

# Interfacing Phonology with LFG

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## Proceedings of the LFG98 Conference

The University of Queensland, Brisbane

Miriam Butt and Tracy Holloway King (Editors)

1998

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## 1 Introduction

Phonological information, especially prosodic (both phrasal and intonational) information, is an essential ingredient in accounting for the well-formedness of sentences (Zec and Inkelas 1990).<sup>\*</sup> That is, phonology interacts with and hence constrains the possible analyses of a sentence. A simple example of this is seen in spoken English questions, such as *You ate the entire cake?*, in which the intonation is the only overt mark of interrogativity. Another example is presented by Bengali V-V constructions which are potentially ambiguous between a complex predicate and a sequential (adverbial) reading, but which can be clearly disambiguated by taking their phonological properties into account. This interaction between phonology and other aspects of the grammar, including syntax, information structure, and semantics, has also clearly been attested in the analysis of clitic placement (e.g., Halpern 1992) and will be explored here with regard to complex predicates and focus in Bengali.

Although most syntactically oriented frameworks acknowledge the importance of phonological information, there has been little attempt with regard to a formal integration (with the notable exception of Steedman 1997).<sup>(Fn1)</sup> In this paper, we argue that the projection architecture of LFG provides an ideal platform for integrating phonological information into theoretical analyses, and present a concrete proposal for such an integration, concentrating on Bengali.

## 2 The Phonology-Syntax Interface

In order to integrate phonological representations into LFG, we posit a p(honological)-structure which feeds into a further phonological component in the same way that s(ematic)-structure feeds into a more elaborate semantics; that is, p-structure is the interface with those postlexical phonological processes that cannot be encoded in parallel with the syntactic analysis. Or, to put it differently, we encode that part of phonological information at p-structure that the syntax can know about and can therefore contribute to the full analysis of a clause.

This approach is in line with current prosodic conceptions of the phonology-syntax interface as we understand them. In particular, the architecture allows a transparent connection of the syntactic properties of differing N-V and V-V constructions in Bengali with their phonological properties as argued for by Hayes and Lahiri (1991), Fitzpatrick-Cole (1996), and Lahiri and Fitzpatrick-Cole (1997). We argue for a syntactic and semantic analysis of the N-V and V-V constructions which differs slightly from those assumed in the phonological approaches and then formulate a proposal which allows the integration of the prosodic properties with our syntactic analyses. Pushing the architecture of the grammar still further, we also take previous work of our own (Butt and King 1996, 1997) on the discourse structure of Urdu/Hindi and demonstrate how this level of analysis interacts with both the prosodic and the syntactic information present in a clause.

## 2.1 Prosodic Structure

Since the primary information encoded in our p-structure is prosodic, we introduce some basic information about prosodic theory here.

Of primary import is the *Prosodic Hierarchy* (Selkirk 1984). The prosodic hierarchy contains the types of prosodic units into which an utterance is divided. A given category non-recursively immediately dominates a series of categories of the next lower category: this is referred to as the *strict layering hypothesis*. Here we assume, but do not argue for, the strict layering hypothesis and our analysis of Bengali does not crucially depend on it. (Fn2)

### Elements of the Prosodic Hierarchy

1. Intonational Phrase
2. Phonological Phrase
3. Prosodic Word
4. Foot
5. Syllable
6. Mora

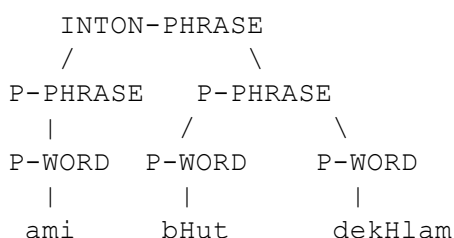
In this paper, we are primarily concerned with intonational phrases, phonological phrases, and prosodic words since these interact most clearly with the syntax. (Feet, syllables, and mora are generally used to govern wellformedness within words.)

An example of how a sentence is parsed by the Prosodic Hierarchy is seen in (1) (Fn3). We have represented the parse as a tree structure for ease of exposition. However, in the actual implementation the same information is encoded by means of an attribute-value matrix.

(1) ami bHut dekH-l-am

I ghost see-Past-1Sg

'I was startled.'



In the above example, 'ghost-see' is interpreted idiomatically and the object plus verb are phrased together as a single p-phrase. The string in (1) is in fact potentially ambiguous in that the speaker could also be referring to an "actual" ghost. Under this reading, however, the object and verb form separate p-phrases, as discussed in section 4.

## 2.2 Mapping from Syntax to Phonology

Theories of the phonology-syntax interface vary on a number of issues including: whether or not the phonology has direct access to the syntax and vice versa; how the mapping, whether direct or indirect, is encoded; what types of information in one are relevant and/or accessible to the other (see Zec and Inkelas 1990 for a more detailed discussion from a variety of perspectives). Here we propose a mutually constraining model, which is in accordance with both the general principles of LFG and the view of the syntax-phonology interface presented by Zec and Inkelas (1995). That is, there are principles governing not only the wellformedness of the syntax and of the phonology, but also of the possible mappings between them. As such, a p-structure, f-structure, and c-structure may all be well-formed independently but not be a possible representation of any given sentence.

