10

Prosodic Constituency in HPSG

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10.1 Introduction

It is widely assumed that prosodic structure is related in some way to syntactic structure, yet there is little agreement about what the nature of that relation might be. We might take the null-hypothesis to be the following:

Prosodic Isomorphism Hypothesis:

> *Prosodic constituency is isomorphic to 'conventional' constituent structure.*

Although prosodic constituency is clearly informed by syntactic constituency of the standard sort, isomorphism seems to be too strong in general. As an example, consider example (10.1), discussed by Gee and Grosjean (1983), where square brackets are used to indicate prosodic boundaries:

(10.1) [By making his plan known][he brought out][the objections of everyone].

The boundary between *known* and *he* is unsurprising, since it coincides with a syntactic boundary between a preposed adverbial phrase and the main clause. By contrast, the second prosodic constituent, *he brought out* departs dramatically from standard syntactic constituency; for the subject *he* has a tighter juncture with the following main verb (plus particle) than the latter does with its noun phrase object, *the objections of everyone*.

One possible response to this kind of datum is to abandon conventional notions of surface syntactic constituency. This is the approach to prosodic constituency advocated by Steedman (1991), where the availability of function composition and type-raising in a combinatory catego-

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rial grammar allows subjects and main verbs to combine as constituents. An alternative, due to Abney (1989, 1991), proposes a multistep model of grammatical analysis whose first stage involves the identification of syntactic 'chunks'—roughly, just that part of a conventional constituent up to and including the lexical head. Although this provides an attractive basis for the identification of prosodic constituents, it requires a radically different account of the semantics of complementation to that typically assumed in current grammatical frameworks.

By contrast, I will explore how prosodic constituency might be articulated within recent versions of HPSG (e.g., Sag, 1997). This will be closer to Selkirk's (1984) approach (discussed below), insofar as a fairly traditional notion of syntactic constituency is maintained. However, it differs in that prosodic constituents will be built recursively, in parallel with the recursive definition of syntactic phrases by the grammar. I will not attempt to deal with issues of accent placement, focus and information structure, nor with the possible meanings of intonational tunes. I shall also restrict attention to 'core' syntactic constructions, including transitive and ditransitives VPs, modals, nominal complements, pronominal subjects; other constructions will be largely ignored.

From the perspective of the practising theoretical linguist, prosodic phonology has the disadvantage that relying on one's own or others' intuitions about well-formedness is even more fraught with danger than in the case of syntax. In order to mitigate this problem, I have drawn most of the data used in this paper from the SOLE spoken corpus (Hitzeman et al., 1998).[1] The corpus was based on recordings of one speaker reading around 40 short descriptive texts concerning jewelry, and has sufficient syntactic complexity (unlike typical spoken corpora consisting of spontaneous utterances (Croft, 1995)) to exhibit the kind of phenomena that I am interested in.

Before turning to the treatment of prosodic constituents in HPSG, I will first briefly review some of the main approaches that have been taken in the literature, and then summarise the key areas where syntax and prosody seem to diverge.

10.2 Prosodic Preliminaries

10.2.1 The Prosodic Hierarchy

Much of the work on English prosodic structure above the foot adopts a model that was first published in Selkirk 1981. Prosodic constituents at one level are assembled into those of a higher level:

[1] The task of recovering relevant examples from the SOLE corpus was considerably aided by the Gsearch corpus query system (Corley et al., 2000).

> . . . we will see that prosodic words first group in phonological phrases (ϕ), that the phonological phrases are grouped into intonational phrases (I), and finally, that the intonational phrases make up the utterance (υ).

This notion of a prosodic *hierarchy* has been expanded and varied in the subsequent literature; cf. Beckman and Pierrehumbert 1986; Hayes 1989; Nespor and Vogel 1986; Pierrehumbert and Beckman 1988; Selkirk 1984, 1986, 1996. As pointed out by Shattuck-Hufnagel and Turk (1996, p207), there is a fair degree of agreement about the top of the hierarchy (the levels of Utterance and Intonational Phrase), and at the bottom (the levels of Foot, Syllable and Mora), but substantive and terminological disagreement about the midlevels.

According to the widely-accepted Strict Layer Hypothesis (Selkirk, 1984, p26), the hierarchy is non-recursive: a category of level i in the hierarchy can be exhaustively decomposed into a sequence of categories of level $i - 1$. Selkirk (1986, p384) notes that "cases of languages where all layers are instantiated are rare".

Intonational Phrases (IPs) are phonologically defined as units which are associated with a characteristic intonational contour; in particular, an IP is marked by the presence of a major pitch accent. The boundary of an IP is canonically manifested as a perceptible pause, accompanied by a local fall or rise in F_0 (fundamental frequency); it can also be marked by constituent-final syllable lengthening, and stronger articulation of constituent-initial consonants. Nevertheless, the phonetic cues to a postulated IP boundary may be considerably weaker than suggested by the canonical case.[2] Selkirk (1984) claims that a sequence of words will belong to a given IP only if they constitute a 'sense unit'; that is, the well-formedness of a given decomposition into IPs is constrained by some notion of semantic coherence. However, this claim has recently been challenged by Taglicht (1998).

The characterization of Phonological Phrases, as a prosodic level lying between Intonational Phrases and Prosodic Words, has been the subject of some debate. Selkirk (1984, p29) denies that they exist in English; however, they have been taken as demarcating the domain for phonological phenomena in several other languages; cf. (Chen, 1997; Nespor and Vogel, 1986; Selkirk, 1986).[3]

In this paper, I will not make a great deal of use of the Prosodic Hierarchy. Most of the phenomena that I wish to deal with lie in the blurry

[2] See (Ladd, 1996) for discussion of this issue.

[3] Interestingly, Chen (1997) claims that, *contra* the Strict Layer Hypothesis, Phonological Phrases in Xiamen cross-cut Intonational Phrase boundaries.

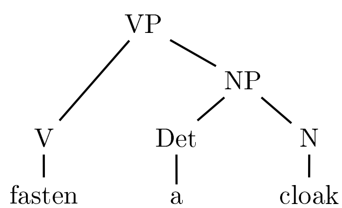
region between the Phonological Word and the Intonational Phrase, and I will just refer to 'prosodic constituents' without committing myself to a specific set of labels. I will not adopt the Strict Layer Hypothesis, which has in any case been significantly weakened in Selkirk (1996). However, it is important to note

that every IP will be a prosodic constituent, in my sense. Moreover every such prosodic constituent is *potentially* an IP, though in practise the kinds of prosodic utterances to be considered in this paper will have several prosodic constituents which are not actually IPs.

10.2.2 Metrical Trees

The Prosodic Isomorphism Hypothesis is the starting point for the construction of metrical trees proposed by Liberman and Prince (1977). Thus consider the syntactic analysis in (10.2):

(10.2)



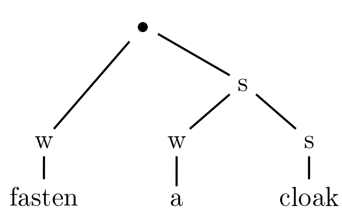
On the approach of Liberman and Prince (1977, p257) , syntactic constituents are assigned relative prosodic weight according to the following rule:

(10.3) *NSR*: In a configuration $[_C$ A B$]$, if C is a phrasal category, B is strong.

Prominence is taken to be a relational notion: a constituent labelled 's' is stronger than its sister. Consequently, if B in (10.3) is strong, then A must be weak.

