German case ambiguities at the interface: production and comprehension

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Abstract

This paper describes a new approach to the interface between phonology/prosody and syntax with regard to two perspectives: production and comprehension. It assumes two transfer processes responsible for the exchange of information at the interface: the *transfer of vocabulary*, which operates at the word-level and below, and the *transfer of structure*, which is concerned with the association of syntactic and prosodic phrasing above the word-level. The approach is supported by a concrete example of German genitive/dative case constructions, which can result in syntactic ambiguities. By means of a production study, it is shown that these ambiguities can be resolved via prosodic phrasing, even though the use of acoustic cues is not uniform across speakers. The proposed interface allows for a straightforward and elegant solution to these ambiguities and is furthermore able to account for speaker variability.

1 Introduction

Over the last few decades, several theories on how syntactic phrasing influences prosodic phrasing have been proposed (see Elordieta (2008) for an overview). It is equally assumed that prosodic phrasing is not only determined by syntactic structure, but by other modules as well, e.g., information structure, in the sense that prosody can be applied to express concepts like focus, topic, and givenness (see, e.g., Féry (1993), Baumann (2006)). Furthermore, prosodic phrasing often seems to undergo postsyntactic 'rephrasing' processes to meet well-formedness constraints. Function words in trochaic languages, for example, are often phrased with the previous prosodic word, independent of (and often in opposition to) their syntactic affiliation (a.o., Selkirk (1995), Lahiri and Plank (2010)). As a consequence, this interplay between different modules and postsyntactic prosodic rephrasing results in frequent mismatches between syntax and prosody and often makes it difficult to disentangle the individual influences of the different modules on a specific phenomenon.

The idea of grammar as consisting of different modules with their own principles and parameters has been adopted into several frameworks, among them Lexical Functional Grammar (LFG; Kaplan & Bresnan (1985)). These modules are assumed to relate *form* (i.e., what is said/perceived) and *meaning* (i.e., what is intended/comprehended), with each module contributing relevant information on, e.g., semantics, syntax, or phonology. An additional important factor with respect to any act of speech and the different modules assumed is the distinction between two perspectives that are essential for the communication between speaker and listener: 1) *production*, which is concerned with the question how the speaker's original intention is transformed into a structured utterance; that is, how meaning is transformed into form. And 2) *comprehension*, which discusses the question as to how information from a concrete speech signal is processed and transformed into syntactic structure (followed by the fundamental 'understanding' of what is being said, i.e., from form to meaning).

The underlying assumption of the present paper is that the different modules of grammar are related in a basic linear way (where overlapping can and should be assumed during performance), as illustrated in Figure 1. However, it is also clear from phenomena relating semantics/pragmatics/information structure to prosody and vice versa, that the basic linear structure is not enough.[1] It is also obvious from postlexical phonological rephrasing phenomena that each module should be assumed to have a certain amount of individual generative power. Following models of speech production as they have been proposed by, among others, Jackendoff (2002) and Levelt (1999), the following underlying architecture with respect to the linear order of the different modules of grammar is adopted.

$\boxed{\text{MEANING}}$ ... $\longleftrightarrow$ semantics/pragmatics $\longleftrightarrow$ syntax $\longleftrightarrow$ prosody/phonology $\longleftrightarrow$ ... $\boxed{\text{FORM}}$

production $\rightarrow$ $\leftarrow$ ***comprehension***

Figure 1: The underlying linear order of grammar modules

As a consequence of the model proposed in Figure 1, each interface always has a certain directionality depending on the process: production (i.e., the interface *from* syntax *to* prosody) or comprehension (i.e., the interface *from* prosody *to* syntax, a topic that has received considerably less attention with respect to theories of the interface).

This paper focusses solely on the interface between syntax and prosody/phonology and discusses a new account of the interface from both perspectives, comprehension and production, providing a detailed formal implementation of German case ambiguities. Given spoken data (and with it the variability between speakers), the research question is in how far prosodic phrasing can be reliably predicted on the basis of syntactic phrasing and in how far this process is reversible in the sense that prosody influences syntactic phrasing during comprehension. In order to gain insight into these questions and the acoustic realisations of each syntactic structure, genitive or dative, a production experiment was conducted.

