THE PROSODY-SEMANTICS INTERFACE

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Abstract

In recent years, the relationship between prosody and syntax has been the subject of a considerable amount of work while the prosody-semantics interface has received less attention in the literature. However, any complete analysis of spoken language must account for those contributions to meaning which intonation and other aspects of prosody can make. In this paper, we focus on two such phenomena in English, the prosody-only indication of polar interrogativity in declarative questions and the so-called 'comma intonation' associated with non-restrictive relative clauses. Based on standard theoretical assumptions augmented with a more fine-grained view of the contents of the lexicon, we propose a formal treatment of the interactions between prosody, syntax and semantics, motivated by a strong commitment to modular specificity, that is consistent with LFG's co-description architecture. The revised architecture we posit situates the string at the heart of interface phenomena and offers a new perspective within the LFG framework not only on the interface between prosody and semantics, but also on the prosody-syntax interface.

1 Introduction[1]

The interaction between prosody and other aspects of linguistic structure has received an increasing amount of attention over the last 30 years (e.g. Nespor & Vogel 2007; Selkirk 1984). This work has overwhelmingly focused on the relationship between prosody and syntax, and has primarily been concerned with identifying and defining prosodic units and their relationship to syntactic units. Formalizations of the prosody-syntax interface exist in a variety of theoretical frameworks (e.g. Szendrői 2003, Minimalism; Klein 2000, HPSG), including LFG (e.g. Butt & King 1998; O'Connor 2006; Mycock 2006), most recently by Bögel et al. (2009, 2010). However, any analysis of prosody's place in the grammar is incomplete without a formal characterization of how it interacts with other aspects of linguistic structure in addition to syntax, given that prosody alone can indicate information structure status (as in a case of prosodic focusing such as *ANNA was studying at the university*, where capitals indicate prosodic prominence) and make semantic contributions (e.g. in a declarative question such as *Anna was studying at the university?*). In this paper, we will confine ourselves to discussing two such interface phenomena: the prosody-only indication of polar interrogativity found in declarative questions such as *Anna was studying at the university?* and the so-called 'comma intonation' associated with non-restrictive relative clauses exemplified by the sentence *Anna, who Bill met, was yawning*. In order to account for these phenomena, we propose to augment existing standard theoretical assumptions with (i) a more fine-grained view of the contents of the lexicon, and (ii) a formal treatment of interactions involving prosody, syntax, and semantics.

The proposed analysis is based on a view of modularity and domain specificity rooted in the fundamental differences that have been shown to exist between different aspects of linguistic structure. We take it to be a fact

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about the nature of language that, for instance, syntax interprets only syntactic units and structure, while phonology interprets only phonological units and structure. However, it is clear that syntax and phonology, as integral parts of any string, are related to one another in a non-trivial way. If syntax and phonology are to interact, it is clear that certain syntactic information should be available to the phonology, and as a consequence phonological structure or processes may (or may not) correlate with syntactic structure. This interaction is crucial when one comes to consider the semantic contributions that can be made by prosody within an LFG approach because, under standard assumptions about the architecture of the grammar, semantic structure is projected from f-structure, i.e. from the syntax. In this paper, we explore the prosody-semantics interface in terms of an architecture in which the two are mediated by syntax (c-structure, f-structure) and which places the string itself at the heart of any account of the relevant interface phenomena.

We begin in Section 2 by describing the two interface phenomena to be analysed. In Section 3, we outline our approach to the lexicon, lexical entries and the string. Crucial assumptions about prosody and prosodic structure are summarized in Section 4. We then present our proposals for modelling the prosody-syntax interface (Section 5) and the prosody-semantics interface (Section 6) within the LFG framework, with specific reference to the analysis of declarative questions (6.1) and comma intonation (6.2) in English. Section 7 offers a comparison to other approaches.

2   The two phenomena: declarative questions, comma intonation

The two phenomena through which we will explore the prosody-semantics interface are declarative questions and the comma intonation associated with non-restrictive relative clauses. In both cases, prosody makes a crucial semantic contribution. In this section, we outline key features of the relevant English data.

The morphosyntax of a declarative question is identical to that of its non-interrogative counterpart. The two are distinct only in terms of their intonation: specifically, a declarative question has a sentence-final rise in intonation, represented as a Low (L) to High (H) pitch movement in (1).[2] (In writing, this is usually indicated by punctuation.)

(1)   Declarative question: declarative syntax, final rise in intonation
       Anna was studying at the university?
       'æ.nə.wəz.'stʌ.di.ɪŋ.ət.ðə.ju.nə.'vɜː.sə.ti

                                    L   H

In contrast to a polar interrogative involving subject-auxiliary inversion such as *Was Anna studying at the university?*, there is nothing in the syntax of a declarative question such as (1) to indicate that it is an interrogative. Rather, the appropriate interrogative interpretation is communicated by this

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[2] Throughout, we represent spoken utterances using IPA symbols. Syllables are separated by full stops; stress is marked on the relevant syllables by a superscript mark (primary stress) or a subscript mark (secondary stress). Following widely accepted convention, we represent pitch patterns as annotations on specific syllables. We assume two tones (pitch targets): High (H) and Low (L).

sentence's intonation pattern, namely the interrogative tune with which it is pronounced. Thus, prosody makes a meaning contribution in a declarative question.

The interrogative tune shown in (1) consists of a L tone followed by a H tone. Each of these tones (or pitch targets) is linked to a specific syllable; phonetically they are rendered simultaneously with the relevant syllable. We make the basic assumption, following much work on intonational phonology, that a tune minimally consists of a nuclear tone and a boundary tone. In a tune, the nuclear tone is the pitch target which represents the main stress in a major prosodic constituent known as the Intonational Phrase, while boundary tones appear at one edge or both edges of that Intonational Phrase. A left boundary tone is therefore associated with the first syllable in the Intonational Phrase (IntP) and a right boundary tone with its final syllable. We can therefore characterize the interrogative tune in (1) as consisting of a right boundary tone which is High (H) and a nuclear tone which is Low (L). This nuclear tone is associated with the stressed syllable of a specific prosodic constituent, smaller than IntP, to be defined in Section 3. At this stage, it suffices to say that the interrogative tune consists of a final L H pitch movement, i.e. a rise.

As well as indicating clause type, prosody may make other kinds of semantic contribution. The second phenomenon that we will analyse in this paper is so-called 'comma intonation' (Emonds 1976; Potts 2005), a specific pattern of prosodic phrasing associated with non-restrictive relative clauses. A claim repeatedly made in the literature is that a non-restrictive relative clause is separated from the rest of the utterance in which it appears by a pause on either side of it, indicated in (2) by double forward slashes.

(2)   Comma intonation
       Anna, who Bill met, was yawning.
       'æ.nə.//ˌhu.'bɪl.mɛt.//ˌwəz.'jɔː.nɪŋ

In terms of its prosodic structure, the non-restrictive relative clause forms a separate prosodic constituent; it is an IntP. While comma intonation is regularly characterized as involving a pause on either side of the non-restrictive relative clause, this is not necessarily the case – there may instead be other prosodic indications of its status as a separate IntP, such as pitch reset at its left edge and at the start of the following IntP.

As a first step towards analysing these two interface phenomena, it is necessary to outline our approach to the lexicon, which we contend to be crucial in capturing the appropriate relations between prosody, syntax and semantics.