In the case of a tree like (10.2) above, Liberman and Prince's (10.3) yields a binary-branching structure of the following sort (where the root of the tree is unlabeled):

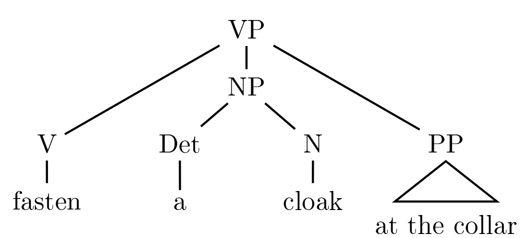
(10.4)



For any given constituent analysed by a metrical tree t, the location of its main stress can be found by tracing a path from the root of t to a terminal element α such that all nodes on that path are labelled 's'. Thus the main stress in (10.4) is located on the element *cloak*. In general, the most prominent element, defined in this way, is called the *Designated Terminal Element* (DTE) (Liberman and Prince, 1977). Note that (10.3) is the metrical version of Chomsky and Halle's 1968 Nuclear Stress Rule (NSR) , and encodes the same claim, namely that in the default case, main stress falls on the last constituent in a given phrase. Of course, it has often been argued that the notion of 'default prominence' is flawed, since it supposes that the acceptability of utterances can be judged in a null context. Nevertheless, there is an alternative conception: the predictions of the NSR correctly describe the prominence patterns when the whole proposition expressed by the clause in question receives broad focus (cf. Ladd, 1996). This is the view that I will adopt. Although I will concentrate in the rest of the paper on the broad focus pattern of intonation, the approach I develop is intended to link up eventually with pragmatic information about the location of narrow focus.

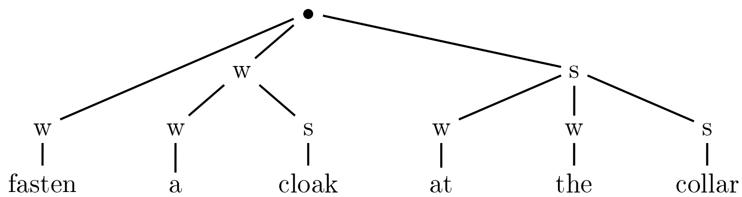
In the formulation above, (10.3) only applies to binary-branching constituents, and the question arises how non-binary branching constituent structures, such as (10.5), should be treated:

(10.5)



One solution, proposed by Hogg and McCully (1987) , is to build a new prosodic node, in a right-to-left mapping from the syntax tree. This allows us to replace the ternary branching VP in (10.5) by a binary right-branching metrical structure. An alternative, advocated by Beckman (1986); Pierrehumbert and Beckman (1988); Nespor and Vogel (1986) would be to drop the restriction that metrical trees are binary, allowing structures such as (10.6).

(10.6)



One of the arguments put forward by Pierrehumbert and Beckman (1988, p142) in favour of n-ary metrical tree concerns the phonetic interpretation of such structures.[4] As emphasised by Liberman and Prince (1977) , a purely relational representation of prominence provides a phonological constraint on accentual patterns, but does not determine them: a given metrical tree will correspond to numerous pronunciations. Beckman and Pierrehumbert argue that phonetic realization is best handled by assigning absolute values for stress subordination to elements of relatively flat trees, rather than to arbitrarily deep binary-branching trees. In the interests of avoiding unnecessary structure, I will adopt n-ary metrical trees for the rest of this paper.

10.2.3 Juncture

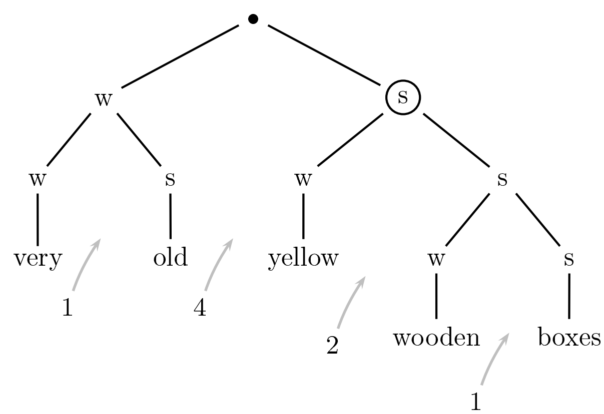
At this point, it will be useful to be more explicit about the intended interpretion of constituent boundaries within metrical trees. That is, I want to clarify how a metrical tree encodes a notion of *juncture*. Borrowing from Gee and Grosjean (1983), let us adopt the the following definition:

Definition 1 (Juncture Value) Let J be the lowest node to dominate two adjacent words in the frontier of a metrical tree. Then the *tightness* of the juncture between those two words corresponds to the number n of branching nodes dominated by J (taking dominance to be reflexive, we include J itself in the count). 1 represents the tightest juncture, and tightness decreases in proportion to n.

To illustrate, let us look at the metrical tree in (10.7):

[4] A second argument is that n-ary metrical trees lend themselves better to headless prosodic constituents, which are claimed to be appropriate for Tokyo Japanese.

(10.7)



The grey arrows below the tree indicate the value of the relevant juncture, as determined by the definition above. For example, the juncture value between *yellow* and *wooden* is 2 because the relevant node, i.e., the circled 's' node which exhaustively dominates *yellow* and *wooden boxes*, dominates both itself and another one branching node. In Gee and Grosjean (1983), weak monosyllabic function words attach with a degree of juncture that is tighter than 1; I will return to this issue in Section 10.2.5 below.

I will not make any formal use of the notion of juncture value in what follows. However, I will adopt the view that juncture, as defined over metrical trees, is adequate to capture the intuitive notion of 'breaks' between prosodic constituents.

10.2.4 Phonological Phrases

It is argued by Selkirk (1981, 1986), Selkirk and Shen (1990) and Nespor and Vogel (1986) that Phonological Phrases are determined by syntactic structure. In an early presentation (Selkirk, 1981, p126), the mapping is determined in the following manner:

(i) An item which is the specifier of a syntactic phrase joins in with the head of the phrase.[5]

(ii) An item belonging to a non-lexical category, such as Det, Prep, Comp, Verb_{aux}, Conjunction, joins with its sister constituent.

More recently, Selkirk (1986, p385) has reformulated this claim as follows:

> the relation between syntactic structure and prosodic structure above the foot and below the intonational phrase is de-

[5] The term 'specifier' here encompasses pre-head adjectives and adverbs

> fined in terms of the *ends* of syntactic constituents of designated types. . . . a unit of phonological structure, a derived domain, will have as its terminal string the stretch of the surface syntactic structure that is demarcated by the right or left ends of selected constituents . . . .

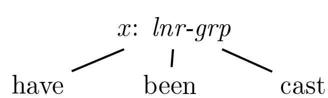
Although, as pointed out earlier, the existence of Phonological Phrases in English has been controversial, the end-based approach just sketched appears to accurately capture prosodic properties of headed phrases in English, particularly those headed by nouns.

10.2.5 Function Words

Zwicky (1982, p5) introduces a class of words called *leaners*: these "form a rhythmic unit with the neighbouring material, are normally unstressed with respect to this material, and do not bear the intonational peak of the unit. English articles, coordinating conjunctions, complementizers, relative markers, and subject and object pronouns are all leaners in this sense". Zwicky takes pains to differentiate between leaners and *clitics* ; the former combine with neighbours to form Phonological Phrases (with juncture characterized by external sandhi), whereas clitics combine with their hosts to form Phonological Words (where juncture is characterized by internal sandhi).[6] This sharp distinction between leaners (word external) and clitics (word internal) is disputed by Nespor and Vogel (1986, chap.5) on the basis of data involving Italian clitic pronouns. An alternative approach, advocated by Selkirk (1996), is to classify clitics into distinct subgroups; her *free* clitics seem to correspond best to Zwicky's leaners.

Despite these substantive and terminological divergences, there are good reasons to assign a special prosodic status to the units in question, and I will call them *leaner groups*. I will assume that they consist of a sequence of one or more leaners followed by a single Phonological Word; that is, the stress-bearing element is alway rightmost in the unit. We can represent such a unit within a metrical tree as follows, where x stands for 'w' or 's', and *lnr-grp* is a type annotation of the metrical tree:

(10.8)



In such a metrical tree, the juncture between elements is intended to be

[6] Zwicky also points out that some morphemes, such as infinitival *to*, which are ordinarily leaners can also contract with selected verbs to form Phonological Words (e.g., *wanna, hafta*).

tighter than the 1 value given by Definition 1 of Juncture Value.