Proposals which have provided detailed algorithms with regard to a phonology-syntax mapping such as Selkirk (1986), Nespor and Vogel (1986), and Hayes and Lahiri (1991) essentially fall into two basic schools of thought. Selkirk (1986) puts forth the requirement that a unit of phonological structure will have as its terminal string the stretch of the surface syntactic structure that is demarcated by the right or left ends of selected syntactic constituents. Wrap operations such as those proposed by Truckenbrodt (1997) serve to augment such alignment constraints by allowing reference to the span of the constituent. Another school of thought places greater importance on the detailed structure of the syntactic tree with regard to notions such as head-complementizer relations and maximal projection (Nespor and Vogel 1986), as well as c-command. In this paper, we propose to follow this second school of thought, illustrated in (2) by the algorithm proposed by Hayes and Lahiri (1991:92).

(2)

### (a) *Default P-phrasing*

1. Every phonological word may be a P-phrase.
2. For consecutive constituents X, Y: if
  - i. X forms a legal P-phrase
  - ii. Y is a head c-commanding X.
  - iii.  $Y \not\sim V$  (Y does not equal V)then [XY] may form a P-phrase.

### (b) *P-phrase Restructuring*

Where X and Y are consecutive permissible P-phrases, [X,Y] may form a P-phrase, provided the following conditions are met:

1. X c-commands Y
2. One of the following:
  - i. Rapid speaking rate.
  - ii. X or Y is a non-initial constituent constituting old information in the discourse.

The basic idea behind this algorithm is to form phonological phrases out of prosodic words. The default rule forms a phonological phrase out of the prosodic word of the head of a constituent which it c-commands together with the prosodic words that it c-commands, i.e., a syntactic constituent generally forms a phonological phrase. However, verbs behave differently in that they do not form phonological phrases with the elements in the VP (there is very clear evidence for this with respect to Bengali). Note that although we follow this basic algorithm, our LFG analysis does not have to refer to c-command. Rather, the information as to prosodic phrasing is encoded directly in parallel with the generalizations as to syntactic phrasing, i.e., as a projection off of syntactic constituents. This approach is in fact very close to proposals within Optimality Theory by Truckenbrodt (1997) that syntactic and prosodic phrases be related to one another via constraints on correspondence.

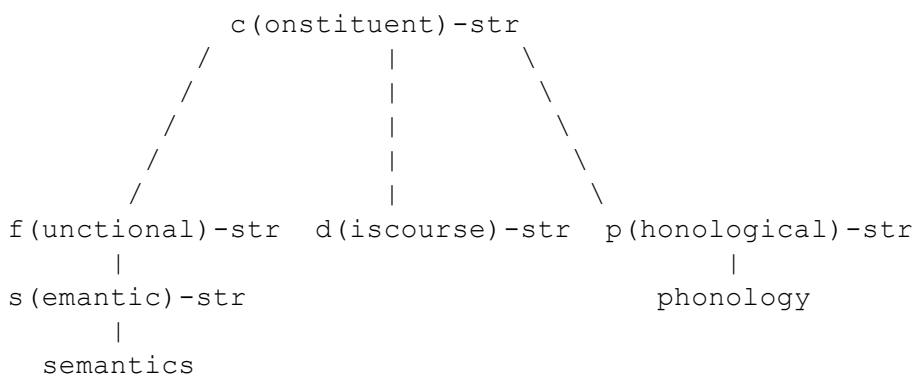
We also assume that headedness is important in the formation of phonological phrases. However, as will be seen below, we argue that this is based on the constituent-structure of the phrase and that by properly annotating the c-structure rules, the overt mention of c-command and headedness can be avoided and instead can be encoded directly as part of the grammar.

The restructuring portion of the algorithm in (2) is concerned with situations in which the default algorithm does not apply, yet two prosodic words are combined into a single phonological phrase. In particular, this can occur in certain environments during rapid speech and when old information is involved (as opposed to focused, new information). As shown below, LFG provides an easy way in which to incorporate information about discourse functions into wellformedness constraints on the phonological structure.

### 3 Integration into a Projection Architecture

Selkirk 1986, Hayes 1990 and others have argued that the only influence of syntax on phonology is in determining the prosodic structure of the string and that syntax has no other direct effect on phonology. We propose that the spirit of this generalization can indeed be captured if p-structure is a mapping off the c-structure. In particular, the independence of c-structure from f-structure in LFG provides an ideal division as to which information can be used in projecting the p-structure: c-structure contains exactly the information about syntactic constituency needed for determining prosodic phrasing, but does not contain information irrelevant to the determination of prosodic phrasing, such as information about subjects, objects, or agreement. The architecture of grammar relevant for this paper is shown in (3)

(3)



In this architecture, f-structure is projected from the c-structure, as usual (and the semantics are projected from the f-structure). In addition, p-structure and d-structure are also simultaneously projected from the c-structure. As discussed in section 4 with regard to Bengali focus clitics, we assume that d-structure contains

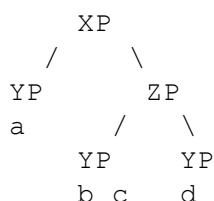
information about discourse functions such as TOPIC, FOCUS, etc.