As prosody in general seldomly influences unambiguous syntactic structures, syntactically fully ambiguous sentences were chosen in order to determine the influence of prosody on syntactic phrasing. In the following example, the verb's optional subcategorization for an object and the syncretism between the feminine forms of the German dative and genitive determiners leads to an ambiguity in the subordinate clause's second DP *der Gräfin*.

(1)
Alle	waren	überrascht	dass
Everyone	was	surprised	that

[der	Diener]$_{DP1}$	[der	Gräfin]$_{DP2}$	zuhörte.
the.MASC.NOM	servant	the.FEM.GEN/DAT	Countess	listened

'Everyone was surprised that [the Countess' servant listened // the servant listened to the Countess].'

The concrete acoustic cues resulting from experiments are commonly replaced by the abstract notion of a prosodic domain (boundary). However, with respect to spoken data, the question remains as to how far a 'real act of performance' contributes to the determination of rules and constraints that form the core of the grammar, and how (and if) such naturally occuring

[1] This is indicated by the dotted line in Figure 1, but is not further pursued in this paper, as it goes far beyond the relationship between syntax and prosody that is the main focus of this paper.

and often highly variable data can be integrated into a model of the syntax–prosody interface. Thus, one aim of this paper is to bridge this gap between categorical interpretation and naturally occurring data. It will be shown that the present syntax–prosody interface model can formally integrate both, naturally occuring variability as well as categorical representation, thus allowing for a straightforward analysis of complex ambiguities at the syntax–prosody interface from both perspectives: production and comprehension.

The paper is structured as follows: Section 2 explains German case ambiguities in more detail and describes the possibilities for prosodic phrasing. Section 3 describes the production experiment conducted for examples as the one given in (1) and shows the range of varieties found between different speakers. In Section 4, the formal implementation of the syntax–prosody interface is described in more detail, followed by Section 5 which analyses the case ambiguities during production as well as comprehension and offers a solution to speaker variability. Section 6 concludes the paper.

2 The genitive/dative ambiguity

Speakers and listeners can use prosodic information to clarify the meaning of syntactically ambiguous sentences like the subordinate clause given in example (2), where the second DP can either have a dative or a genitive interpretation.

(2) ... dass [der Partner]$_{DP1}$ **[der Freundin]**$_{DP2}$ zuhörte
... that the.MASC.NOM partner the.FEM.GEN/DAT friend listened
(Everyone was surprised) ...
... that the friend's partner listened // the partner listened to the friend.

There are two reasons for this particular ambiguity. First, the ambiguity of the second DP in the subordinate clause (*der Freundin*) is based on the syncretism between the feminine dative and genitive form of the determiner (*der*, Table 1).

case	**masc**	**fem**	**neut**
nom	der	die	das
gen	des	***der***	des
dat	dem	***der***	dem
acc	den	die	das

Table 1: German determiner system (for the singular)

Second, in addition to the case-related ambiguity with the determiner, the final verb (*zuhörte*) can either be intransitive or transitive, requiring a dative object in the latter case. In combination with the syncretic feminine determiner, the second DP (*der Freundin*) in example (2) can either be interpreted as a dative object of the verb or as a possessor phrase to the first DP *der Partner*, resulting in full ambiguity of the complete subordinate phrase. Crucially, however, in an example with a masculine second DP, the ambiguity is no longer given ((3)). Even though the verb would in principle allow for an ambiguous construction, the masculine dative and genitive determiners are not syncretic. As a consequence, their use clearly disambiguates the second DP as either a dative object ((3a)) or a possessor ((3b)).

(3)	a.	... dass	[der Partner]$_{DP1}$	**[dem Freund]**$_{DP2}$	zuhörte
		... that	the.MASC.NOM partner	the.MASC.DAT friend	listened
		(Everyone was surprised) ... that the partner listened to the friend.			
	b.	... dass	[der Partner]$_{DP1}$	**[des Freundes]**$_{DP2}$	zuhörte
		... that	the.MASC.NOM partner	the.MASC.GEN friend	listened
		(Everyone was surprised) ... that the partner's friend listened.			