10.3 Prosody-Syntax Mismatches

I have already alluded to some cases where syntax and prosody appear to diverge. In this section I want to look in more detail at two classes of constructions which support such a claim.[7]

Prosodic Flattening

As noted in Section 10.2.2, it has been suggested that prosodic structure is flatter than syntactic structure. Schematically we have the pattern shown in Fig. 1.

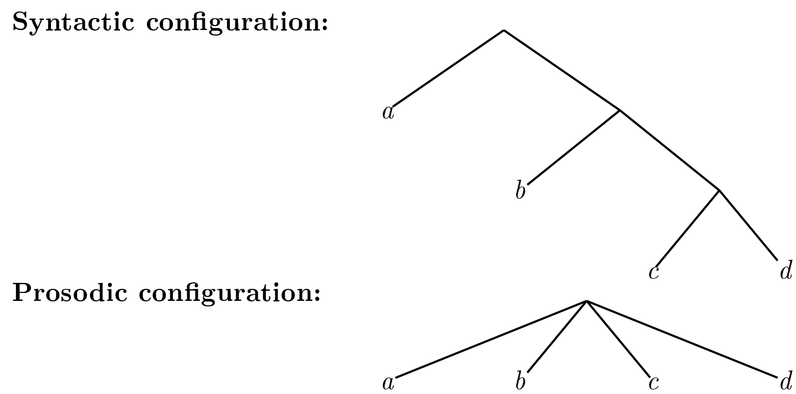


FIGURE 1 Prosodic Flattening

A particularly clear example of where the Prosodic Isomorphism Hypothesis makes the wrong predictions concerns constituent structures with deeply embedded right-branching structure. Fig. 2 and the corresponding metrical tree in Fig. 3 illustrate this point (assuming a GPSG-style (Gazdar et al., 1985) treatment of modal and auxiliary verbs).

Discussing an example similar to Fig. 3, Selkirk (1984, p164) remarks:

> Such a tree is both too rich and too impoverished as a representation of phrasal prominence—too rich because it in principle allows for all the distinctions in level (degree) of stress

[7] I am indebted to Butt and King (1998) for the idea of presenting syntax-prosody mismatches in this format. The notion and terminology of *flattening* is identical to theirs, but I have not adopted the patterns of *heightening* and *regrouping*, which they employ in an analysis of Bengali. It is probably premature to attempt to identify a set of language-universal constraints on syntax-prosody mappings.

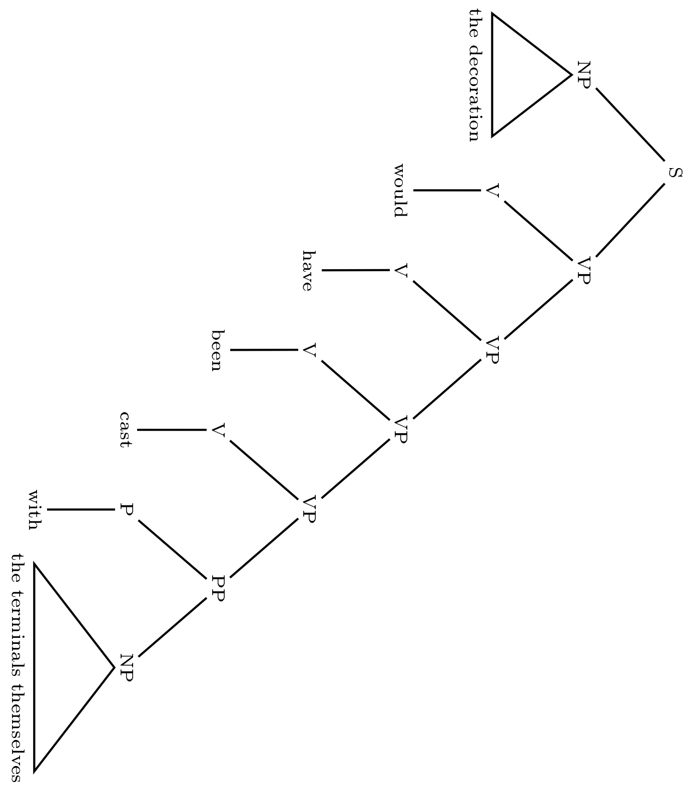


FIGURE 2 Syntactic Structure of Nested Auxiliaries

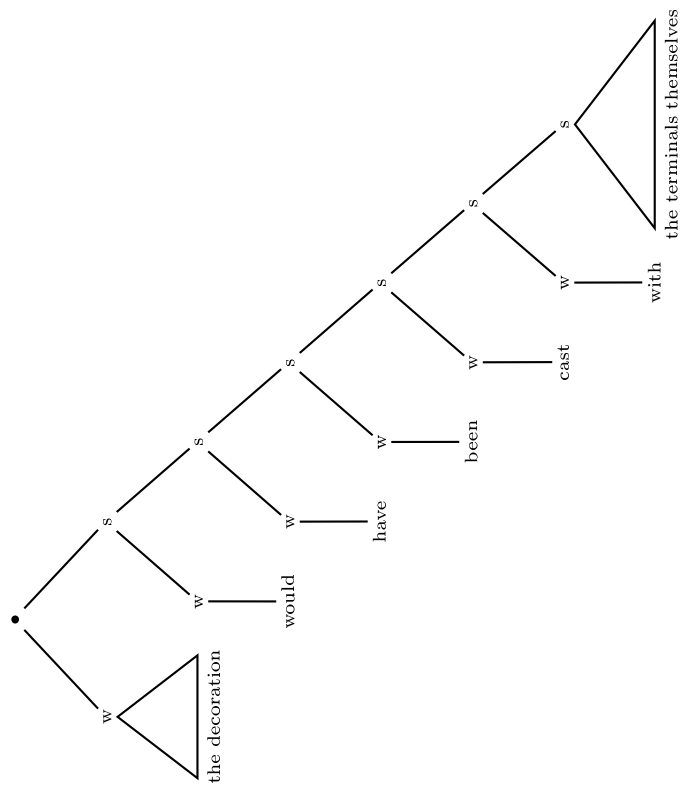


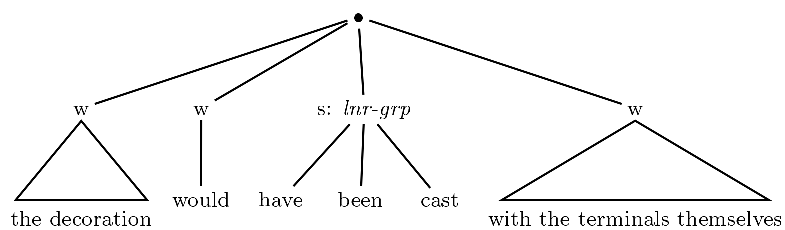
FIGURE 3 Prosodic Structure of Nested Auxiliaries

> found in the standard [i.e., SPE] description, too impoverished because it does not represent the patterns of recurrent alternating prominence within the sentence.

There are two considerations which allow us to replace Fig. 3 with a more empirically sound analysis. First, as we saw above, unstressed auxiliaries such as *have* and *been* come into the category of prosodic leaners, and combine with their host to form a function-word group.

Second, *n*-ary metrical trees provide an appropriately flat structure for the attachment of modals with their complements. This is illustrated in (10.9).

(10.9)



It should be noted, in passing, that although patterns such as (10.9) are quite common, modal verbs often receive prominence by virtue of their informational status, as indicated in the next example, where *may* receives narrow focus.

(10.10) The function of this unique object is unclear, but it MAY have been designed to fasten a turban.

Prosodic Promotion

The next type of mismatch is similar, and occurs when the complement or postmodifier of a syntactic head is 'promoted' to the level of sister of the constituent in which the head occurs; this creates a disjuncture between the lexical head and whatever follows. The pattern is schematized in Fig. 4.

(10.11) gives a typical example of this phenomenon, where the noun *possession* is followed by a prepositional complement, while (10.12) represents the attested prosodic constituency.