### 3.1 The Issue of Mismatches

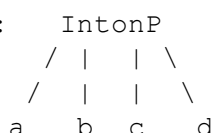
Theoretically mismatches of three basic types can occur between the syntax and the p-structure: flattening of structure; heightening of structure; regrouping. The first two are easy to account for within the traditional LFG projection architecture, while the third, regrouping, is more difficult (and, fortuitously, less common). Abstractly, the three situations are shown in (4) as tree structures, in which the p-structures contain intonational and phonological phrases, as well as prosodic words.

#### (4) C-structure to P-structure Mismatches

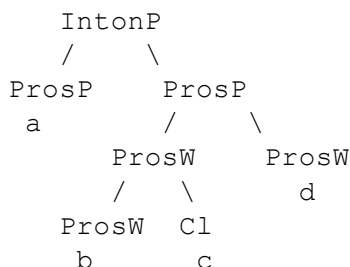
c-structure



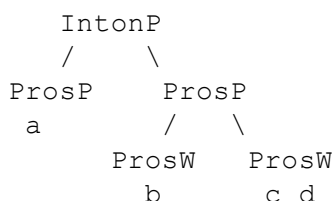
flattening:



heightening:



regrouping:



The formal properties of LFG allowing for a many-to-one relationship between f-structure and c-structure (and vice versa) already provide what is needed to express the effects of heightening and flattening. The functional annotation " $\wedge$ ="!" serves to flatten structures, while annotations such as " $\wedge$  X)!=" or " $! \$ (\wedge X)$ " cause heightening (" $\wedge$ " stands for up arrow, " $!$ " for down arrow, " $\$$ " for element of). Using the regular notation by which "\*" is the node in question and "M" its mother, and "x:." indicates the name of the projection, we can construct the flattening and heightening cases above with the rules in (5) where IntonP is assumed to be the

top level of the p-structure.

## (5) Mismatch Grammars

Flattening:

```
XP -->          YP          ZP
          p::* $ p::M*    p::* = p::M*

ZP -->          YP          YP
          p::* $ p::M*    p::* $ p::M*

YP --> {
          a
          p::* = p::M*

          b          c
          p::* = p::M*  p::* = p::M*

          d
          p::* = p::M*
        }
```

Heightening:

```
XP -->          YP          ZP
          p::* $ (p::M* ProsP)  p::* $ (p::M* ProsP)

ZP -->          YP          YP
          p::* $ (p::M* ProsW)  p::* $ (p::M* ProsW)

YP --> {
          a
          p::* = p::M*

          b          c
          p::* $ (p::M* ProsW)  p::* = (p::M* CL)

          d
          p::* = p::M*
        }
```

YP may be expanded to either a, b, c, or d, allowing for the c-structure in (4). In the flattening case, however, all of the phonological information contained under a, b, c, and d is put into a set at the top level: the information embedded under ZP is simply passed up by the equivalent of an " $\wedge$ =" annotation. In the heightening case, on the other hand, the annotation on ZP (for example) introduces a prosodic phrase and creates an extra level of embedding.

The truly difficult mismatch is posed by regroupings which cannot be captured in the projection from c-structure to p-structure, as is the case with some clitic phenomena (Halpern 1992). We argue that such regroupings are resolved in the relationship between p-structure and the phonology, in a fashion similar to the remappings that occur with quantifiers between s-structure and the semantics (Dalrymple, Lamping, Pereira, and Saraswat 1997).

Another possible approach to modeling the mismatches across prosodic and syntactic structures is to simply

assume that there is in fact no such mismatch. This is essentially the direction taken by Steedman (1997) within a Categorical Grammar (CG) approach. Building on earlier arguments that traditional notions of surface constituency are suspect, Steedman presents a CG approach in which functions defining the combinatorial possibilities of syntactic categories work together with intonational information to derive a surface string. He argues that under this approach a separate representation for intonational and prosodic structure is not necessary, and that information structure can furthermore be then associated with that one all-encapsulating analysis in a transparent way. His approach shares with ours the idea that information structure and intonational, syntactic and semantic information should be part of one analysis and should therefore work together to produce or analyse a given surface string.

We differ strongly in that we not only believe in the necessity of a separate representation for prosodic information, but also in the factoring out of information structure. As we hope to show below in the discussion of Bengali N-V constructions, while the phonological analysis may treat a collection of N-V constructions uniformly, they must be clearly differentiated on a syntactic and semantic basis. Furthermore, while intonation sometimes lines up with discourse functions such as topic and focus, the correspondence is imperfect. This is particularly clear in Bengali, where a given sentence need not have a phonological focus, but could have an information structural focus in the sense that the sentence contains new information.

