prosodic structure established by the interaction between syntax-phonology interface principles and phonological wellformedness conditions on the size of prosodic constituents.

In a related line of research, experimental procedures have been used to examine in a systematic fashion the import of the different syntactic and phonological factors affecting prosodic phrasing, such as alignment to syntactic edges, syntactic complexity, prosodic complexity, or phonological length (e.g. Jun 2003 for Korean, D'Imperio et al. 2005, Elordieta, Frota & Vigário 2005, and Prieto 2005 for several Romance languages, Shaked 2007 for Hebrew). The findings have shown an important role for language specificity in the relative weight of those factors, at the same time as they strengthen the view of prosodic structure as the result of the combined action of syntactic and phonological conditions.

In short, the answer to the question whether there are different kinds of prosodic structure organized on independent principles or whether one prosodic structure is enough is ultimately an empirical question.

9.3.3. Defining prosodic constituents and levels of phrasing

In most approaches to prosodic structure, whether rule-based or intonation/prominence-based, this structure is considered to be fundamentally different from morpho-syntactic structure in that it is crucially flatter. This observation has been embodied in the Strict Layer Hypothesis, which determines a fixed layered organization of prosodic structure that contrasts with the indefinite depth of syntax (Selkirk 1984, Nespor & Vogel 1986). Under this view, prosodic structure consists of a fixed number of possible constituents and thus levels of constituency strictly correspond to levels of phrasing, as in (2a).[3] However, work on prosodic phrasing in various languages has lead to the relaxation of this strong view. For example, accounts of the prosodization of clitics have shown that it is not necessarily the case that a given level of the hierarchy consists exclusively of constituents of the next lower level, and proposals of recursive prosodic words and recursive prosodic phrases have also been put forward (Selkirk 1996, Booij 1996, Peperkamp 1997, Vigário 2003, Gussenhoven 2004, inter

alia). Thus, prosodic representations as in (2b) have been argued for. These structures raise an important question on the depth of prosodic structure and its essential difference relative to syntax. The proposal of compound prosodic structure (Ladd 1996/2008, Frota 2000) addresses this question by constraining recursiveness to compound structures, as in (2c).

(2) a. ( ) A
( ) B
( ) ( ) C
( ) ( ) D
( ) ( ) ( ) E

b. ( ) A
( ) B
( ) C
( ) C
( ) D
( ) ( ) ( ) E

c. ( ) A
( ) ( ) A
( ) ( ) B
( ) ( ) C
( ) ( ) ( ) D
( ) ( ) ( ) E

Unlike in (2a), in the structures in (2b-c) the levels of prosodic constituency do not necessarily correspond to the levels of phrasing, and thus the question arises as to how a given prosodic constituent is defined, both within and across languages. Experimental approaches to prosodic structure have been instrumental in providing evidence for prosodic constituents and levels of phrasing. Indeed, they have been crucial to evaluate the empirical basis of proposals such as (2a) and have motivated new proposals like (2b) or (2c). However, the issue of how levels of constituency and levels of phrasing are defined is clearly not settled yet, as shown by the research cases described below.[4]

Jun's experimental work on prosodic phrasing in Korean, simultaneously based on the tonal patterns and the application of phonological rules, has established two levels of constituency above the PW, namely the accentual phrase and the intonational phrase (Jun 1996, 2005b). The former is characterized by the underlying tonal pattern THLH (where T is either H or L depending on the laryngeal properties of the phrase-initial segment) and is

usually signalled by a phrase-final LH pattern, and is also the domain of three different phrasal rules; the latter is signalled by a final boundary tone, and by limiting the application of two other phonological rules. In Jun (2007), however, experiments on prosodic phrasing and relative clause attachment have prompted a revision of Korean prosodic structure. An additional constituent is proposed, the intermediate phrase, on the basis of juncture strength differences: a stronger accentual phrase boundary, phonetically denoted by a higher tone and/or by a following higher pitch range is interpreted as the boundary of a different and higher constituent. Most strikingly, the phonetic and phonological definitions of the accentual phrase and the IP are clearly independent of each other, whereas the definition of the intermediate phrase seems to be dependent on the properties of the accentual phrase, of which it only provides a stronger version.