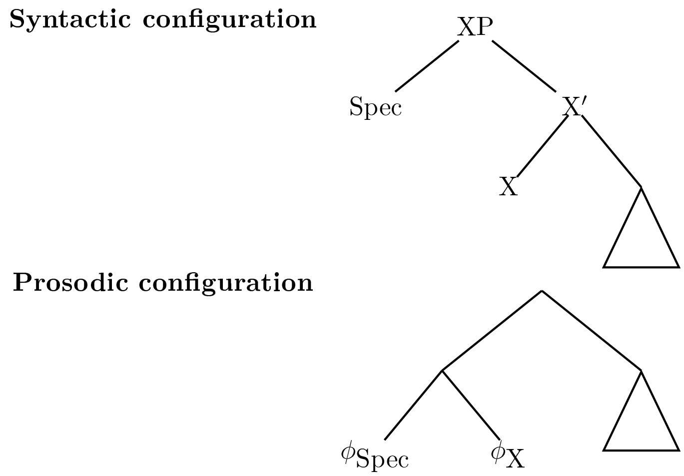
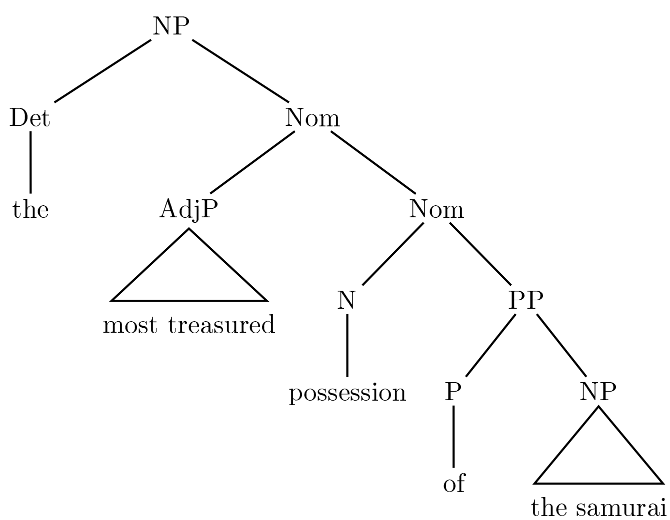
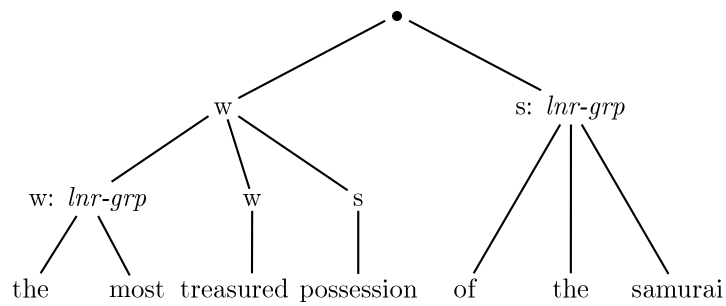


FIGURE 4 Prosodic Promotion of Posthead Material

(10.11)



(10.12)



Note that this is not simply another example of Prosodic Flattening, since *of the samurai* belongs to a different prosodic constituent than the one which immediately dominates *the most treasured possession*.

Other noun phrases from the corpus exhibit a similar prosodic structure:

(10.13) [an extraordinary range of accessories][which people have used to decorate themselves]

(10.14) [an explosion][of new materials for art construction and design]

(10.15) [one of a set of vessels of different shapes][for use in a ceremonial banquet]

(10.16) [gilded with a thin layer of gold leaf][applied to the heated bronze surface]

It should be emphasised that the possibility of introducting a prosodic break between a head and its complement or postmodifier does *not* mean that a break will always occur at such a position. This is clearly illustrated in the data above; for example, in (10.14), there could have been a disjuncture immediately after *vessels*.

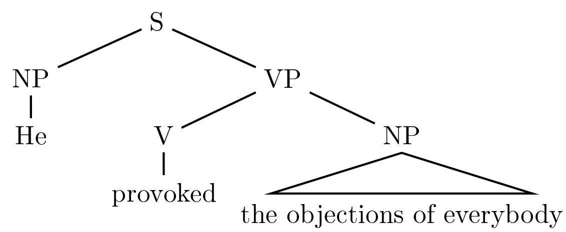
The grammar only places boundary conditions on which strings are well-formed prosodic consituents (relative to a given rhetorical purpose or information packaging). But performance factors, especially those involving formality and speech rate, will determine where prosodic breaks *actually occur* in a given utterance. There is also an oft-noted tendency for the prosodic constituents in an utterance to be of roughly equal length; I am also regarding this as a performance issue.[8]

Finally, we consider an example similar to the one cited at the beginning of this paper, which falls into a class of cases involving leaner

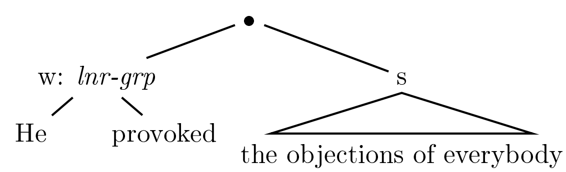
[8]A relatively simple performance model of this behaviour consists in terminating an IP as soon as possible (i.e., as allowed by grammatical constraints) once the number of syllables already uttered in that IP has reached a certain (parametric) threshold. For some discussion of such algorithms, see Gee and Grosjean 1983; Bachenko and Fitzpatrick 1990; Atterer 2000.

groups. That is, the unaccented pronoun *he* forms a tight unit with the following verb, cutting across the syntactic boundary between subject and verb phrase. This is illustrated below.

(10.17)



(10.18)



10.4 An HPSG Analysis

10.4.1 Unstructured Phonology

Before examining how to build prosodic structures, it will be useful to look at the standard HPSG approach to phonology. However, I will follow recent steps (Sag, 1999; Donohue and Sag, 1999) which reinstate the distinction between 'categories' and 'rules', now construed as *signs* versus *constructions*.

Signs retain the usual attributes PHON and SYNSEM, but no longer have attributes for daughters. Instead, phrase structure configurations are defined in constructions, a distinct type of feature structure belonging to a distinct hierarchy (see also Sag, 1997). For example, a headed construction, *hd-cx*, will have attributes MOTHER, HD-DTR and NON-HD-DTRS. Phonology values are taken to be lists, where the PHON value of the mother of a construction is built from the list concatenation of the PHON values of its daughters. If we assume that the order of the mother's PHON simply corresponds to the order resulting from prepending the head-daughter to the list of non-head daughters, we arrive at the following constraint:

(10.19) $$hd\text{-}cx \rightarrow \begin{bmatrix} \text{MOTHER} & \begin{bmatrix}\text{PHON} & \phi_0 \oplus \ldots \oplus \phi_n\end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix}\text{PHON} & \phi_0\end{bmatrix} \\ \text{NON-HD-DTRS} & \left\langle \begin{bmatrix}\text{PHON} & \phi_1\end{bmatrix}, \ldots \begin{bmatrix}\text{PHON} & \phi_n\end{bmatrix} \right\rangle \end{bmatrix}$$

Here, $\oplus$ denotes the standard append operation on lists. The workings of (10.19) are illustrated in Fig. 5. The PHON value of the VP mother in Fig. 5 is arrived at by virtue of the following identity:

(10.20) $$\langle \textit{fasten} \rangle \oplus \langle \textit{a, cloak} \rangle \oplus \langle \textit{at, the, collar} \rangle = \langle \textit{fasten, a, cloak, at, the, collar} \rangle$$

Note in particular that there is no internal structure here; phonology is taken to be a flat list.

When I come to discuss prosodic constraints in more detail later on, it turns out to be more convenient to abstract away from the conventional division of daughters into a head and a list of non-heads. Instead, I shall use an equivalent notation, shown in (10.21).

(10.21) $$\begin{bmatrix} \text{MOTHER} & \begin{bmatrix}\text{PHON} & \phi_0 \oplus \ldots \oplus \phi_n\end{bmatrix} \\ \text{HD-DTR} & \boxed{0} \\ \text{DTRS} & \left\langle \boxed{0}\begin{bmatrix}\text{PHON} & \phi_0\end{bmatrix}, \begin{bmatrix}\text{PHON} & \phi_1\end{bmatrix}, \ldots \begin{bmatrix}\text{PHON} & \phi_n\end{bmatrix} \right\rangle \end{bmatrix}$$

That is, the value of the attribute DTRS is equal to the concatenation of the values of HD-DTR and NON-HD-DTRS.