## 3.2 Phonological-Structure

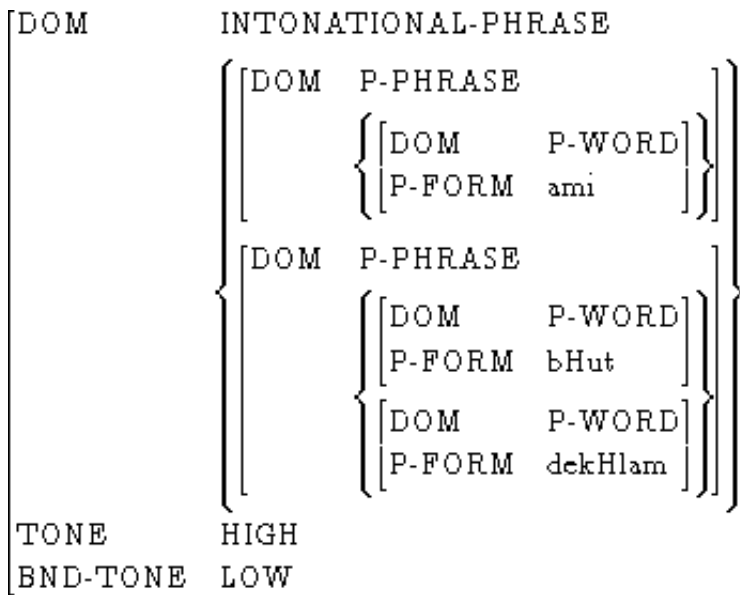
Having considered how to handle possible mismatches between c-structure and p-structure, we now go on to present a possible way of encoding phonological information within the p-projection. As noted above, prosodic phrasing is generally presented in the form of a tree. However, there is no reason as far as we can see why the same information could not also be presented in the form of an attribute-value matrix (given that any tree can be mapped into an attribute-value matrix). We therefore propose that p-structure is an attribute-value matrix which contains attributes such as P(honological)-FORM, DOMAIN (prosodic), TONE, etc. The attributes which we consider are mainly prosodic in nature, i.e., they relate to prosodic structure and tone assignment. However, it is possible to include other information, such as non-predictable word stress, which needs to be listed in the lexical entry of a given lexical item. We do not include phonological default information that is unrelated to other parts of the grammar. For example, in languages with fixed stress patterns stress need not be included. In the Bengali case discussed above, the alignment of the boundary tones need not be included because they are always attached to the right edge of their intonational or prosodic phrase and as such all the p-structure needs to contain is the information as to which phrase they belong to. Similarly, pitch accents by default appear on the first syllable of every prosodic word because stress is invariable word initial. This type of phonological information, which needs to be able to scan the entire syntactic and prosodic analysis, must be handled in the actual phonology and is not included in the p-structure. The relationship between p-structure and the phonological module of grammar must in fact also be seen as one of mutual constraint: the p-structure encodes those pieces of information that the syntax of a language knows about. These pieces of information must be consonant with an independent phonological analysis for the entire analysis to go through.

An example of an attribute-value matrix (AVM) representation of the p-structure is shown in (7). This is the same example which was used to demonstrate phrasing via the Prosodic Hierarchy as a tree structure in (1). The AVM in (7) encodes all the information in the tree structure plus additional information known about the phonology, in this case information about the tones associated with the sentence. The analysis assumed here is that of Hayes and Lahiri (1991:90). The reading is that of a neutral (no phonological focus) declarative, which is characterized by a high tone on the first p-word of the rightmost p-phrase, followed by a low boundary tone. In (7), we have represented the high tone at the top level, leaving the association of the tone with the left p-word in the rightmost p-phrase to the phonological component the p-structure feeds into.

(6) ami bHut dekH-l-am

I ghost see-Past-1Sg

'I was startled.'



Having mastered the basic ingredients for an analysis integrating both syntactic and phonological properties of a given sentence, we can now proceed to take a more detailed look at Bengali N-V constructions in the next section.

One further issue arises with respect to the linear order of the phonological string. If the p-structure is to be of any use to subsequent phonological and phonetic "processes", a preservation of the order of the string is necessary. As the contents of an AVM are not ordered, this could pose a potential problem. However, if one considers the attributes contained within p-structure as being subject to *projection precedence*, the problem disappears: the attributes are guaranteed to be ordered similarly to the string (Zaenen and Kaplan 1995) and this ordering information can be used in the matching of the p-structure to the phonology.

## 4 Bengali

As already mentioned, Bengali N-V and V-V sequences as in (8) and (9) are potentially ambiguous. For the V-V sequences these ambiguities arise when the verbal morphology would allow a complex predicate reading as in (9a): the first verb in the sequence carries "perfect" inflection and the second verb in the sequence carries tense and agreement. For the N-V sequences the possibility for ambiguity arises when the N is a bare noun in the sense that it is not overtly marked for case or by classifiers and other items that would have the effect of a determiner/specifier.

(8) ami bHut dekH-l-am

I ghost see-Past-1Sg

a. 'I was startled.'

b. 'I saw a ghost.'