3   The lexicon, lexical entries, and the string
The starting point for our analysis is a more fine-grained view of the contents of the lexicon and the string.[3] This approach is motivated by a strong commitment to modularity and domain specificity. In this, we agree with

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[3] We take the lexicon to be a theory of the structure of words, albeit a theory which must be complex, as demonstrated by Seiss (2011).

Scheer (2011: 347) when he states that "modules are domain specific and encapsulated … they are unable [to] understand, or even parse, what is going on in other modules". Thus, syntax, for example can manipulate and interpret only syntactic objects and structure – it is 'blind' to phonological objects. These facts about the syntactic and phonological levels of linguistic structure are reflected in our conception of the lexicon's contents. We propose that each lexical entry defines a relation between the s(yntactic)-form of a word and its p(honological)-form, as shown in (3) for the lexical items which appear in example sentence (1). This represents a move away from the standard LFG approach, which conflates these aspects of a lexical entry into a single form consistent with only the associated syntactic unit.

(3)   Lexical entries

| *s-form*
f-descrip
p-form | Anna
N (↑PRED) = 'Anna'
/æ$_S$.nʌ$_W$/ | was
I
/wɒz/ | studying
V (↑PRED) = 'study⟨SUBJ⟩'
/stʌ$_S$.di$_W$.ɪŋ$_W$/ |

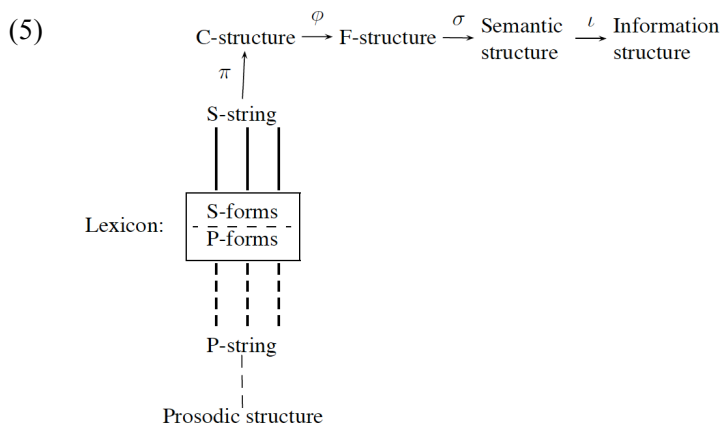| at
P (↑PRED) = 'at⟨OBJ⟩'
/æt/ | the
D (↑SPEC) = 'the'
/ði/ | university
N (↑PRED) = 'university'
/ju$_W$.nɪ$_W$.vɜː$_S$.sɪ$_W$ .ti$_W$/ |

A lexical entry's s-form, shown on the top line inside each box in (3), together with its f-description contains information which is of relevance to the syntax of any sentence in which this lexical item appears. The lexical entry's p-form, which appears below the dashed line in (3), contains phonologically relevant information such as the item's syllable structure, the vowel and consonant sounds of which it consists, and its stress pattern. We distinguish the p-form from the s-form by presenting the former as a broad IPA transcription, with syllables specified as strong (S), weak (W) or unspecified for the purposes of stress placement.

    By defining p-form and s-form, a lexical entry includes form specifications appropriate to the relevant macromodules, viz. syntax and phonology. That is not to say that these two forms are independent: they are after all always related by virtue of being part of the same lexical entry. However, the s-form and the p-form of a lexical entry are subject to different structural principles because they belong by definition to different macromodules of the grammar. This distinction is captured when we recognize and build into the architecture the fact that the string, like each lexical entry, has two separate but related aspects: the s-string, based on the s-forms of each lexical item, and the p-string, based on their p-forms. Setting aside prosody for the time being, these two aspects of the sentence *Anna was studying at the university* are shown in (4).

(4)   *s-string*:   Anna was studying at the university

          p-string: 'æ.nə.wəz.'stʌ.di.ɪŋ.ət.ðə.ju.nə.'vɜː.sə.ti

In each case, the string's features are module specific: the s-string is composed of syntactic units and information relevant at the levels of syntactic structure including syntactic category, whereas the p-string is composed of phonological units and phonologically relevant information such as stress placement and syllable structure. Note that nothing in this approach sets up the expectation that there will be a one-to-one correspondence between syntactic units and phonological units.

The diagram in (5) shows how the p-string and s-string fit into the overall architecture of the grammar which we propose.

(5)

$$\text{C-structure} \xrightarrow{\varphi} \text{F-structure} \xrightarrow{\sigma} \text{Semantic structure} \xrightarrow{\iota} \text{Information structure}$$

$\pi \uparrow$

S-string

Lexicon:

S-forms
P-forms

P-string

Prosodic structure

The organization of modules along the top of the diagram in (5) is standard (constituent-structure maps to functional-structure maps to semantic-structure), with the additional assumption that information-structure is projected from semantic-structure (Dalrymple & Nikolaeva 2011). Moving downwards in (5), c-structure and the s-string are related by the π projection function (Kaplan 1987, Asudeh 2006), and each unit of the s-string is related to a lexical entry, specifically to its s-form which consists of syntactically relevant information. In this manner, we formally distinguish s-string units from the contents of c-structure terminal nodes and from the syntactic information (s-form) that is part of a lexical entry. These relations are shown in (6), which represents an analysis of the syntax of *Anna was studying at the university*.

(6)
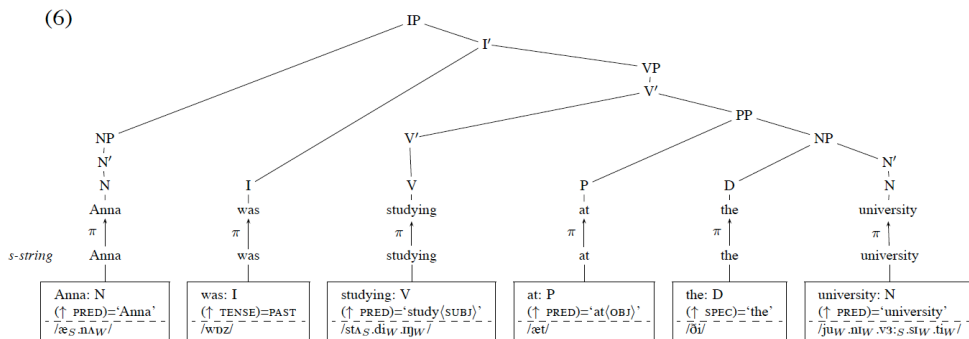
Differentiating between s-forms and units in the s-string may seem unnecessary because it will overwhelmingly be the case that the relationship between the two will be one of identity, as in (6), but in fact this is an important distinction to make because the s-string cannot simply constitute a sequence of s-forms. If it did, in a sentence such as *Anna studies law and Ben studies art*, which contains two instances of the same word, there would have to be two separate s-forms of *studying* with each one necessarily being part of a distinct lexical entry. To avoid such duplication, we posit a mapping between s-forms and units of the s-string, in addition to the π projection function which maps between units in the s-string and terminal nodes at c-structure (Kaplan 1987, Asudeh 2006).[4]

Returning to the diagram in (5), we also propose that p-forms provide information which is used to construct the p-string (cf. the relation between s-forms and the s-string). The units of the p-string, i.e. syllables,[5] which Nespor (1999: 119) notes are "purely phonological in nature", are related to p-structure terminal nodes. The dashed lines in (5) represent the phonological relations between p-forms, the p-string and p-structure. These appear to be considerably more complex than the equivalent mapping between s-forms and c-structure because they involve the application of phonological rules. For instance, the phonological rule which reduces an unstressed vowel in English applies between p-form and p-string, while a phonological rule whose domain is a prosodic unit, e.g. pitch reset at the beginning of IntP, is part of the relation between p-string and p-structure.