Work on the prosodic phrasing of European Portuguese (EP) has provided similar data to that reported for Korean. EP has been shown to have a phonological phrase level and an intonational phrase level. The PhP plays an important role in the account of rhythmic and prominence related phenomena: for example, the clash between two adjacent stressed syllables is solved by lengthening of the first of these syllables if both of them belong to the same PhP, but not across a PhP boundary; and the deletion of a word-final vowel when followed by a word-initial vowel is blocked if the second word involved is the head of PhP, but not otherwise. The intonational phrase level in EP is the domain of many phonological processes, the domain of final lengthening, as well as of the minimal tune (only the IP head must be pitch-accented and only the right-edge of the IP requires tonal boundary marking in the language - Frota 2000, in press). When an IP is short, however, it was found to group with an adjacent IP. This grouping is signalled by weaker boundaries of the short IP expressed by less final lengthening and a narrower boundary rise, at the same time as the domain span rules may apply across the weaker boundary. These facts are interpreted as pointing to a

recursive intonational phrase compound structure, where the difference between the inner and outer edges of the compound phrase is merely a gradient one and rule application across the inner edge simply follows from the span character of the rules within the IP.

In recent work on the prosodic phrasing of word-like structures in various languages (especially compounds), a prosodic constituent different from the PW and the PhP has been proposed, rather than a recursive PW structure (Kabak & Revithiadou 2006, Vigário 2008). The key argument for the PWG (as Vigário 2008 calls it) is that it functions as a domain for phonological processes distinct from those that apply with reference to PWs or PhPs.

The syntactic grounding of the prosodic hierarchy view proposes that prosodic constituent types relate to morpho-syntactic constituents, and experimental work on prosodic phrasing has provided ample phonetic and phonological evidence for levels of constituency and/or levels of phrasing. Taken together, they offer an important empirical insight to be explored in further research: a prosodic constituent involves some kind of morpho-syntax to prosody mapping and an array of phonological properties, including size, prominence, acting as the domain for phonological and phonetic phenomena (segmental, tonal, temporal), and cues to boundary marking; the morpho-syntactic constituent it relates to and at least a subset of the phonetic and phonological properties it shows should be different in type from those defining the other prosodic constituents. By contrast, recursion and compounding refer to forms of grouping of instances of a given prosodic category, yielding levels of phrasing that are reflected only by gradient differences in the strength of the same phonetic properties.

9.3.4. Cues to prosodic structure across languages and language varieties

The detailed study of the implementation of prosodic structure across languages has been perhaps the most fruitful research program within laboratory approaches to prosodic

structure. In this section we review the types of cues that have been reported and present illustrative examples of cue variation and language-specificity of phonetic cues.

9.3.4.1. Types of cues

Phrasal phonological processes in many languages have been among the cues to prosodic phrasing since the early proposals in prosodic phonology. These have included assimilations, lenitions, fortitions, deletions, insertions, and so on (see Nespor & Vogel 1986, Selkirk 1986, Jun 1996, Frota 2000, Hellmuth 2004, Baltazani 2006 for exemplification in various languages). Whether these processes are best described as categorical or gradient changes (see Ladd & Scobbie 2003 and Zsiga 1995 for detailed analysis and arguments in either direction), they have been instrumental in the signalling of prosodic structure across languages.

Another area where the realization of segments and tones has been shown to be affected by the implementation of prosodic structure is constituent-initial strengthening, a set of phenomena for the study of which laboratory phonology approaches have strongly contributed (see also **Ernestus_chap5**). Both acoustic and articulatory studies have shown that initial strengthening is highly correlated with constituency (or phrasal) level, although all the levels posited in the various studies are not necessarily distinguished either within or across languages (Pierrehumbert & Talkin 1992, Jun 1995, 1996, Byrd et al. 2000, Keating et al. 2003, Pan 2007). Similarly, final lengthening has been investigated as a result of the phonetic implementation of prosodic representations. Detailed acoustic and articulatory studies using controlled laboratory materials have inspected the presence of final lengthening, its correlation with prosodic boundary level, and its temporal scope and distribution (Beckman & Edwards 1990, Beckman, Edwards & Fletcher 1992, Wightman et al. 1992, Cambier-Langeveld 2000, Frota 2000, Turk & Shattuck-Hufnagel 2000, 2007, Byrd, Krivopic & Lee 2006; see also **Turk_chap14**). While the presence of final lengthening at

the IP level seems well established in many languages, empirical findings are less clear with regard to lower phrasal levels and the PW, both within and across languages.