(9) tara kagoj-gulo dekH-e pHel-e-cHe

Tara paper.Nom-Class see-Perf throw-Perf-3Sg

a. 'Tara saw the papers (completely).'



b. 'Tara threw away the papers, having looked at them.'

In both cases the phonological properties of the string provide the necessary information for disambiguation: when the N-V or the V-V phrase together, the reading is that of the idiomatic ((8a)) or complex predicate ((9a)) construction; when the finite verb phrases separately, the b readings emerge. In addition, when focus clitics such as *o* 'also' are attached to either the N in (8) or the first verb in (9), the two readings behave differently with respect to the scope of focus: the b readings essentially exhibit constituent focus in that the object in (8) and the embedded verb in (9) are focused. In the a readings on the other hand, the entire predicate must be seen as focused, i.e., the idiomatic 'ghost-see' in (8a) and the complex predicate in (9a).

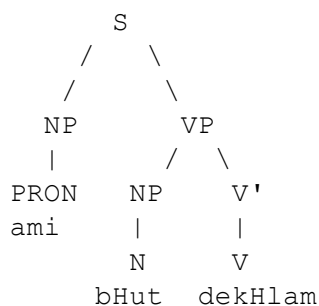
In the following we first discuss the level of granularity that prosodic phrasing appears to be sensitive to with regard to syntactic analyses, then go on to consider how the intonational cues provided either by focus clitics or differing tonal patterns can be encoded at p-structure so as to interact both with syntactic and discourse structural analyses resulting in an (almost) complete analysis of a given clause within LFG's projection architecture.

## 4.1 Granularity of C-Structure

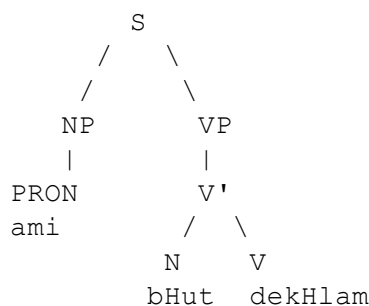
Based on the fact that the idiomatic reading of (8) can only arise when the N and V are adjacent (no scrambling), but that the N and V have not as yet been lexicalized, as is evident from the ability to insert focus clitics between the N and the V, we propose the following c-structure analyses for the basic transitive reading in (8b) and the idiomatic reading in (8a) respectively. In both analyses, S branches into a subject NP and a VP. However, in the basic transitive, the VP has an NP and V' daughter (V' in Bengali is the domain of complex predicate formation). In the idiomatic reading, the VP expands to a V' which in turn contains a bare N and a V. Note that we assume a VP for Bengali for now.

(10) C-structure

Basic Transitive



Idiomatic Reading



Recall that part of Steedman's (1997) proposal for the phonology-syntax interface contained the idea that a separate level of phonological information was not necessary, as the prosodic phrasing could be considered isomorphic with the syntactic representation. Given just the two examples in (10), it might seem that Steedman's proposal could also indeed extend into Bengali. In particular, note that in Bengali the main predicate of the clause (plus whatever auxiliaries might be contained in the verbal complex) always phrases separately. This fact can easily be read off the c-structures above as we take the V' to contain the main predicate of the clause. However, there are actually a number of N-V constructions which have been found to have the same phonological properties as the idiomatic 'ghost-see', but which must be acknowledged to be different creatures syntactically and semantically. N-V complex predicates like *ranna kora* 'cook do', for instance, line up with idiomatic N-V constructions phonologically (see Lahiri and Fitzpatrick-Cole 1997), but should presumably receive a different syntactic and semantic analysis (cf. Mohanan (1994) for Hindi N-V

complex predicates).

It would thus appear (pending further detailed investigation, of course), that prosodic phrasing is actually sensitive to a very rough granularity at c-structure in the sense that major constituents and rough groupings matter. The finer distinctions between idiomatic expressions and complex predicates that must also be represented at a syntactic level of analysis do not matter. Since LFG encodes grammatical function status and complex predication in the relationship between argument structure and f-structure, c-structure would then appear to be the ideal level from which to project p-structure.

## 4.2 P-Structure

As already discussed briefly, the p-structure is structured by DOMAINs which correspond to the prosodic hierarchy (intonational-phrase, phonological-phrase, prosodic-word). Roughly, clauses form intonational-phrases. Noun phrases form their own phonological-phrase, as do most types of complex predicate, and main verbs always phrase separately (i.e., they do not form a phonological phrase with the object or subject in basic, non-idiomatic types of predication).

In addition to the above generalizations for prosodic phrasing, the presence of focus also affects the p-structure and can play a role in determining phrasing possibilities (see Hayes and Lahiri 1991, Lahiri and Fitzpatrick-Cole 1997). Focused phrases in Bengali are marked by a low tone on the p-phrase containing the focused word and a high tone demarcating the right edge of the p-phrase. If there is no contrastively or emphatically focused element, then neutral declaratives receive a high tone on the first p-word of the rightmost p-phrase (usually the verb). In general, different types of statements have different boundary tones; in this paper we only consider declaratives, which are marked by a low boundary tone on the intonational-phrase.