According to our version of the architecture in (5), there is no direct mapping between c-structure and p-structure (cf. Butt & King 1998), but rather the lexicon, along with other interface principles, mediates between s-string and p-string. We posit that the lexicon plays a crucial part in determining which syntactic, prosodic and semantic information is potentially available at the interface between the syntax and phonology. This assumption of an absolute distinction between syntax and phonology prompts the question: what of prosody?

4   Prosody and prosodic structure

A large body of work has shown that prosody has its own primitives and organizing principles which cannot be reduced to those of syntax or phonology. Here, we follow Selkirk (1986) in assuming the hierarchy of prosodic units in (7). This hierarchy results in structural configurations which are much flatter than syntactic ones; for instance, phrases are not maximal projections of heads.[6] Given the hierarchy in (7), we can now define the interrogative tune in (1) more accurately by specifying the default location of the nuclear tone. As stated previously, the right boundary tone, which is H, is associated with the last syllable in the IntP. The other component of the interrogative tune is a nuclear tone L, which is associated with the stressed
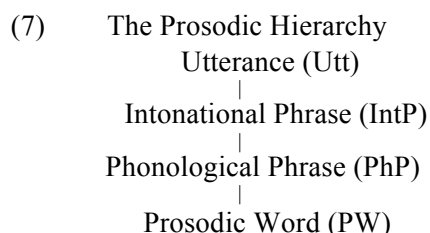
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[4] The π projection function may be relevant in the analysis of clitics. See Section 7.

[5] We assume that the basic unit of the p-string is the syllable, but p-structure may refer to smaller units in some circumstances.

[6] Whether there is recursion in prosodic structure is a topic of much current debate, but one which falls outside the scope of this paper.

syllable of the first prosodic word (PW) of the final phonological phrase (PhP) in the IntP. We return to the issue of intonation in Section 6. In the remainder of Section 4 and in Section 5, the focus will be on prosodic phrasing and our proposals for the formal characterization of the prosody-syntax interface, an issue which it is necessary to address before an analysis of the phenomena introduced in Section 2 can be provided.

(7)   The Prosodic Hierarchy
              Utterance (Utt)
                     |
         Intonational Phrase (IntP)
                     |
        Phonological Phrase (PhP)
                     |
           Prosodic Word (PW)

The issue of how prosody should be integrated into the LFG architecture has received increasing attention in recent years. Butt & King (1998) were the first to propose that prosody should be regarded as a distinct level of structure in the LFG architecture. In a sense though, prosodic structure straddles the boundary between syntax and phonology: it is clear that phonological processes can make reference to units of prosody, e.g. Nespor & Vogel (2007) claim that the PhP is the domain of application for the phonological rule of Iambic Reversal in English as in *thir'teen 'men* → *'thirteen 'men*, and that prosodic structure can be closely related to constituent structure, e.g. prosodic phrasing can disambiguate in cases of syntactic ambiguity such as (*old men*) (*and women*) where a pause serves to indicate that the adjective modifies only the first N conjunct.[7] Prosodic structure thus appears in at least some cases to have a relatively close relationship to constituent structure. It must be stressed though that alignment of constituents at these two different levels of linguistic structure is only partial: data clearly show that constituent structure and prosodic structure are not isomorphic. Indeed, Lahiri & Plank (2010) argue, citing work dating back to Steele (1775/1779), that in Germanic languages phonological phrasing is by default determined on the basis of rhythm, and thus non-isomorphism between syntax and prosody is to be expected, even to the extent that morphological word integrity is not necessarily respected. This is the case even in a simple sentence uttered at a normal speech rate such as (8).

(8)   c-structure:
           [$_{IP}$ [$_{NP}$ Anna] was [$_{VP}$ studying [$_{PP}$ at [$_{NP}$ the university]]]]

p-structure (default prosodic phrasing):

($_{IntP}$ ($_{PhP}$ ($_{PW}$ 'æ.nə.wəz.)) ($_{PhP}$ ($_{PW}$ 'stʌ.di.ɪŋ.ət.ðə.ju.nə.)) ($_{PhP}$ ($_{PW}$ 'vɜː.sə.ti)))

In the p-structure in (8), prosodic units are constructed on the basis of rhythmic principles, forming trochaic groups. The result is a massive

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[7] We follow the widely adopted convention of indicating prosodic phrasing with rounded brackets. Square brackets are used to represent syntactic constituency.

disparity between c(onstituent)-structure and p(rosodic)-structure, right down to the number of basic units (six and three, respectively). Morphological word integrity is not respected: the final unit of this sentence's p-structure does not constitute a unit at c-structure. Any analysis must capture the non-isomorphic nature of the relationship between syntax and prosody, exemplified by (8).

5   Modelling the prosody-syntax interface

Following Lahiri & Plank (2010), we assume that in the case of a spoken sentence such as (8), the smallest prosodic unit (the prosodic word, PW) is constructed on the basis of rhythmic principles. Trochaic groups are formed with the consequence that there are significant mismatches between c-structure and p-structure, as shown in (9). (This is the same as example (6), but (9) includes this sentence's p-string and p(rosodic-)structure.) Note that the p-structure terminal nodes, which appear in the lower tree, are prosodic words. These prosodic words are related to syllables in the p-string as indicated.

(9)   Default phrasing: (Anna was)$_{PW}$ (studying at the uni)$_{PW}$ (versity)$_{PW}$.
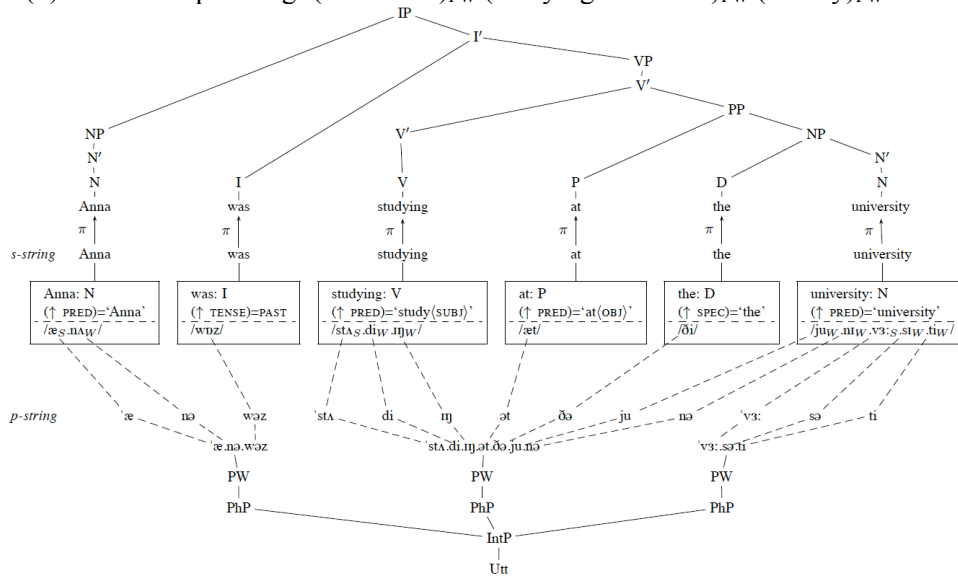
As noted previously, the extensive misalignment which Lahiri & Plank (2010) highlight extends as far as the number of basic units in this sentence: there are six terminal c-structure nodes, but only three terminal p-structure nodes. In (9), *Anna was* maps to a single terminal node at p-structure but to two terminal nodes at c-structure, and *university* maps to two separate terminal nodes at p-structure but to a single c-structure terminal node.