The full ambiguity in examples like the one in (2) results in two possible syntactic structures (modelled after the computationally implemented LFG-grammar of German (Dipper 2003)). In Figure 2a, the two DPs are independent daughters of the VP, indicating a dative construction with the second DP *der Freundin* as the object of the verb *zuhörte*. The syntactic tree in Figure 2b, on the other hand, represents a genitive construction with the second DP in the role of the possessor.

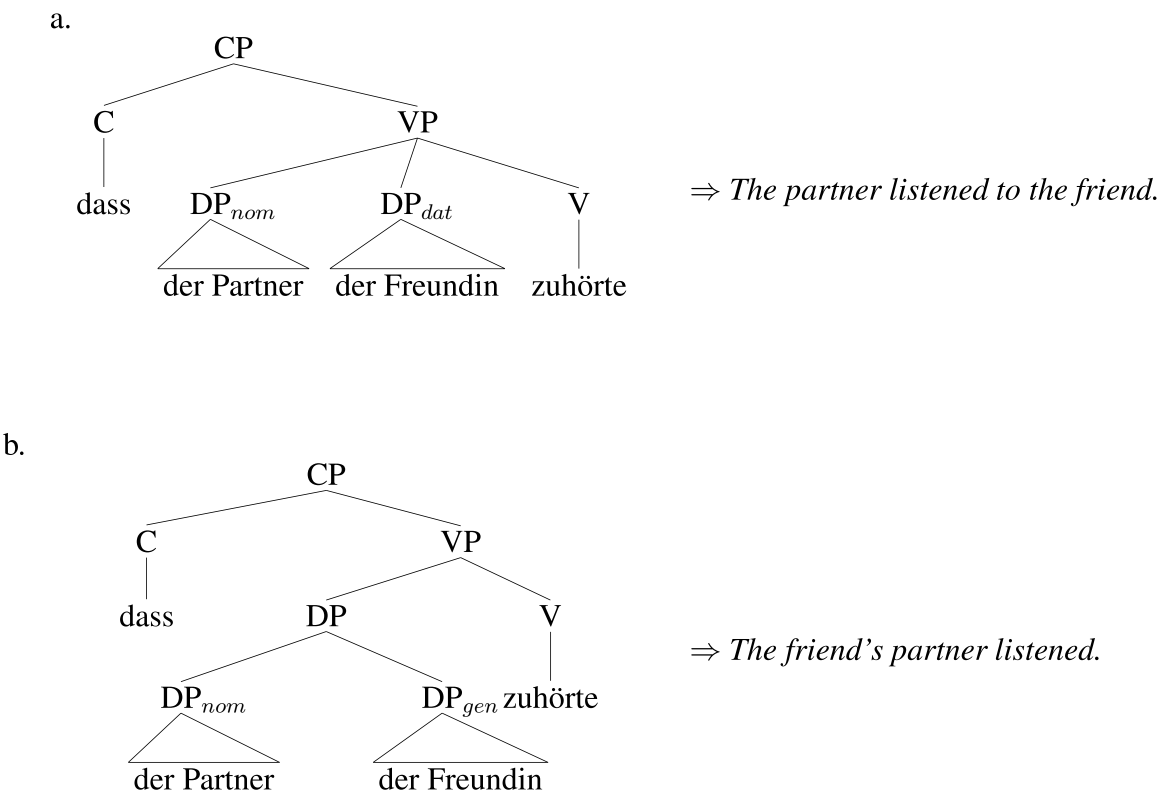

Figure 2: Syntactically ambiguous structures for *dass der Partner der Freundin zuhörte*.

While the purely syntactic analysis of ambiguous structures leads to multiple representations, a disambiguated structure and with it a singular meaning can be signalled to the listener via the use of different acoustic cues (Lehiste et al. 1976, Price et al. 1991, a.o.). These acoustic cues signal prosodic domain boundaries (inter alia), which can be crucial for the disambiguation of syntactic ambiguities. Thus, the question addressed in the present paper is if prosodic information can also be applied to help disambiguate syntactically ambiguous structures like the ones given in (2), and if so, which acoustic cues are associated with which syntactic structure.