One important point to make is that intonational data on Bengali show very clearly that clauses do not always contain a phonological focus. Clauses which do not contain a phonologically marked focus are given the label *neutral focus* in Hayes and Lahiri (1991). Here, we designate these types of clauses as having a *neutral focus*, indicating that other factors such as position and word order can then determine which items are in focus from a discourse structural point of view. That is, we differentiate between phonological focus and discourse structure focus. In our view, phonological focus is just one of several factors determining the discourse structure of a sentence. Our take on the discourse structure of a clause is summarized briefly in the next section, after a presentation of some of the basic types of p-structure associated with our 'ghost-see' example.

Consider first the basic transitive construction with neutral focus. This will have the p-structure in (11). Again, the high TONE in combination with the low BOUNDARY-TONE reflects neutral focus, but the high TONE must in fact be associated with the first p-word of the rightmost p-phrase (in this case the verb). Since this association can only be done once the prosodic phrasing (and therefore also the syntactic analysis) has taken place, we leave this default association to the phonological component.

(11) P-structure (basic transitive; neutral focus)

DOM	INTONATIONAL-PHRASE
	$\left[ \begin{array}{l} \left[ \text{DOM P-PHRASE} \right. \\ \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{P-FORM ami} \end{array} \right] \right\} \right. \\ \left. \left[ \text{DOM P-PHRASE} \right. \right. \\ \left. \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{P-FORM bHut} \end{array} \right] \right\} \right. \right. \\ \left. \left. \left[ \text{DOM P-PHRASE} \right. \right. \\ \left. \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{P-FORM dekHlam} \end{array} \right] \right\} \right. \right. \end{array} \right]$
TONE	HIGH
BND-TONE	LOW

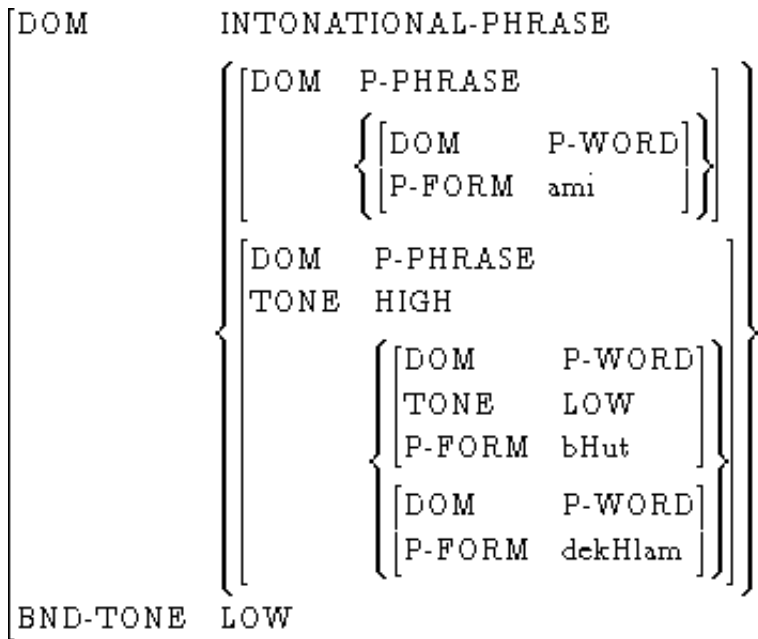
Next consider the minimally different basic transitive construction with contrastive focus on the object *bHut*. In this case, the p-structure is as in (12), where the p-word corresponding to *bHut* is marked by a low tone and the p-phrase containing this focused element has a high tone. Since the sentence is still a declarative, there is a low boundary tone.

(12) P-structure (basic transitive; contrastive focus)

DOM	INTONATIONAL-PHRASE
	$\left[ \begin{array}{l} \left[ \text{DOM P-PHRASE} \right. \\ \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{P-FORM ami} \end{array} \right] \right\} \right. \\ \left. \left[ \begin{array}{l} \text{DOM P-PHRASE} \\ \text{TONE HIGH} \end{array} \right. \right. \\ \left. \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{TONE LOW} \\ \text{P-FORM bHut} \end{array} \right] \right\} \right. \right. \\ \left. \left[ \text{DOM P-PHRASE} \right. \right. \\ \left. \left. \left\{ \left[ \begin{array}{l} \text{DOM P-WORD} \\ \text{P-FORM dekHlam} \end{array} \right] \right\} \right. \right. \end{array} \right]$
BND-TONE	LOW

Now for the idiomatic reading. Since the p-structure representation for neutral focus was already shown in (7), we do not repeat it here, but instead show what happens when *bHut* is focused in the idiomatic reading. Rather than achieving constituent focus, as was the case in (12) above, focusing *bHut* under this reading results in the entire predicate being focused: the noun *bHut* is marked with a low tone and the p-phrase containing it ('ghost-see' in this case) is marked with a high tone at its right edge (this alignment is again left to a subsequent phonological component).