The diagram in (9) serves to illustrate the most important features of our approach to the interface between syntax and prosody. We relate c-structure and p-structure through those aspects of the string (the s-string and the p-string, respectively) which are constructed on the basis of the s-form and p-form values that are necessarily part of any lexical entry. The connection

between a word's s-form and p-form is made in the lexicon, meaning that the lexicon is at the heart of the prosody-syntax interface. The excerpt of the architecture given in (10) shows how a lexical entry, the string and c- and p-structures are related to one another.

(10)

C-structure

Lexical entry

π

| s-form — | —s-string |
| p-form — | — p-string |

P-structure

(11) Default phrasing: (Anna was)$_{PW}$ (studying at the uni)$_{PW}$ (versity)$_{PW}$.

```
                         IP
                          \
                           I'
                            \
                             VP
                              |
                              V'
                               \
                                PP
     NP          V'                NP
      |           |                 \
      N'          |                  N'
      |           |                  |
      N     I     V     P     D      N
    Anna   was studying  at   the  university
     π↑    π↑    π↑     π↑   π↑    π↑
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s-string   Anna   was   studying   at   the   university

p-string   'æ nə wɔz   'stʌ di iŋ   ət ðə ju nə   'vɜː sə ti

          'æ.nə.wɔz   'stʌ.di.ɪŋ.ət.ðə.ju.nə   'vɜː.sə.ti

              PW   PW   PW
               | | |
             PhP ———   PhP   — PhP
                    \   / \   /
                     \   /   \   /
                      IntP
                       |
                      Utt
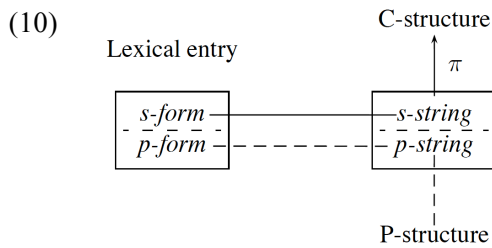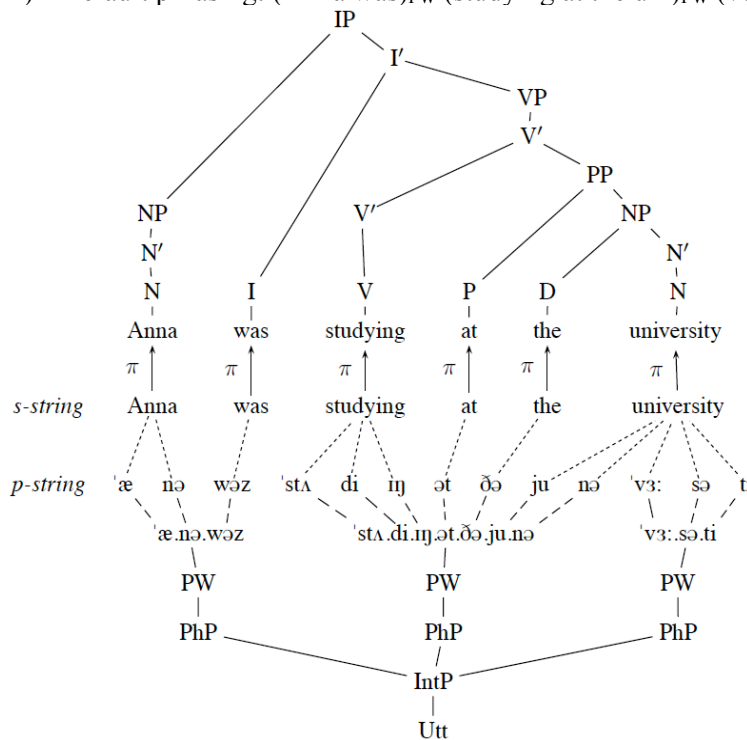
For the purposes of clarity and because it is perhaps more intuitive to do so, we henceforth represent the interface between syntax and phonology in terms of the relationship between the s-string and the p-string, and omit the details of lexical entries from all diagrams. The relationship established between s-string and p-string units via lexical entries is instead represented by dotted lines, as in (11). (The information expressed in (11) is the same as in (9), only without the lexical entries.)

Example (11) represents a sentence uttered at a regular tempo, with prosodic phrasing established according to the rhythmic principles which

Lahiri and Plank (2010) identify as applying in the default case. The extent to which rhythmic principles determine prosodic phrasing varies though, and syntactic structure may be reflected in a sentence's prosodic structure to different degrees depending on a number of factors including speech tempo. For instance, when spoken more slowly and carefully our example sentence would have a different prosodic structure, such as the one shown in (12). The most striking difference between this example of careful speech and the default case shown in (11) is that the syntactic and prosodic constituents in (12) align to a greater degree. For instance, in (12) *university* occupies a single terminal node at both c-structure and p-structure, in contrast to (11) where *university* illustrates the point that morphological word integrity need not be respected at the level of p-structure. However, even in (12) there is still not complete isomorphism. For example, *Anna* and *was* map to two separate terminal nodes at c-structure but only one at p-structure, as in (11). To summarize, there appears to be a greater degree of alignment between c-structure and p-structure constituents in careful speech than there is in the default cases discussed by Lahiri & Plank (2010).

(12) 'careful speech': (Anna was)$_{PW}$ (studying)$_{PW}$ (at the)$_{PW}$ (university)$_{PW}$.

IP
I′
VP
V′
PP
NP V″ NP
N′ N′
N   I   V   P   D   N
Anna was studying at the university

π π π π π π

s-string Anna was studying at the university

p-string 'æ nə wɔz 'stʌ di ɪŋ 'æt ðə ˌju nə 'vɜː sə ti

'æ.nə.wɔz   'stʌ.di.ɪŋ   'æt.ðə   ˌju.nə.'vɜː.sə.ti

PW   PW   PW   PW

PhP   PhP   PhP

IntP

Utt
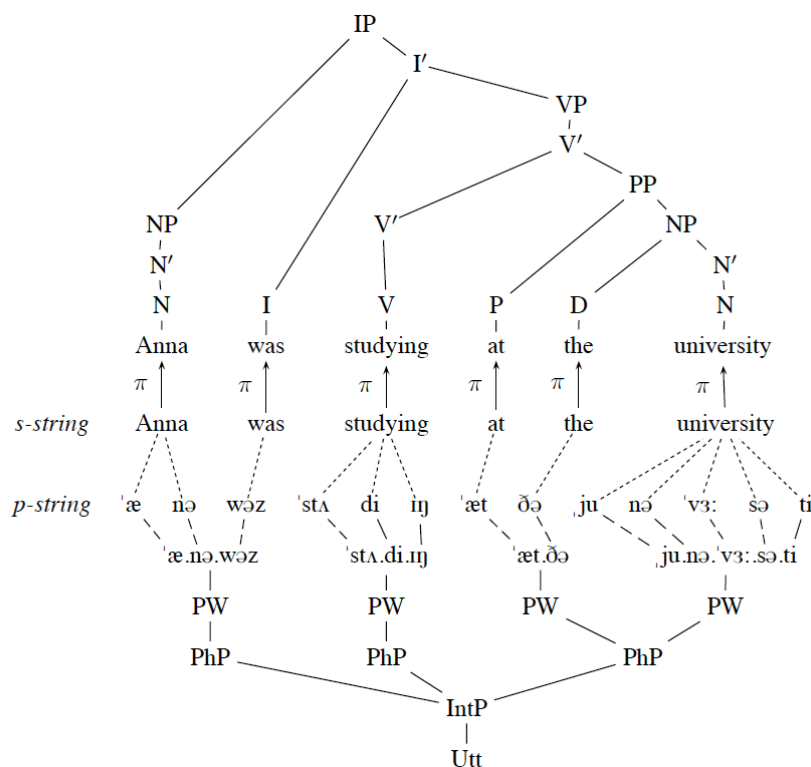
Facts about (non)isomorphism must be captured by any analysis of the prosody-syntax interface. In order to achieve this goal while at the same time respecting strict modularity, we contend that it is necessary for information about prosodic structure that is relevant for syntax and information about

syntactic structure that is relevant for prosody to be simultaneously available for the purposes of alignment within LFG's co-description architecture. We propose to augment the existing LFG framework with two new structural levels: chi-structure, projected from p-structure and the p-string by the χ function, and e(psilon)-structure, projected from c-structure and the s-string by the ε function. Chi-structure contains information about prosodic structure, while epsilon-structure contains information about syntactic structure. (13) is a version of (10) revised to include chi-structure and e-structure.