Evidence for a prosodic disambiguation of structures as in (2) come from a production experiment on the impact of different acoustic cues on the interpretation of German sentences with a genitive/dative ambiguity. Gollrad et al. (2010) found f_0, *pause* and *duration* to be relevant cues for the indication of a phonological phrase boundary in a dative construction. In a follow-up perception experiment, they furthermore identified *duration* to be the most important factor for the disambiguation of syntactic structures in language comprehension.

However, in contrast to (2) given above, Gollrad et al. (2010)'s study did not involve completely ambiguous structures. Instead, sentences consisted of three determiner phrases whose relation with each other was disambiguated by a final verb with an unambiguous subcategorization frame. In addition to the incomplete ambiguity, the use of three DPs increased the chance of 'list intonation',[2] which might have distorted the results. Furthermore, Gollrad et al. did not look at the occurence frequency of the different acoustic cues, a topic, which is of particular interest to the present paper as it reflects speaker variety and addresses the question as to how 'likely' it is that a speaker indicates a particular interpretation by means of prosody.

Thus, in order to gain insight into the prosodic realization of fully ambiguous sentences with a reduced number of DPs and the use of prosody in general across speakers, a further production experiment was conducted with constructions as exemplified in (2). Based on the findings in Gollrad et al. (2010), the phonological phrase boundary for (2) and similar sentences is expected to be placed between the first and the second DP in the dative condition (4a), but does not occur in the genitive condition (4b), for both directions: comprehension and production.

(4) a. ... dass der Partner$)_{\text{PhP}}($ der Freundin ...
b. ... dass der Partner der Freundin ...

In contrast, in the unambiguous dative example in (3), the phonological phrase boundary is expected to be placed between the two DPs.

(5) ... dass der Partner$)_{\text{PhP}}($ dem Freund ...

This crucial difference between (4) and (5) shows that a certain dominance of syntax over prosody can be assumed. In example (5) it does not matter whether prosodic phrasing is unexpected, that is, whether the phonological phrase boundary is placed somewhere else or is completely missing – under no circumstances can prosody alter the syntactic interpretation of the second DP as a dative object. From the two viewpoints of comprehension and production it thus can be concluded that while for production the placement of a phonological phrase boundary is part of a well-formed sentence, prosodic phrasing is only crucial for syntactic structuring during comprehension in the context of syntactic ambiguities.[3] Phonological phrase boundaries thus *can* determine syntactic phrasing, but *only* if a syntactic ambiguity is given.

[2] List intonation refers to the downstepping intonation pattern used if expressing a list, e.g., as in *I bought an apple, a sausage, an orange, and a banana* (see Liberman and Pierrehumbert 1984).

[3] This does not exclude the impact prosodic indicators might have on meaning interpretation; however, the discussion in *this* context is reduced to the interface between prosody and syntax and does not include references to, e.g., information structure.

3 Experiment

In order to determine the acoustic cues that contribute to the representation of each case condition (including the less significant ones) and to identify the distribution and frequency of each acoustic cue across all speakers, a production experiment with fully ambiguous constructions as described in (2) was conducted.

3.1 Methods

3.1.1 Stimuli

Each stimuli belonged to one of three groups:

1. Six ambiguous and six unambiguous case constructions placed within a larger text, where context disambiguated the ambiguous sentences.

2. Twelve unambiguous structures consisting of two masculine DPs each, whose relation with each other was disambiguated via the respective determiners. Six of these structures were in the dative and six in the genitive condition. Each speaker had to produce a total of six sentences mixed from both conditions and interspersed with fillers.