(13) P-structure (idiom; contrastive focus)



### 4.3 D-Structure

Given that p-structure encodes intonational information about focus, we here briefly introduce our views on discourse structure (for more information on discourse functions in LFG see King 1995, 1997, and Choi 1996). Basically, we assume a four way division of the sentence into discourse functions (based on Vallduvi 1992 and Choi 1996; see Butt and King 1997, 1998 for our specific interpretation). This division is shown in (14).

- (14) [+New] = FOCUS [+Prom]  
 COMPLETIVE INFORMATION [-Prom]  
 [-New] = TOPIC [+Prom]  
 BACKGROUND INFORMATION [-Prom]

Focus is prominent new information; its primary function is to fill the informational gap between the speaker and the hearer; we further distinguish between neutral new information focus and contrastive focus. Completive information is also new information but it is not of primary importance to the information structure of the discourse at hand. (Fn4) Topic and background information are both old information. The topic is prominent old information providing the hearer with the information as to what the focus pertains to, while the background information merely further specifies how the new information fits in with that which is already known. In Urdu, for example, these four types of discourse functions are distinguished positionally: topic is either dropped or occurs in first position; focus is immediately preverbal; completive information encompasses all of the information that occurs preverbally, but that is not topic or focus; background occurs postverbally.

This discourse function information is encoded in LFG by a projection off of the c-structure referred to as the d(iscourse)-structure or i(nformation)-structure. In different languages, different c-structure positions are associated with different discourse functions. For example, topics may be in SpecIP (Russian, for example), while foci may be in SpecVP (Hungarian, for example). Given LFG's projection architecture, in which both d-structure and p-structure are projected from the c-structure, it is a simple matter to integrate c-structural information pertaining to discourse functions with the phonological information encoded at p-structure. A concrete analysis for a Bengali clause which also contains a focus clitic is shown in the next section.

## 4.4 Focus Clitics and Discourse-Structure

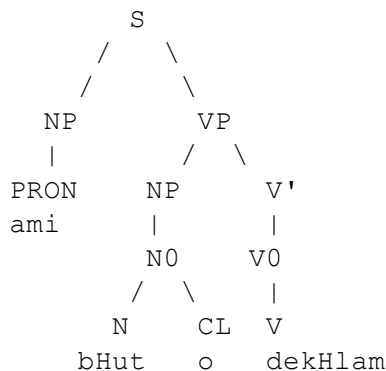
Bengali has a focus clitic *o* which attaches to prosodic-words and results in that word being obligatorily focused and receiving focus intonation. An example is shown in (15), which is minimally different from the example seen in the previous section.

- (15) ami bHut o dekH-l-am  
 I ghost Foc-Cl see-Past-1Sg  
 a. 'I also saw a GHOST.'  
 b. 'I was also STARTLED.'

Lahiri and Fitzpatrick-Cole (1997) argue that focus clitics in Bengali lexically introduce a high tone, thus directly providing a part of the focus tune. Within an LFG approach, this tonal contribution of the clitic can be modeled by projecting the tonal information to p-structure as part of the lexical entry. The resulting c-structure, f-structure, d-structure, and p-structure representations for (15a) are shown in (16). For lack of space, we do not present the analysis of (15b), but it should by now follow fairly straightforwardly for the reader.

(16)

c-structure



f-structure

PRED	'dekHlam<SUBJ,OBJ>'
TNS-ASP	[TENSE PAST]
FIN	+
PASSIVE	-
STMT-TYPE	DECLARATIVE
VTYPE	MAIN
SUBJ	[PRED 'pro']
	[CASE NOM]
	[PERS 1]
	[NUM SG]
OBJ	[PRED 'bHut']
	[CLITIC-FORM o]
	[SPECIFIC +]
	[PERS 3]
	[NUM SG]

p-structure

DOM	INTONATIONAL-PHRASE												
BND-TONE	<table border="1"> <tr> <td>DOM</td> <td>P-PHRASE</td> </tr> <tr> <td></td> <td>{ [DOM P-WORD]</td> </tr> <tr> <td></td> <td>{ [P-FORM ami]</td> </tr> </table>	DOM	P-PHRASE		{ [DOM P-WORD]		{ [P-FORM ami]						
	DOM	P-PHRASE											
		{ [DOM P-WORD]											
	{ [P-FORM ami]												
	<table border="1"> <tr> <td>DOM</td> <td>P-PHRASE</td> </tr> <tr> <td>TONE</td> <td>HIGH</td> </tr> <tr> <td></td> <td>{ [DOM P-WORD]</td> </tr> <tr> <td></td> <td>{ [TONE LOW]</td> </tr> <tr> <td></td> <td>{ [LEX-TONE HIGH]</td> </tr> <tr> <td></td> <td>{ [P-FORM bHut]</td> </tr> </table>	DOM	P-PHRASE	TONE	HIGH		{ [DOM P-WORD]		{ [TONE LOW]		{ [LEX-TONE HIGH]		{ [P-FORM bHut]
DOM	P-PHRASE												
TONE	HIGH												
	{ [DOM P-WORD]												
	{ [TONE LOW]												
	{ [LEX-TONE HIGH]												
	{ [P-FORM bHut]												
	<table border="1"> <tr> <td>DOM</td> <td>P-PHRASE</td> </tr> <tr> <td></td> <td>{ [DOM P-WORD]</td> </tr> <tr> <td></td> <td>{ [P-FORM dekHlam]</td> </tr> </table>	DOM	P-PHRASE		{ [DOM P-WORD]		{ [P-FORM dekHlam]						
DOM	P-PHRASE												
	{ [DOM P-WORD]												
	{ [P-FORM dekHlam]												
BND-TONE	LOW												

d-structure

FOCUS	[FOCUS-TYPE EMPHATIC]
	[D-PRED bHut]
TOPIC	{ [TOPIC-TYPE DEFAULT]
	{ [D-PRED pro]