(13)
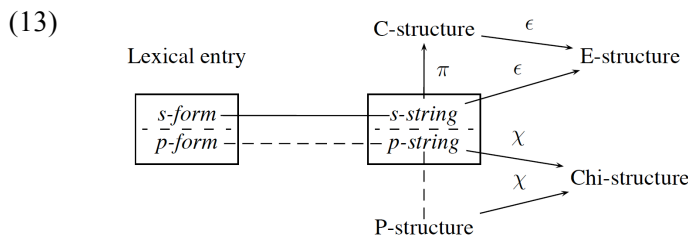
Chi-structure and e-structure contain information which is potentially relevant to the interaction between syntax, prosody and semantics, for instance for the purposes of alignment. In this paper, two types of such information are of particular concern: (i) prosodic constituent boundaries (or edges), and (ii) information about the presence of a semantically contentful tune such as the interrogative tune. Crucial for the former is that chi-structure contains information about prosodic constituent boundaries which is passed through p-structure and into the p-string, where the location of these boundaries is available to be aligned with the location of c-structure boundaries according to relevant interface principles (i.e. depending on factors such as speech tempo). The p-string and the chi-structure with which it is associated thus represent an important aspect of the interface between prosody and syntax, along with the lexicon and additional interface principles, such as those that determine the degree of alignment between prosodic and syntactic boundaries. In order for any alignment to occur though, similar information about syntactic constituent boundaries must also be available at the interface. This information is part of e-structure, which serves to pass it through c-structure and into the s-string, where the location of these boundaries is available to be aligned with the location of p-structure boundaries (cf. the relationship between p-structure and chi-structure). The relevant interface principles are thus able to apply. They determine the appropriate degree of isomorphism and enforce this on the basis of information about syntactic and prosodic structure contained within e-structure and chi-structure, respectively.

   To give an example, we can begin by augmenting (11) – our analysis of *Anna was studying at the university* with default prosodic phrasing – with chi-structures which contain the information about prosodic structure that is available at the interface for the purposes of alignment. Chi-structures are associated with nodes at p-structure, as well as with units of the p-string (i.e. syllables). In formal terms, this involves the addition of rules containing information about the mapping between p-structure and p-string units and

chi-structure (see Appendix). These rules ensure that a prosodic constituent inherits the relevant edge information from its mother via the associated chi-structure. In this way, information about the edges of prosodic constituents is passed through the p-structure tree, and is ultimately associated via chi-structure with the relevant syllables in the p-string. For example, the final syllable of the sentence, */ti/*, represents the right edge of a PW, a PhP, and the IntP. We represent chi-structures as attribute value matrices containing attributes L(eft) and R(ight). These attributes' values are sets consisting of members that indicate with which constituent edge(s) the relevant unit is associated, e.g. [L {PW}] denotes 'left edge of a Prosodic Word', [R {IntP}] denotes 'right edge of an Intonational Phrase'. The revised version of (11) is (14).

(14) (Anna was)$_{PW}$ (studying at the uni)$_{PW}$ (versity)$_{PW}$.
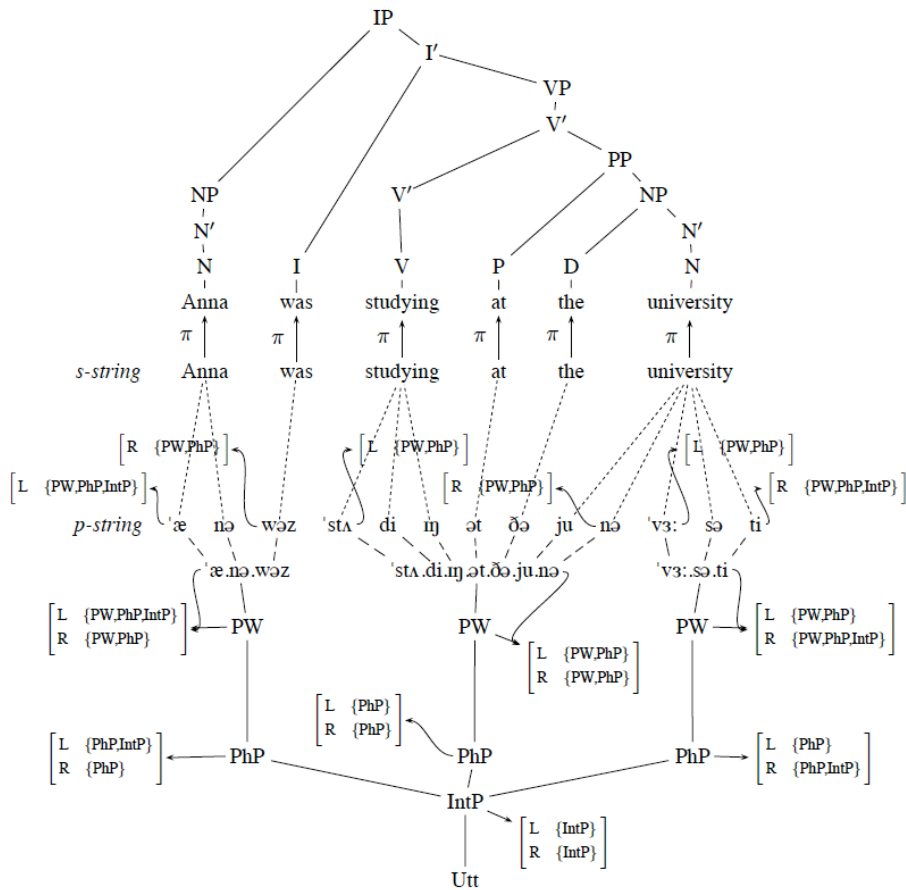
The next step is to add e-structures to (14) according to a set of rules that map c-structure and s-string units to e-structure (see Appendix). These rules ensure that a syntactic constituent inherits all relevant information about the edges of syntactic constituents via the associated e-structures, and that this information is passed through the c-structure tree and into the s-string, where

it is associated with one of its units, as shown in (15).

Passing information about the edges of all major constituents into the p-string and the s-string, as in (15), may seem excessive. Certainly, very little of this information seems to be relevant in the default case as there is extensive misalignment of syntactic and prosodic constituents (see Section 4). However, as the 'careful speech' example in (12) illustrates, in some utterances there is a greater degree of alignment between syntactic and prosodic constituents than we find in (15). Therefore, information about constituent boundaries must be available at the interface in order that the relevant alignment principles can apply to give phrasing which reflects the appropriate degree of increased isomorphism. Thus, at this stage, we elect to represent all potentially significant information about syntactic and prosodic structure in the relevant e- and chi-structures. This does not mean that we necessarily expect all of this information to emerge as being relevant at the interface. In fact, it is an important feature of this architecture that it enables us to explore the question of precisely which aspects of prosodic and syntactic structure are important at the interface and to investigate why this should be, both cross-linguistically and on a language-by-language basis.