In the remainder of this section, I will examine ways of modifying the phonology attribute of signs so that prosodic structure can be handled. The task can be broken into three subtasks:

(i) *representing* prosodic structure in a feature structure;
(ii) defining a prosodic *relation* between phononology values and metrical trees; and
(iii) incorporating the relation into *prosodic constraints* within a constructional hierarchy.

Subtask (i) is concerned with elaborating the value of the PHON attribute in constructions such as Fig. 5. In particular, it requires a choice of representation for metrical trees. Subtask (ii) addresses the ways in which the PHON values of daughters in such a construction can combine to form a PHON value for the mother. Subtask (iii) has two aspects: defining prosodic constraints in terms of the relation provided by (ii); and showing how prosodic constraints interact with syntactic constructions.

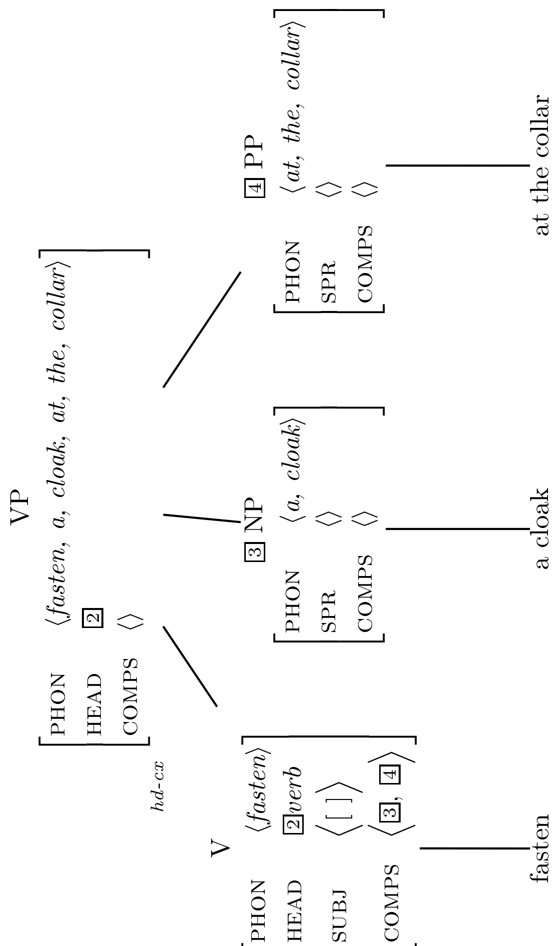


FIGURE 5 Deriving unstructured phonology

As I mentioned at the outset, the goal of the analysis is to induce prosodic structures in parallel with syntactic phrases. The induction is driven, as might be expected, by HPSG's rules for combining heads with complements, modifiers and specifiers. In this respect, my approach will be analogous to that of Steedman (1991), who builds intonational representations in parallel with combinatory categories for strings; and differs from many approaches (primarily in the transformational grammar paradigm) (Butt and King, 1998; Nespor and Vogel, 1986; Selkirk, 1984, 1986) which map from complete surface structure trees into prosodic representations. I also depart in this respect from Taglicht (1998), who despite using an HPSG framework, does not provide an inductive construction of prosodic constraints.

10.4.2 Representing Prosodic Structure

It is easy to devise ways of encoding metrical trees in a constraint-based grammar framework; unfortunately, it is not so easy to come up with reasons for preferring one over another. The approach I shall propose here is correspondingly tentative, and is perhaps best regarded as a representative of a class of encodings.

Working outside-in from signs, we have the following appropriateness conditions for signs:

(10.22) $$sign \rightarrow \begin{bmatrix} \text{PHON} & pros \\ \text{SYNSEM} & synsem \end{bmatrix}$$

Informally, the type *pros* will have two subtypes: word-forms (the default phonology value for words) and metrical trees. For present purposes, I am not going to decompose words into smaller prosodic elements such as syllables. However, it will be useful to draw a further distinction within the class of word-forms, namely between full lexical items (of type *p-wrd*) and weak function words (of type *lnr*).

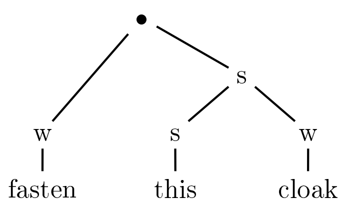
Let us turn now to metrical trees. The minimum requirements are that we have, first, a way of representing nested prosodic domains, and second, a way of marking the most prominent element in a given domain. Consequently we postulate a parametrised type *mtr(τ)* of metrical tree which introduces two features: DOM (prosodic domain) whose value is a list *list(τ)* of prosodic elements, and DTE whose value is a prosodic element of type *full*. We impose the condition that τ's value is one of the subtypes that are *covered* by *pros*, notated $\tau \lessdot pros$, i.e., that it is a subtype s of *pros*, and there is no x such that $s < x < pros$. As we will see shortly, this limits possible values of τ to *lnr* and *full*.

$$(10.23) \quad mtr(\tau \lessdot pros) \rightarrow \begin{bmatrix} \textsc{dom} & list(\tau) \bigcirc \langle \boxed{1} \rangle \\ \textsc{dte} & \boxed{1}\ full \end{bmatrix}$$

Three points of clarification about (10.23) should be made. First, the parameter $\tau \lessdot$ *pros* in (10.23) is intended to act as a bound variable, in the sense that any instantiation of τ by a subtype in *mtr*($\tau \lessdot$ *pros*) is paralled by the same instantion in *list*(τ). Second, $\bigcirc$ is the domain union relation of Reape (1994); Kathol (1995)INAKathol, A.; that is, the DOM value is a list of *pros* values with an object of type *full* intercalated somewhere within. By default, I will take the DTE to the be final element of the list, but the above constraint does not restrict the location of the DTE. Third, items of type *full* in the DOM value of a *mtr(full)* can be word-forms or metrical trees. This means that the DOM value in a *mtr* can, in principle, be a list whose elements range from simple *p-wrd*s to metrical trees of any depth. One way of interpreting this is to say that DOM values fail to obey the Strict Layer Hypothesis (briefly discussed in Section 10.2.1).

To illustrate the feature encoding of metrical trees, the phonology value of sign which corresponded to the metrical tree (10.24) (where the word *this* receives narrow focus) would look like (10.25).

(10.24)



$$(10.25) \quad \begin{bmatrix} sign & \\ \textsc{phon} & \begin{bmatrix} full\text{-}mtr & \\ \textsc{dom} & \left\langle fasten,\ \boxed{1} \begin{bmatrix} full\text{-}mtr & \\ \textsc{dom} & \left\langle \boxed{2} this,\ cloak \right\rangle \\ \textsc{dte} & \boxed{2} \end{bmatrix} \right\rangle \\ \textsc{dte} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Let us now consider those prosodic groupings where one or more weak monosyllabic function words attach to a stress-bearing host. As hinted above, I will treat these as a subtype *mtr(lnr)* of *mtr*(τ), and hence the DOM value will be of type *list(lnr)*. However, the prosodic host in *mtr(lnr)* will always be of type *p-wrd*, and since it will be the most prominent element in the metrical tree, it will also be the DTE. This is imposed by the following type constraint.

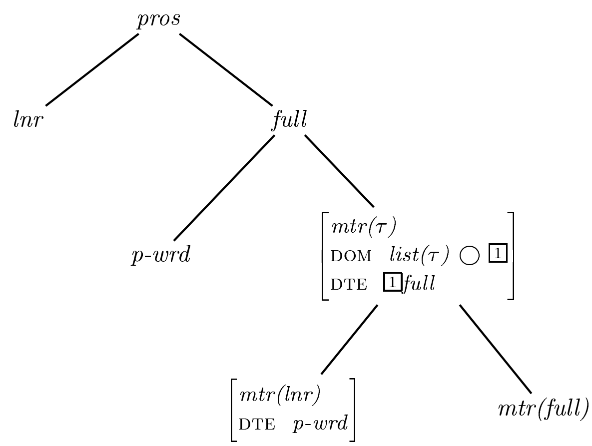


FIGURE 6 Hierarchy of Prosodic Types

(10.26) $\mathit{mtr(lnr)} \rightarrow \begin{bmatrix} \text{DTE} & \boxed{1}\mathit{p\text{-}wrd} \end{bmatrix}$

By inheritance, then, a *mtr(lnr)* has the following characteristics.