The c-structure is as already discussed, the f-structure simply encodes the fact that there is a subject and an object that the predicate 'see' subcategorizes for. In addition, the clause is recognized as declarative. This information at the syntactic level must be consonant with intonational information encoded at p-structure,

otherwise the analysis will fail. The p-structure this time contains a high tone, encoded as LEX-TONE, which has been contributed lexically by the focus clitic *o* 'also'. Focus clitics are taken to attach to p-words and to be integrated into that p-word (Lahiri and Fitzpatrick-Cole 1997), as such the clitic itself is not registered at p-structure, only its effect in terms of the high tone. At f-structure the clitic itself is not encoded, but its presence is registered, on a par with functional words like determiners, etc.

In Lahiri and Fitzpatrick-Cole's (1997) analysis, the focus clitics are treated as selecting for a focused constituent. That is, they do not do all of the focusing work by themselves, but attach to a constituent that is already marked with a high tone as focus. This phrasal high tone (which is part of the L-H pattern) is deleted in the phonological component. In our approach, we have modeled both the phrasal and the lexical high tones in the p-structure as input for the phonological component.

The d-structure, finally, analyzes the pronominal as TOPIC based on its syntactic position. The topic type is given as default, indicating that we have assumed clause initial position to be the default topic position: we actually do not have evidence either for or against this in Bengali: for the purposes of this paper we have simply assumed the analysis we proposed for Urdu (Butt and King 1997). The identification of focus, on the other hand, is not based on positional information, as it was with the topic, but is gleaned from the intonational information encoded at p-structure. The focus type is given as emphatic in order to distinguish it from contrastive and neutral focus.

## 5 Conclusion

This paper can basically be seen as experimenting with LFG's projection architecture in order to test the viability of integrating phonological information with syntactic (and semantic) analyses. That is, this paper has taken an initial step towards exploring the phonology-syntax interface from an LFG point of view. One immediate advantage of integrating phonological information in terms of a projection from c-structure is that it can then serve to constrain syntactic analyses. Thus, the architecture allows a bidirectional influence: syntax constrains phonology and vice versa (Zec and Inkelas 1990, 1995). A further advantage of the architecture explored in this paper is that it allows for a treatment of discourse structure in which both phonological and syntactic clues can be combined to arrive at the discourse structural analysis of a clause.

### Endnotes

- The paper owes thanks to the audience of LFG98, to Mary Dalrymple, Jennifer Fitzpatrick-Cole, Ron Kaplan, Astrid Krähenmann, Aditi Lahiri, and John T. Maxwell III for discussions on the phonology-syntax interface, the phonological properties of Bengali, and critical examinations of a small Bengali grammar implementation that accompanies the research presented in this paper. The implementation was done within the XLE (Xerox Linguistic Environment) grammar development platform. Miriam Butt's contribution to this paper was made possible by financial support from the DFG (the German Science Foundation) via the SFB 471 at the University of Konstanz. ([Back](#)).
1. We are of course aware of other approaches connecting phonological phenomena to syntactic analyses. One example is Cinque (1993), whose null theory on phrase and compound stress proposes that the unmarked pattern of stress for a given language can be determined entirely on the basis of the surface constituent structure of that language because stress is placed on the most deeply embedded constituent. Another relevant direction of research is represented by Reinhart (1996) and Neeleman and Reinhart (1998), who argue that Case checking follows from prosodic phrasing requirements, and that so-called "definiteness" effects must be related to stress assignment and the interaction of stress

with focus. However, these papers do not make any explicit claims about the relationship between phonological and syntactic representations in general (i.e., they are not exploring the encoding of the overall phonology-syntax interface), but instead are pointing out interesting interrelationships between phonological and syntactic phenomena that should push one even further towards exploring the phonology-syntax interface in some explicit detail. ([Back](#)).

2. Note that we have not included the *clitic group* in this Prosodic Hierarchy since it is not needed in our analysis of Bengali. Furthermore, despite the presence of clitics in Bengali, we are not convinced that it is necessary in general. See Zec and Inkelas (1990) for an alternative approach and Lahiri, Jongman and Sereno (1990) for some psycholinguistic evidence from Dutch supporting this alternative. ([Back](#)).
3. Note that 'H' stands for aspiration in the examples below, and 'E' for a schwa. ([Back](#)).
4. Our notion of complete information often falls under the notion of extended focus in other approaches: information which is not old, but also not the core information in focus. ([Back](#)).

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