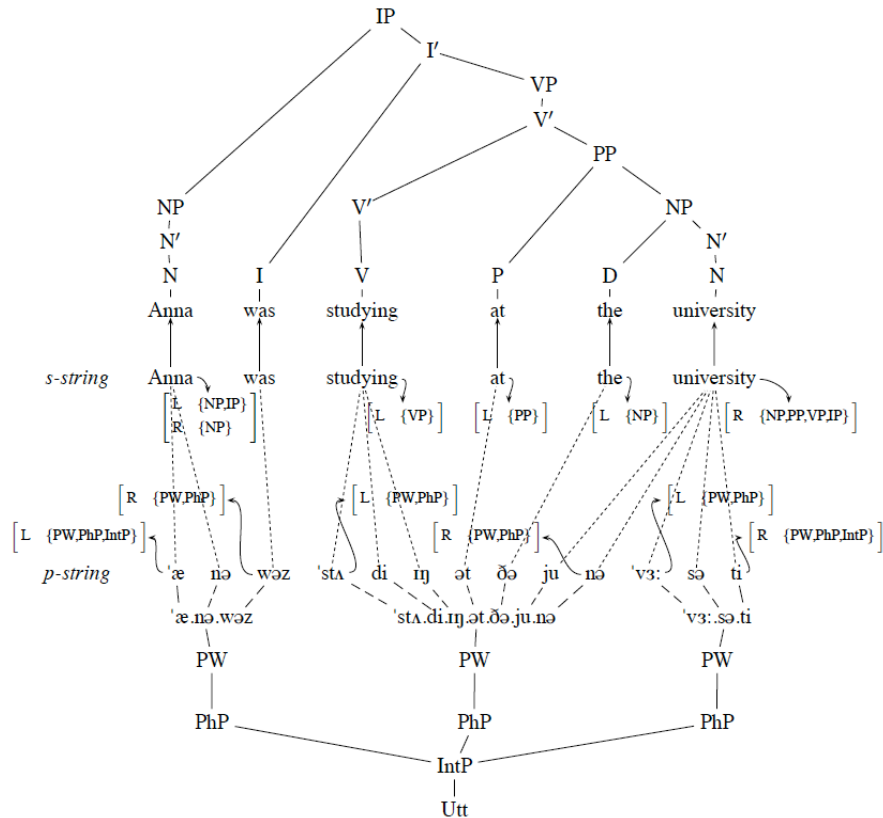
(15)
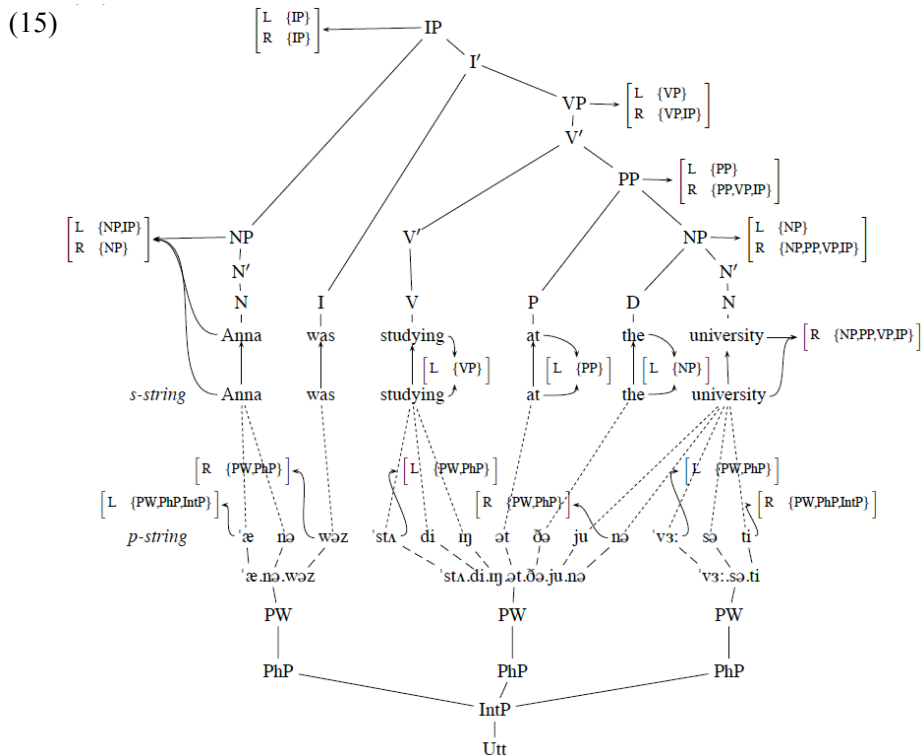
For clarity of exposition, we can strip the nodes in the p- and c-structure trees of their chi- and e-structures, leaving only the information available at the interface that is contained in and associated with the p-string and the s-string. If we trim the trees in (15) in this way, the result is (16).

We now have a formalization of the interface between the syntax and

phonology macromodules which is consistent with modularity and domain specificity. Thus far, the chi- and e-structures presented have only contained information about constituent edges. However, this is not the only type of information which these two types of structure may contain; they may also contain information about semantics.

(16)

IP
I′
VP
V′
PP
NP   V′   NP
N′   N′
N   I   V   P   D   N
Anna was studying at the university

s-string   Anna   was   studying   at   the   university

$\begin{bmatrix} L & \{NP,IP\} \\ R & \{NP\} \end{bmatrix}$ $\begin{bmatrix} L & \{VP\} \end{bmatrix}$ $\begin{bmatrix} L & \{PP\} \end{bmatrix}$ $\begin{bmatrix} L & \{NP\} \end{bmatrix}$ $\begin{bmatrix} R & \{NP,PP,VP,IP\} \end{bmatrix}$

$\begin{bmatrix} R & \{PW,PhP\} \end{bmatrix}$ $\begin{bmatrix} L & \{PW,PhP\} \end{bmatrix}$ $\begin{bmatrix} L & \{PW,PhP\} \end{bmatrix}$

$\begin{bmatrix} L & \{PW,PhP,IntP\} \end{bmatrix}$ $\begin{bmatrix} R & \{PW,PhP\} \end{bmatrix}$ $\begin{bmatrix} R & \{PW,PhP,IntP\} \end{bmatrix}$

p-string   'æ nə wəz   'stʌ di ɪŋ ət ðə ju nə 'vɜː sə ti

'æ.nə.wəz   'stʌ.di.ɪŋ.ət.ðə.ju.nə   'vɜː.sə.ti

PW   PW   PW

PhP   PhP   PhP

IntP

Utt

6   The prosody-semantics interface

As stated in Section 1, according to standard assumptions, semantic structure is projected from f-structure in LFG, i.e. from the syntax. We retain this view of the architecture and do not propose a direct relationship between prosody and semantics, in contrast to, for example, Butt & King (1998). Instead, we propose to capture facts about the meaning contributions that prosody can make by requiring 'semantic harmony' to hold at the interface between syntax and prosody. Under this approach, information about a meaning constructor annotated on a c-structure node is also included in the chi-structure projected from the node in question, i.e. this information is associated with one or both edges of the relevant constituent and will thus be a member of the appropriate attribute-value set. At the interface, principles of semantic harmony require a meaning contribution that represents an attribute-value set member at e-structure to be a member of the corresponding chi-structure as well. Of course, this chi-structure information is associated with a unit of the p-string and certain dominating p-structure nodes. If a chi-

structure contains information about a meaning contribution, this must be reflected in the prosody of the relevant p-structure constituent. In this way, the meaning contribution of a prosodic configuration is related to the c-structure, from which f-structure and ultimately s-structure are projected. We exemplify this approach to the prosody-semantics interface by providing analyses of a declarative question in Section 6.1 and comma intonation in Section 6.2.

6.1 Declarative questions

In the case of a declarative question such as (17), it is the interrogative tune which the sentence bears that is crucial to its interpretation. For this interpretation to hold, since information about clause-type relates to the entire sentence and assuming that c-structure maps to f-structure which maps to s-structure, the c-structure root node (IP) must introduce the relevant meaning constructor [**PolarInt**], i.e. the semantics of a polar (yes/no) interrogative, defined as $\lambda P.Ques(P)$: $\downarrow_\sigma \multimap \downarrow_\sigma$. This interrogative meaning contribution is associated with the right edge of the root IP. Given the general form of the relevant c-structure rules and the relation they establish with the epsilon projection (see Appendix), this R(ight) edge attribute-value information is also included in the e-structures projected from certain nodes which dominate this final word, i.e. the nodes along the right edge of the c-structure tree.

(17) Anna was studying at the university?
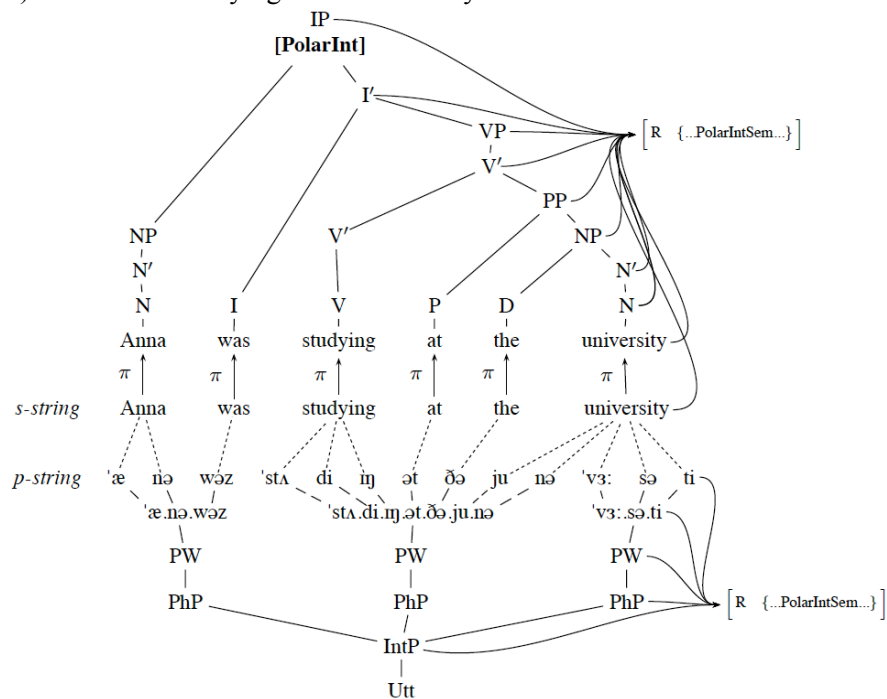
In formal terms, *PolarIntSem* is a member of the set that is the value of the attribute R(ight) in the appropriate e-structures. Thus, via e-structure, this information about interrogativity is passed along the c-structure tree's right