(10.27) $\begin{bmatrix} \mathit{mtr(lnr)} & \\ \text{DOM} & \mathit{list(lnr)} \bigcirc \langle \boxed{1} \rangle \\ \text{DTE} & \boxed{1}\ \mathit{p\text{-}wrd} \end{bmatrix}$

As we observed earlier, *p-wrd*s and metrical trees pattern together in being possible daughters within a *mtr(full)*, and consequently they are grouped together as subtypes of *full*. This leads us to the hierarchy of prosodic types shown in Fig. 6.

10.4.3 The mkMtr Relation

Now that we have defined some prosodic structures, it is time to consider ways in which such structures are built. As pointed out in Section 10.4.1 above, the prosodic operations will be incorporated into prosodic constructions, which themselves will have to dovetail with syntactic constructions such as the *head-comp-cx* and *head-spr-cx*.

I shall introduce one basic relation for building metrical trees, called mkMtr. This combines a list of prosodic elements (word-forms or metrical trees) into a metrical tree whose right branch is strong. The relation mkMtr is polymorphic in that it applies to a list of objects of any of the subtypes of *pros*.[9] For example, the nodes of the resulting tree could be labelled by elements of type *p-wrd*, or they could be the roots of metrical

[9] This is termed *inclusion polymorphism* by Cardelli and Wegner (1985).

subtrees. Moreover, the relation is parametrised with a type variable, as we saw earlier for the type *mtr(τ⋖ pros)*. To reduce notational clutter, I shall usually write mkMtr^{τ} in place of $\mathsf{mkMtr}^{\tau \lessdot pros}$, and I shall omit angle brackets around its argument list wherever there is no risk of confusion.

Definition 2 $\mathsf{mkMtr}^{\tau \lessdot pros}$: *list(pros)* $\mapsto$ *mtr(τ)*

(M1) $\mathsf{mkMtr}^{\tau}(\boxed{1}pros) = \boxed{1}$

(M2) $\mathsf{mkMtr}^{\tau}(\boxed{1}, \boxed{2}, \ldots, \boxed{n}) = \begin{bmatrix} mtr(\tau) & \\ \textsc{dom} & \langle \boxed{1}, \boxed{2}, \ldots \boxed{n} \rangle \\ \textsc{dte} & \boxed{n} \end{bmatrix}$

(M1) accounts for the case where mkMtr^{τ} has only one prosodic element in its argument list; since a metrical tree must contain at least two daughters, mkMtr^{τ} returns its input element. If there are at least two elements in the argument list, (M2) builds a metrical tree in the standard way. The fact that mkMtr assigns rightmost prominence is intended as a default rule of English prosody. The assignment of prominence as a result of narrow focus would override this default. (10.28) illustrates (M2); mkMtr^{full} builds a constituent of type *mtr(full)*, while mkMtr^{lnr} builds one of type *mtr(lnr)*.

(10.28) a. $\mathsf{mkMtr}^{full}(different,\ shapes) =$
$$\begin{bmatrix} mtr(full) & \\ \textsc{dom} & \left\langle different,\ \boxed{2}shapes \right\rangle \\ \textsc{dte} & \boxed{2} \end{bmatrix}$$

b. $\mathsf{mkMtr}^{full}\left(Mary,\ \begin{bmatrix} mtr(full) & \\ \textsc{dom} & \left\langle prefers,\ \boxed{1}corduroy \right\rangle \\ \textsc{dte} & \boxed{1} \end{bmatrix}\right) =$
$$\begin{bmatrix} mtr(full) & \\ \textsc{dom} & \left\langle Mary,\ \boxed{2}\begin{bmatrix} mtr(full) & \\ \textsc{dom} & \left\langle prefers,\ \boxed{1}corduroy \right\rangle \\ \textsc{dte} & \boxed{1} \end{bmatrix} \right\rangle \\ \textsc{dte} & \boxed{2} \end{bmatrix}$$

c. $\mathsf{mkMtr}^{lnr}(a,\ cloak) = \begin{bmatrix} mtr(lnr) & \\ \textsc{dom} & \left\langle a,\ \boxed{2}cloak \right\rangle \\ \textsc{dte} & \boxed{2} \end{bmatrix}$

It will be useful to have a more succinct notation for prosodic constituents than that illustrated in (10.28). I will use square brackets to indicate constituents of type *mtr(full)* and parentheses for constituents of type *mtr(lnr)*. Thus, the right-hand sides of the equations in (10.28) will have the following abbreviated counterparts.

(10.29) a. [*different shapes*]
b. [*Mary* [*prefers corduroy*]]
c. (*a cloak*)

As we will see later on, there are cases where the potential input to $\mathsf{mkMtr}^{\mathcal{T}}$ cannot be exhaustively and exclusively interpreted as being either of type *mtr(full)* or of *mtr(lnr)*. An example is shown in (10.30).

(10.30) shŏuld hăve béen thóroughly révised

Given the type constraint declared in (10.27), the whole string cannot be treated as a *mtr(lnr)* (i.e., as in (10.31a)), because it contains more than one element of type *p-wrd*; given (10.23), it cannot be treated as *mtr(full)* (i.e., as in (10.31b)), since it contains elements which are not of type *full*. However, (10.31c) *is* a legitimate prosodic analysis of the string.

(10.31) a. *(shŏuld hăve béen thóroughly révised)
b. *[shŏuld hăve béen thóroughly révised]
c. [(shŏuld hăve béen) thóroughly révised]

Procedurally, we can think of the problem as trying to find the longest prefix of the input string which can be analysed as a *mtr(lnr)*, and then taking the resulting subtree together with the remaining elements of the string as the components of a *mtr(full)*. This approach is incorporated in the following definition, which depends on non-deterministically decomposing a list of prosodic elements into inputs for mkMtr^{lnr} and mkMtr^{full}.

Definition 3 mkMtr: *list(pros)* $\mapsto$ *mtr(pros)*

$$\mathsf{mkMtr}(\boxed{1} \oplus \boxed{2}) = \mathsf{mkMtr}^{full}(\mathsf{mkMtr}^{lnr}(\boxed{1}) \oplus \boxed{2})$$

The definition is illustrated in the next example.

(10.32) $\mathsf{mkMtr}(\langle$should, have, been$\rangle \oplus \langle$thoroughly, revised$\rangle) =$

$\mathsf{mkMtr}^{full}(\mathsf{mkMtr}^{lnr}$(should, have, been), thoroughly, revised) =

[(should have been) thoroughly revised]

To round off this section, I want to consider the problem posed by the following two analyses, where an unaccented preposition combines with a complement NP.

(10.33) a. (*of the necklace*)

of (*the necklace*)

b. [(*of this*)*necklace*]

of [*this necklace*]

In (10.33a), the complement's PHON value is of type *mtr(lnr)*, as is that of the mother. By contrast, in (10.33a) the complement's PHON value is of type *mtr(full)*, and the leaner combines with the first *p-wrd*of this *mtr(full)* to form a subtree of type *mtr(lnr)*. So far, nothing licenses the combination of a leaner and metrical tree, and consequently the definition of mkMtr^{lnr} needs to be augmented with a further clause.

Definition 4

$$\mathsf{mkMtr}^{lnr}(\boxed{1}\ lnr, \begin{bmatrix}\text{DOM} & \boxed{2}\end{bmatrix}) = \mathsf{mkMtr}(\langle\boxed{1}\rangle \oplus \boxed{2})$$

Informally, this clause says that when a leaner is adjacent to a metrical tree, the mkMtr relation is invoked on the leaner and the daughters of that metrical tree. More informally still, this can be thought of as 'erasing the brackets' around the leaner's complement's prosody. There is a presupposition built into the definition that the metrical tree representing the complement's prosody is of depth one; so far, I have not come up with examples where this restriction is violated.