Rhythmic phenomena like stress clash resolution strategies are also sensitive to prosodic structure (cf. **Turk_chap.14**). The phonology and phonetics of these phenomena, especially the rhythm rule, has been studied in detail. There are two main accounts for the rhythm rule, a phenomenon whereby the major prominence within a word is moved to an early vowel when the stress of the following word is adjacent: the stress-shift account, according to which the main stress moves leftwards to avoid the stress clash, and the early accent account, that sees the change in prominence as a reflection of early pitch accent placement within the word (e.g. Nespor & Vogel 1989, Horne 1990, Grabe & Warren 1995, Vogel, Bunnell & Hoskins 1995, Shattuck-Hufnagel 1995, 2000). However, in both accounts there is agreement that the rhythm rule applies within a prosodic domain, is blocked across a phrase boundary, and is constrained by prosodic conditions related to the rhythmic organization of prosodic word and phrase level prominences.

The realization of tonal targets has been shown to rely on the implementation of prosodic structure, as is illustrated by work on pitch scaling and final lowering phenomena (see Ladd 1996/2008). For example, empirical studies of scaling in German show that different prosodic constituents define different phonetic reference lines that establish the relative height of a tone (Truckenbrodt 2002, 2007). In the same vein, experimental evidence suggests that the lowering of the final peak in a series of peaks is the phonetic manifestation of a grammaticalised pitch range relation determined by prosodic constituency, at least in some languages (Arvaniti & Godjevac 2003, Arvaniti 2007).

Distributional properties such as those established by edge tones, pitch accents, patterns of occurrence of prenuclear and nuclear accents or of nuclear accents and edge tones and their relative frequencies, have been shown to reflect prosodic structure. Specific patterns

of combination of pitch accents may be informative of their prenuclear/nuclear position in a prosodic phrase (Dainora 2006). Languages may exhibit a dense or sparse distribution of pitch accents, depending on the level of prosodic constituency that serves as the domain for accentuation. The lower the prosodic domain relevant for pitch accent distribution, the more dense pitch accentuation is; the reverse obtains if a higher level domain regulates pitch accent distribution. Illustrative examples are: Egyptian Arabic, with the PW as the relevant domain and a dense distribution of pitch accents (i.e., every PW is accented); Standard European Portuguese, with the IP as the domain for accentuation and thus a sparse pitch accent distribution (i.e., only IP-heads must be accented); and Northern European Portuguese, with a lower phrase as the relevant domain and therefore a richer distribution of pitch accents than in the standard variety (Vigário & Frota 2003, Hellmuth 2007, Frota in press).

9.3.4.2. Variation of cues

The cues mentioned above may show variation across languages in their presence/absence, in the level of constituency or phrasing they signal, or in the specific ways they are implemented. We illustrate this variation with three examples.

In a comparison of cues to phrasing across Bantu languages, Zerbian (2007) shows that similar patterns of phrasing are found across some languages but with considerable diversity in the phonetic cues that implement them: different cues can be used to signal the same level of phrasing, like blocking of high tones at phrase boundaries in Northern Sotho, but deletion of high tones within the same phrase in Kinyambo; and the same cues can indicate boundaries of different levels, as in the case of penultimate lengthening (i.e., the lengthening of vowels in the penultimate syllable of a prosodic domain) that signals the PhP in Chichewa, but marks the IP in Northern Sotho.