side and into the s-string, where it is part of the e-structure associated with the final syntactic unit in the s-string, namely *university*. At the interface between s-string and p-string, principles of semantic harmony require that, if *PolarIntSem* is part of the value of an e-structure, it must also be a value in the corresponding chi-structure. In (17), that chi-structure is associated with the final syllable */ti/* in the p-string (i.e. the final syllable of the final IntP). As with c-structure, the relevant rules (see Appendix) mean that R(ight) edge attribute-value information is also included in the chi-structures projected from nodes along the right edge of the p-structure tree which dominate this final word. Each chi-structure, up to and including the one associated with IntP in (17), contains the attribute-value pair *R { ... PolarIntSem ...}*. The IntP constituent must exhibit prosodic features consistent with this information about meaning, so this IntP is the domain for the interrogative tune and ends with a final rise in intonation. Under this approach, information about a meaning constructor introduced at c-structure is also included at the levels of e-structure and chi-structure, the latter being associated with p-structure and the p-string. The prosody-syntax interface is therefore integral to our proposal for modelling the interaction between prosody and semantics.

6.2   Comma intonation

Our analysis of the comma intonation associated with non-restrictive relative clauses also relies on chi-structure, e-structure and the information about meaning which they may both contain. Based on the insights of Potts (2005) and Arnold & Sadler (2010), we assume that the c-structure configuration which characterizes comma intonation introduces the meaning constructor [**Comma**] which is associated with *CommaSem*. As was the case with interrogativity and the declarative question in (17), information about this contribution to meaning is included in the e-structure projected from the relevant c-structure node, which in (18) is the CP. Specifically, *CommaSem* is a member of the set that is the value of the relevant CP's L and R attributes. This information is inherited by the smaller constituents which represent the edges of the CP, as shown in (18). Thus, in the s-string *who* is associated with an e-structure whose L attribute-value set contains a member *CommaSem*, and *CommaSem* is a member of the R attribute-value set in the e-structure associated with *met*.

At the interface between p-string and s-string, principles of semantic harmony require *CommaSem* to also be a member of the L attribute-value set in the chi-structure associated with the corresponding prosodic unit (established via the relation between s-form and p-form in the lexicon), i.e. */hu/*. Similarly, the chi-structure associated with */mɛt/* has a R attribute-value set member *CommaSem*. This information, associated with L and R attributes (left and right edges) at chi-structure, is also associated with all of the dominating prosodic constituents up to and including the middle IntP, a node whose chi-structure indicates that it represents both the left and right edges of the 'comma' configuration and which will exhibit the appropriate prosodic features (comma intonation).

As in the case of declarative questions, under this approach the semantic contribution made by comma intonation is analysed in terms of the prosody-

syntax and syntax-semantics interfaces, based on the proposal that semantic information contained in e-structures must also be part of the related chi-structures, and vice versa. In this way, p-string and s-string and p-structure and c-structure (and s-structure) are related to one another.

(18)   Anna, who Bill met, was yawning.
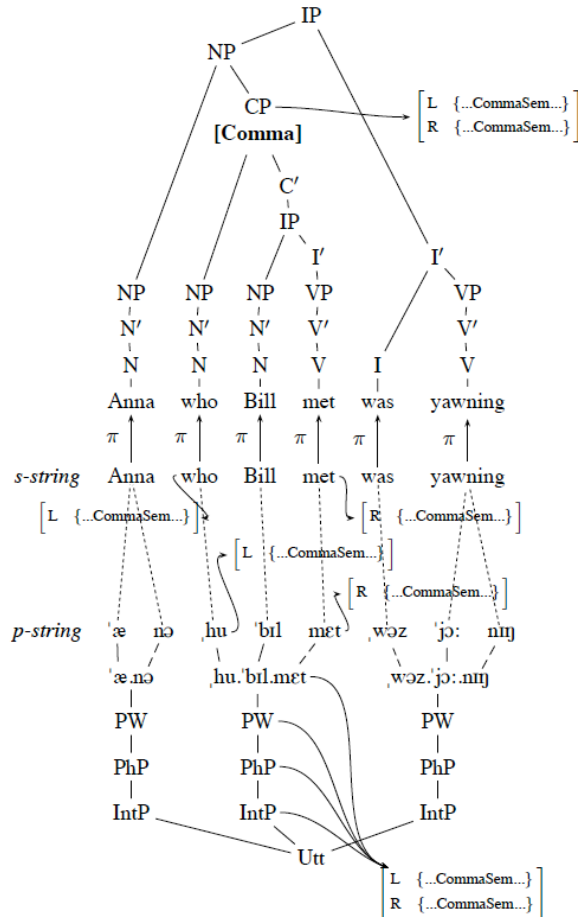
7   Comparison to other approaches

In recent work, Bögel et al. (2009, 2010) outline an approach to the prosody-syntax interface within the LFG framework which differs in significant respects from the one presented in this paper. Given that the two overlap with respect to some of the phenomena for which they seek to account, we offer a brief discussion of their key aspects for the purposes of comparison.

In common with the approach we have outlined in this paper, Bögel et al.'s (2009) work is in large part motivated by a desire to capture the extensive mismatches in syntactic and prosodic constituency highlighted by Lahiri & Plank (2010). Bögel et al. (2009) successfully account for many of these mismatches in their 'pipeline architecture' by inserting prosodic boundaries in the string, which is assumed to comprise syntactic units, i.e. c-

structure words. However, it is not clear how their analysis could be extended to cover violations of morphological word integrity, such as that found in example (9), in which a prosodic boundary appears in the middle of a c-structure word.