3. Nine fully ambiguous structures where the first DP was masculine and the second one feminine. All speakers produced these sentences twice, once in the dative, and once in the genitive condition, resulting in a total of 18 sentences. As noted by Allbritton et al. (1996), subjects will not consistently use phonetic cues to indicate a certain interpretation of syntactically ambiguous sentences. However, if the speakers were made aware of the ambiguity and were asked to pronounce a sentence according to a certain interpretation, the phonetic cues were much more distinct for each condition. In order to ensure clear phonetic cues, the speakers were thus provided with a context that supported one of the two possible interpretations.

Each DP followed a trochaic foot pattern and consisted of two syllables plus a determiner across all conditions and sentence types, resulting in the following pattern for the two DPs:

(6) $$\underbrace{det\ \overset{\mathrm{x}}{syll_1}\ syll_2}_{\mathrm{DP}_1}\quad \underbrace{det\ \overset{\mathrm{x}}{syll_1}\ syll_2}_{\mathrm{DP}_2}$$

Only DPs that were able to form a possessive as well as a subject-object relationship were chosen. With respect to the verbs there are only nine verbs in German which allow for an optional dative object, so the possible constructions used in the experiment were limited.

3.1.2 Participants

For the experiment, 15 female native speakers of German aged between 20 and 30 were recorded and paid € 4 for their participation.

3.1.3 Procedure

Target sentences and randomly distributed fillers were presented on MS PowerPoint ordered in three successive blocks of sentence types, whereby the ambiguous sentences were split into two parts and grouped around the unambiguous sentences. Participants were asked to read the context silently and to 'mentally understand' the sentence, before producing the sentence as naturally as possible.

Participants were recorded in the soundproof booth of the phonetic laboratory at the University of Konstanz (sampling frequency 44.1 kHz, 16 Bit resolution). Every speaker produced 30 target sentences, resulting in a total of 450 items.

3.1.4 Data analysis

18 of the 450 sentences were discarded because there was no discernable pitch. The remaining files were manually annotated using Praat (Boersma and Weenink 2013). The annotation was conducted syllablewise across the two DPs and included the duration of each syllable, possible pauses, and a mean pitch value for each syllable vowel, on the basis of which the difference in pitch between two adjacent syllables was calculated as well.

The statistical analysis of the different phonetic cues was done with a linear mixed effects regression model (LMER), with subject and item as crossed random factors and the two conditions (genitive and dative) as fixed factors. Participants were analysed as a group, but also as individuals in order to investigate the frequency of occurrence for each acoustic cue across all speakers.

3.2 Results

The statistical analysis for all speakers showed the following results:

- A significant drop in fundamental frequency from the last syllable of the first DP to the determiner of the second DP in the dative condition (β=-9.31, SE=2.64, t=-3.53).
- A significant pause between the first and the second DP in the dative condition: (β=-2.35, SE=0.92, t=-2.55).
- The duration of the last syllable of the first DP was significantly longer in the dative condition compared to the genitive condition (β=-2.8, SE=0.79, t=-3.58).

The aim of this experiment, however, was not only to capture the significant phonetic cues indicating a dative or genitive interpretation, but to also consider the less dominant cues which might still be relevant for the calculation of a prosodic phrase boundary if the other indicators are not present, and to examine speaker variability. Therefore, the statistical analysis was applied to individual speakers as well, including phonetic cues that were non-significant in the overall analysis, but were used by at least 20% of the speakers. Particular attention was paid to the fact that the individual cues did not contradict each other.[4]

Surprisingly, when tested individually for strategies to indicate the dative or the genitive, around 33% of the participants did *not show any* significant or non-significant results. Only 67% of the speakers applied acoustic cues, to a varying extent. In addition to the findings

[4]For example, if one subgroup used a rising pattern and another group used a falling pattern on the same syllable in the same condition, this acoustic cue was excluded from the analysis.

above, two further indicators were found for the genitive: a) a less pronounced difference in the fundamental frequency between the first and the second syllable of the first DP's noun, and b) a drop in fundamental frequency from the second determiner to the first syllable of the second DP's noun. However, there are no significant results identifying a phonological phrase boundary for the genitive construction (no pause, no lengthening of the last syllable, no drop/rise in f_0), neither between the two DPs nor following both DPs.[5]