In their comparative study of intonational phrasing in Romance, Frota et al. (2007) show that while a high boundary tone is the main cue across languages, both nuclear pitch

accent choices and the detailed phonetics of intonational boundaries vary in consistent ways and group the languages in two sets: the Catalan-Spanish group and the Italian-European Portuguese group. In the former, rising accents are the dominant choice, and the scaling of the boundary tone is correlated with the scaling of the first peak in the phrase, while there is no impact of phrase length on the height of the tonal boundary. In the latter, by contrast, both rising and falling accents are common, and the length of the phrase and not the height of the first peak crucially affect the scaling of the boundary tone.

Final lengthening (especially at the IP-level) has been shown to be present in many languages, but references to its absence are also found (as in Chimwiini, Estonian, Finnish). Myers & Hansen (2007), based on the results of a series of production and perception experiments, have shown the presence of both final lengthening and final devoicing in Finnish, and argue that final devoiced vowels tend to be identified as short vowels by native speakers. Resorting to highly controlled laboratory materials, Nakai et al. (2009) have also shown that a quantity language like Finnish exhibits final lengthening, but its implementation is regulated to preserve the language-specific quantity system, namely the contrast between single or short vowels and double or long vowels. This important empirical finding raises the question whether final lengthening, and perhaps also other prosodic cues, is a universal cue to phrasing that is implemented in language-particular ways. If so, cue variation may be the result of the conspiracy of specific phonologies against universal tendencies in language, and experimental approaches are decisive to disentangle the two factors.

9.3.5. Recent developments and explorations

There are at least three areas in which experimental research in prosodic structure is developing rapidly and holds the promise to provide new insights into the nature of prosodic

phrasing and its implementation: sign languages, language processing, and language acquisition.

Work on the prosody of sign languages has shown a similar chunking into prosodic constituents, which are signalled by sets of cues, as in spoken languages (e.g. Sandler 2006, Sandler & Lillo-Martin 2006). Although very different articulators are used, sign languages also exhibit sandhi rules (like the spreading of the non-dominant hand) and intonation (facial expressions), as markers of prosodic constituency.

Using both behavioural methods and ERP measures (cf. **Prieto_chap.21**), the investigation of the processing of prosodic structure has shown that adult listeners are sensitive to different levels of constituency, and that prosodic boundaries play an important role in lexical access and syntactic disambiguation (Christophe et al. 2004, Millotte, Wales & Christophe 2007, Li & Yang 2009, Frota, Severino & Vigário 2009). Strikingly, lexical processing is not only affected by local boundary cues, but also by distant prosodic properties such as pitch and rhythm patterns (Dilley & McAuley 2008). Infant listeners seem to show a similar sensitivity to prosodic structure, and they are able to use it both for lexical segmentation and syntactic analysis (Gout, Christophe & Morgan 2004, Homae et al. 2007, Christophe et al. 2008).

Clearly, the task for the future is twofold: the cross-linguistic exploration of these recent lines of research, and the development of experimental studies that integrate the simultaneous assessment of the multiple cues to prosodic structure (i.e., intonation, boundary strength, prominence, rhythm, and the realization of segments and lexical tones in connected speech). Together, these two movements promise to significantly push the frontiers of our understanding of prosodic structure in language(s).

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[1] The prosodic hierarchies in (1) are organized for comparison purposes and only the most well-established and/or discussed levels are included. The relevance of a given constituent may depend on the language, as is the case in (1b) for the mora in Japanese, and the foot in English (see Pierrehumbert & Beckman 1988, Grice 1995). Structure at the word level and above will be the focus of interest in this chapter.

[2] On production studies in the analysis of prosody, see also **Prieto_chap21**.

[3] The labels A, B to E represent constituent types, where A is higher in the hierarchy than B, and B than C, and C than E.

[4] See also Ladd (1996/2008) for an extended discussion on the empirical adequacy of proposals of phonological structure. Other work directly bearing on the issue is D'Imperio & Fivela (2003) for levels of phrasing above the word in Italian, Hellmuth (2004) and Chahal & Hellmuth (in press) for the discussion of the presence/absence of a minor phrase in Egytian Arabic, and Arvaniti & Baltazani (2005), Baltazani (2006) and Kainada (2009) for levels of prosodic phrasing in Greek.