To summarise, $\mathsf{mkMtr}^{\mathcal{T}}$ is the basic (parametrised) relation, building a metrical tree and assigning a DTE. mkMtr acts as a kind of wrapper for $\mathsf{mkMtr}^{\mathcal{T}}$, and allows any leaners at the beginning of a sequence of words to be assembled into a *mtr(lnr)*. If there are no leaners, then mkMtr reduces to mkMtr^{full}; if there is no prosodic elements beyond what is required to build a *mtr(lnr)*, then mkMtr reduces to mkMtr^{lnr}. Finally, as we have just seen, mkMtr^{lnr} requires an extra clause which allows leaners to associate directly with the daughter nodes of a following metrical tree.

10.4.4 Prosodic Constraints

In this section, I will concentrate on the prosody of headed constructions. The crucial factor here seems to be not the dependency status of the non-head daughters—that is, whether they are complements, modifiers or specifiers—but whether they follow or precede the head.

Following Sag (1997); Koenig (1999), I adopt a cross-classification of constructions in which the dimensions of clausality and headedness are augmented by the dimension of prosody. Tentatively, I propose that the types of prosodic constructions enter into the multiple inheritance hierarchy shown in Fig. 7. There are only two prosodic constraints

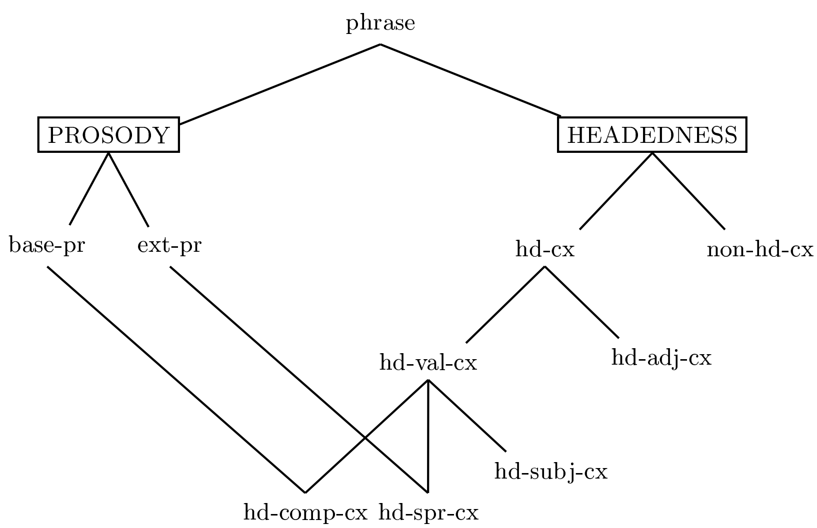


FIGURE 7 Prosody and Headedness

proposed here: *base-pr* (basic prosody) and *ext-pr* (extending prosody). Constructions of type *hd-comp-cx* only inherit from the former, while those of type *hd-spr-cx* only inherit from the latter. *hd-subj-cx* is allowed to inherit from both. The absence of additional information about head-adjunct phrases and non-headed phrases in Fig. 7 reflects the fact that I have not been able to give them sufficient consideration as yet.

Head-Initial Constructions

To begin with, we consider the combination of a head with daughters that follow it. I am following the standard assumption, made in HPSG and other frameworks, that heads combine first with their complements, and only subsequently with specifiers. I am also going to assume (Miller, 1992; Bouma et al., 2000) that posthead modifiers appear on the dependents list of lexical heads, together with complements and specifiers. By and large, the prosody of head-complement contructions obeys the Prosodic Isomorphism Hypothesis.

The type constraint *base-pr* (basic prosody) in (10.34) straightforwardly uses mkMtr to relate the daughters' PHON values to that of the mother.

(10.34) *base-pr* →

$$\begin{bmatrix} \textsc{mother} \mid \textsc{phon} & \mathsf{mkMtr}(\boxed{1}, \ldots, \boxed{n}) \\ \textsc{dtrs} & \left\langle \begin{bmatrix}\textsc{phon} & \boxed{1}\end{bmatrix}, \ldots, \begin{bmatrix}\textsc{phon} & \boxed{n}\end{bmatrix} \right\rangle \end{bmatrix}$$

An example of the phonology constructed by this constraint is illustrated in (10.35), which should be compared with the mother node in Fig. 5. Unlike the latter, the revised approach preserves the prosodic structure of the daughter nodes.[10] that I use (*a cloak*) to abbreviate the AVM representation of the metrical tree for *a cloak*, and similarly for (*at the collar*).

(10.35)

$$\begin{bmatrix} \textit{hd-comp-cx} \wedge \textit{base-pr} & \\ \textsc{mthr} \mid \textsc{phon} & \begin{bmatrix} \textit{mtr(full)} & \\ \textsc{dom} & \left\langle \boxed{1}\textit{fasten},\ \boxed{2}(\textit{a cloak}),\ \boxed{3}(\textit{at the collar}) \right\rangle \\ \textsc{dte} & \boxed{3} \end{bmatrix} \\ \textsc{dtrs} & \left\langle \boxed{0}\begin{bmatrix}\textsc{phon} & \boxed{1}\end{bmatrix}, \begin{bmatrix}\textsc{phon} & \boxed{2}\end{bmatrix}, \begin{bmatrix}\textsc{phon} & \boxed{3}\end{bmatrix} \right\rangle \\ \textsc{head-dtr} & \boxed{0} \end{bmatrix}$$

The second instance of *base-pr* illustrates a nominal head combining with its complement.

(10.36)

$$\begin{bmatrix} \textit{mtr(full)} & \\ \textsc{dom} & \left\langle \textit{possession},\ \boxed{1}[\textit{of the samurai}] \right\rangle \\ \textsc{dte} & \boxed{1} \end{bmatrix}$$

What happens when a lexical head combines with a weak pronominal object, as in (10.37)?

(10.37) a. fasten ĭt
 b. fasten ĭt at the collar
 c. gave hĭm ĭt

[10] See Asudeh and Mikkelsen (2000) for a segment-based approach to achieving this result.

Since unaccented *it* is of type *lnr*, it cannot participate in a *mtr(full)*, since this requires all its daughters to be of type *full*. However, the definition of mkMtr provided earlier deals successfully with such cases, yielding the following structures.

(10.38) a. (fasten it)
b. [(fasten it) (at the collar)]
c. (gave him it)

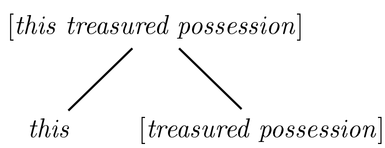
Recall that mkMtr can only assemble a *mtr(lnr)* if the required constituents are initial in the input list. Consequently, when (10.34) and *hd-comp-cx* are conjoined, they require any leaner non-head daughters to be adjacent to the head. Where this restriction is not met, as in (10.39), no prosodic structure will be assigned.[11]

(10.39) *We told Kim ĭt.

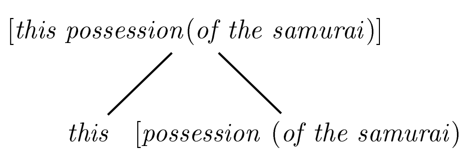
Head-Final Constructions

I shall take *head-spr-cx* as representative of head-final constructions. One of the phenomena to be captured is illustrated by the following trees.

(10.40) a.

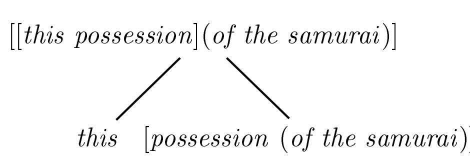


b.



The generalisation seems to be that the specifier 'extends' an existing metrical tree by adding a new prosodic element to the beginning. However, it would also be desirable to capture the structure termed *prosodic promotion* in Section 10.3. This can be viewed as the result of grouping a prehead element with the head, as in (10.41).