We believe that our approach is more consistent with LFG's co-description architecture than the pipeline approach of Bögel et al. because it respects strict modularity: primitives from the phonology are not introduced into the syntax, nor vice versa. Furthermore, we contend that this new approach can be used to analyse the same phenomena as the pipeline one. For example, Bögel et al. (2010) propose using prosodic inversion (Halpern 1995) to analyse clitic placement within the LFG framework. Distinguishing the s-string from the terminal nodes of the c-structure and relating them via the π projection function (Kaplan 1987, Asudeh 2006) allows for the possibility of units in the s-string to have a different linear order from the terminal nodes at c-structure. This may be relevant to an analysis of clitic placement which incorporates prosodic inversion (Halpern 1995; see Bögel et al. 2010 and Lowe 2011 for LFG), though under the approach outlined the inversion would take place in the syntax rather than the prosody. Limits of time and space mean that the treatment of clitics at the interface and a more detailed assessment of the relative merits of these approaches must await further research.

Finally, in addition to an approach to the prosody-syntax interface, this paper offers a theory of the prosody-semantics interface and therefore goes beyond the scope of Bögel et al.

It is hoped that the formal LFG approach to the interaction between prosody, syntax and semantics presented in this paper will provide a framework for further research that will in turn increase our understanding of interface phenomena.

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Appendix

Passing information about the edges of prosodic constituents within p-structure

Prosodic-structure rules with chi-structure annotations about prosodic edges:

$$(19) \quad \text{IntP} \quad \rightarrow \quad [\quad \text{PhP} \qquad \text{PhP*}]$$
$$\text{IntP} = (\downarrow_\chi \text{L})$$
$$\& \quad [\text{PhP*} \qquad \text{PhP} \qquad]$$
$$\text{IntP} \in (\downarrow_\chi \text{R})$$

$$(20) \quad \text{PhP} \quad \rightarrow \quad [\quad \text{PW} \qquad \text{PW*}]$$
$$(\uparrow_\chi \text{L}) \sqsubseteq (\downarrow_\chi \text{L})$$
$$\text{PhP} \in (\downarrow_\chi \text{L})$$
$$\& \quad [\text{PW*} \qquad \text{PW} \qquad]$$
$$(\uparrow_\chi \text{R}) \sqsubseteq (\downarrow_\chi \text{R})$$
$$\text{PhP} \in (\downarrow_\chi \text{R})$$

$$(21) \quad \text{PW} \quad \rightarrow \quad \text{Syll}^+$$
$$\uparrow_\chi \sqsubseteq \downarrow_\chi$$
$$\text{PW} \in (\downarrow_\chi \text{L})$$
$$\text{PW} \in (\downarrow_\chi \text{L})$$

These specifications hold of all prosodic-structure rules.

Passing information about the edges of syntactic constituents within c-structure
All XP-level rules are of the following form:

(22)   XP   →   [Σ   Σ*]
                            ($\uparrow_\varepsilon$ L) ⊑ ($\downarrow_\varepsilon$ L)
                              XP ∈ ($\downarrow_\varepsilon$ L)
                    &   [Σ*   Σ   ]
                                          ($\uparrow_\varepsilon$ R) ⊑ ($\downarrow_\varepsilon$ R)
                                            XP ∈ ($\downarrow_\varepsilon$ R)

All other rules simply pass information:

(23)   Cat   →   [Σ   Σ*]
                            ($\uparrow_\varepsilon$ L) ⊑ ($\downarrow_\varepsilon$ L)
                    &   [Σ*   Σ   ]
                                          ($\uparrow_\varepsilon$ R) ⊑ ($\downarrow_\varepsilon$ R)

Prosodic tune specification
General form of prosodic-structure rules specifying intonational tunes:

(24)   IntP   →   [PhP   PhP*]
                            (↑ LBOUNDARY) = (↓ LBOUNDARY)
                    &   [PhP*   PhP   PhP*]
                                        (↑ NUCLEAR) = (↓ NUCLEAR)
                    &   [PhP*   PhP   ]
                                    (↑ RBOUNDARY) = (↓ RBOUNDARY)

Introducing the interrogative tune at the IntP level.

(25)   IntP   →   PhP*   PhP
                                    (↓ NUCLEAR) = L
                                    (↓ RBOUNDARY) = H
                                    PolarIntSem ∈ ($\downarrow_\chi$ R)

(26)   PhP   →   [PW   PW*]
                            (↑ LBOUNDARY) = (↓ LBOUNDARY)
                                (↑ NUCLEAR) = (↓ NUCLEAR)
                    &   [PW*   PW   ]
                                    (↑ RBOUNDARY) = (↓ RBOUNDARY)

(27)   PW   →   [Syll   Syll*]
                            (↑ LBOUNDARY) = (↓ LBOUNDARY)
                    &   [Syll *   Syll   ]
                                    (↑ RBOUNDARY) = (↓ RBOUNDARY)
                    &   [Syll*   Syll   Syll *]
                                        (↑ NUCLEAR) ⇒
                                    (↓ SYLLSTRESS) = $_c$ PRIMARY
                                     (↑ NUCLEAR) = (↓ NUCLEAR)