(10.41)



[11] For more discussion of this constraint, see Zwicky 1986.

In order to accommodate both of these patterns, I propose a minor generalisation of mkMtr, called $\mathsf{mkMtr}^{\mathrm{LA}}$, which allows a *p-wrd* as well as a leaner to left-associate with a following prosodic element.

Definition 5 $\mathsf{mkMtr}^{\mathrm{LA}}$: *list(pros)* $\mapsto$ *mtr(pros)*

$$\mathsf{mkMtr}^{\mathrm{LA}}(\boxed{1} \oplus \boxed{2}) = \mathsf{mkMtr}^{full}(\mathsf{mkMtr}^{\mathcal{T}}(\boxed{1}) \oplus \boxed{2})$$

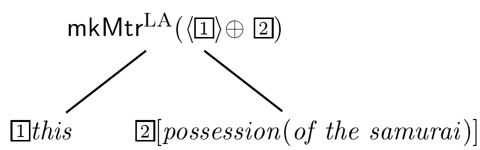
$\mathsf{mkMtr}^{\mathrm{LA}}$ is now invoked by *ext-pr* (extend prosody), the main prosodic constraint to govern head-final constructions:

(10.42) *ext-pr* $\rightarrow$

$$\begin{bmatrix} \textsc{mother} \mid \textsc{phon} & \begin{bmatrix} \textit{mtr(pros)} \\ \textsc{dom} & \langle \mathsf{mkMtr}^{\mathrm{LA}}(\langle \boxed{1} \rangle \oplus \boxed{2}) \rangle \\ \textsc{dte} & \boxed{3} \end{bmatrix} \\ \textsc{dtrs} & \left\langle \begin{bmatrix} \textsc{phon} & \boxed{1} \end{bmatrix}, \begin{bmatrix} \textsc{phon} & \begin{bmatrix} \textsc{dom} & \boxed{2} \\ \textsc{dte} & \boxed{3} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

It will be helpful to look at a promotion analysis in more detail. (10.43) illustrates the schematic tree structure, while (10.44) spells out how the mother node's prosodic constituency is computed.

(10.43)



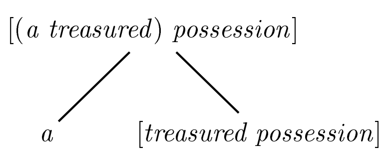
(10.44) $\mathsf{mkMtr}^{\mathrm{LA}}$(*this*, *possession*, (*of the samurai*)) =

mkMtr^{full}(mkMtr^{full}(*this*, *possession*) (*of the samurai*)) =

[[*this*, *possession*] (*of the samurai*)]

Since the definition of $\mathsf{mkMtr}^{\mathrm{LA}}$ has mkMtr as a special instance, left-association of weak determiners follows straightforwardly:

(10.45) a.



b. [(*the possession*)(*of the samurai*)]

the [*possession* (*of the samurai*)]

Unfortunately, $\mathsf{mkMtr}^{\mathrm{LA}}$ overgenerates, allowing structures such as that shown in (10.46).

(10.46) [[*this treasured*] *possession* (*of the samurai*)]

this [*treasured possession* (*of the samurai*)]

Rather than trying to remedy this directly, I suggest that there is a constraint on headed constructions which forbids metrical trees in which a lexical head is immediately preceded by a subtree of type *mtr(full)*. In order to state the constraint, I will assume that phrases like *treasured possession* are of type *hd-pre-adj-ph*, i.e., a phrase which results from modification by a pre-head adjunct.

(10.47) Lexical Head Association Constraint:

$$\textit{hd-cx} \rightarrow \neg \begin{bmatrix} \textsc{mother} \mid \textsc{phon} \mid \textsc{dom} & \left\langle \begin{bmatrix} \textit{mtr(full)} \\ \textsc{dom} \quad \textit{ne\_list} \oplus \boxed{1} \end{bmatrix} \right\rangle \oplus \boxed{2} \\ \textsc{hd-dtr} & \begin{bmatrix} \textit{hd-pre-adj-ph} \\ \textsc{phon} \mid \textsc{dom}\ \boxed{1} \oplus \boxed{2}\ \textit{ne\_list} \end{bmatrix} \end{bmatrix}$$

Informally, (10.47) prohibits headed constructions from building a PHON value for the mother where (i) the head daughter has undergone pre-head modification, and (ii) a proper subpart (i.e., $\boxed{1}$) of the head's prosodic structure is left-associated with some material which precedes the head and its modifiers. In other words, if some element left-associates with material preceding a head, then it must include the head itself in the grouping. This constraint can be seen as a partial implementation of Selkirk's 1986; 1996 notion of end-based mappings between syntax and phonology.

I will now turn briefly to two kinds of construction which are related to what has gone before, but merit special attention: subject-VP constructions and auxiliary-VP constructions.

Subjects As one might expect, subjects can pattern prosodically like specifiers. This is illustrated in (10.48). The first two examples parallel (10.40a) in extending their head's metrical tree.

(10.48) *hd-subj-cx* ∧ *ext-pr*

a. [[*this piece*] *works equally well*]

[*this piece*] [*works equally well*]

b. [*Mary prefers corduroy*]

Mary [*prefers corduroy*]

The next two are cases of left-association; (10.48a) supplies one of the prosodic bracketings for the example (10.28b), discussed by (Selkirk, 1984, p290–291) and Steedman (1991).

(10.49) *hd-subj-cx* ∧ *ext-pr*

a. [*Mary prefers*] *corduroy*]

Mary [*prefers corduroy*]

b. [(*he found it*) [*behind the shed*]]

he [(*found it*) [*behind the shed*]

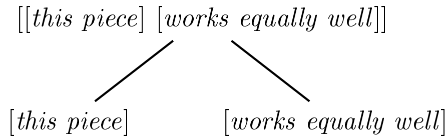
(10.48b) (which is also accommodated by *base-pr*), represents an interesting departure from the tendency noted by Gee and Grosjean (1983); Bachenko and Fitzpatrick (1990) for verbs to group either with clausal material either to the left or the right.

Notice that the Lexical Head Association Constraint will prevent a subject from left-associating with a pre-head adverbial modifier.

(10.50) *[[Mary usually] prefers corduroy]

As well as acting prosodically like specifiers, subjects can also combine with VPs according to the pattern which was identified for head-initial constructions. In this case, a new metrical tree is constructed, with the subject's and VP's prosodies embedded as subtrees.

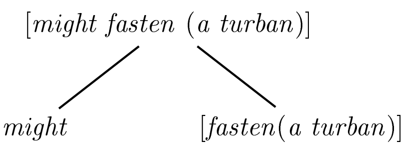
(10.51) *hd-subj-cx* ∧ *base-pr*:



These two possibilities are allowed by the cross-classification of constraints presented earlier in Fig. 7.

Auxiliaries The cross-classification framework allows us to deal with an interesting case which departs from the general correlation between prosodic structure and head-position, namely *hd-comp-cx* constructions where the head is a auxiliary verb. Unlike the case of VPs headed by lexical verbs, (accented) auxiliaries *extend* the prosody of their complements, rather than building a new metrical tree:

(10.52) *aux-hd-comp-cx* ∧ *ext-pr*:



10.5 Conclusion

I hope to have shown that HPSG allows us to express some degree of syntax-prosody mismatch in a succinct and natural manner. The key formal mechanism required is the mkMtr relation, which allows prehead material to combine directly with the phonology of a lexical head, rather than with the phonology of that head's phrasal counterpart. There is little doubt that other frameworks could make appeal to analogous formal mechanisms. Nevertheless, the fact that HPSG adopts a rather conventional approach to phrase structure is highly desirable for my purposes, since it reveals quite clearly just where the tension lies between syntactic and prosodic constituency. Finally, the cross-classification framework of Sag (1997) offers the distinct advantage of allowing prosodic constraints to be defined independently of syntactic constructions, yet related to them by means of multiple inheritance.

Acknowledgements

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