The following table gives an overview of all phonetic cues found for the dative and genitive condition.

condition	**acoustic cue**	**occurrence (%)**
dative	pause between DP_1 and DP_2	40%
	longer duration of the last syllable in DP_1	47%
	drop in f_0 between the last syllable of DP_1 and the Det. of DP_2	40%
genitive	less pronounced difference in f_0 between the two syllables in DP_1	27%
	drop in f_0 between the second Det. and the first syllable of DP_2	20%

Table 2: Frequency distribution of acoustic cues in the genitive and dative condition

The acoustic cues indicating a phonological phrase boundary and thus supporting a dative interpretation are statistically significant across all speakers. Their absence, on the other hand, are an indication of a syntactic structure representing a genitive construction. The two acoustic cues listed for the genitive above are not significant for all speakers, but are applied by some of the speakers (27% and 20%, respectively) to indicate a genitive interpretation.

3.3 Discussion

The following figure shows a 'prototypical' instance of the dative stimulus in Praat with four syllables of example (2) (*der Partner der Freundin*). The annotation provides the (non-IPA) reference syllables, a pause (-b-), and a GToBI annotation, indicating High and Low pitch accents and boundary tones (Grice and Baumann 2002).

[5] It has to be noted that when it comes to the verbs (and thus to the position between the second DP and the following verb, a possible candidate for a phrase boundary), the data does not allow for homogenous conditions: Some of the verbs include the unstressed prefix *ge-*, some are particle verbs, where the particle in the first position is stressed as in *zuhören* 'listen', and some are verbs without any further prefixes/particles (e.g., *folgen* 'follow'). As the number of intransitive verbs that allow for an optional dative object is limited (9 in total), reliable control at this position was not possible. The question whether the genitive construction forms a phonological phrase boundary after the second DP must be left for further research.

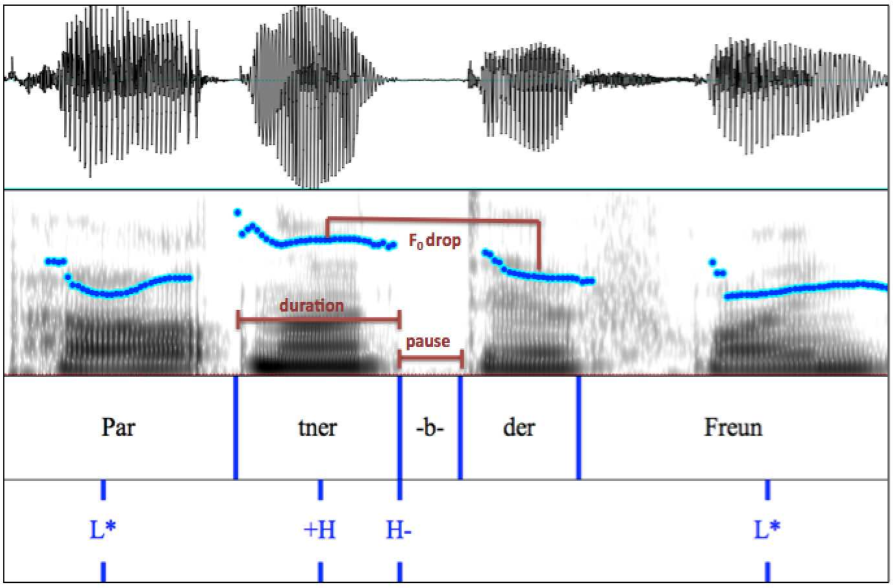

Figure 3: A ‘prototypical’ dative

The dotted lines in Figure 3 represent the fundamental frequency as it was calculated by Praat, the solid lines have been added by hand and indicate the three most frequently used acoustic cues for the dative construction: a) the second syllable of the first DP is longer in duration, b) a small pause is inserted between the two DPs, and c) a drop in f_0 can be found between the first and the second DP. Taken together, these acoustic cues indicate the presence of a phonological phrase boundary after the first DP (as indicated by H-). The phonological phrase boundary found in Figure 3 for the dative is not present in the genitive construction (Figure 4).

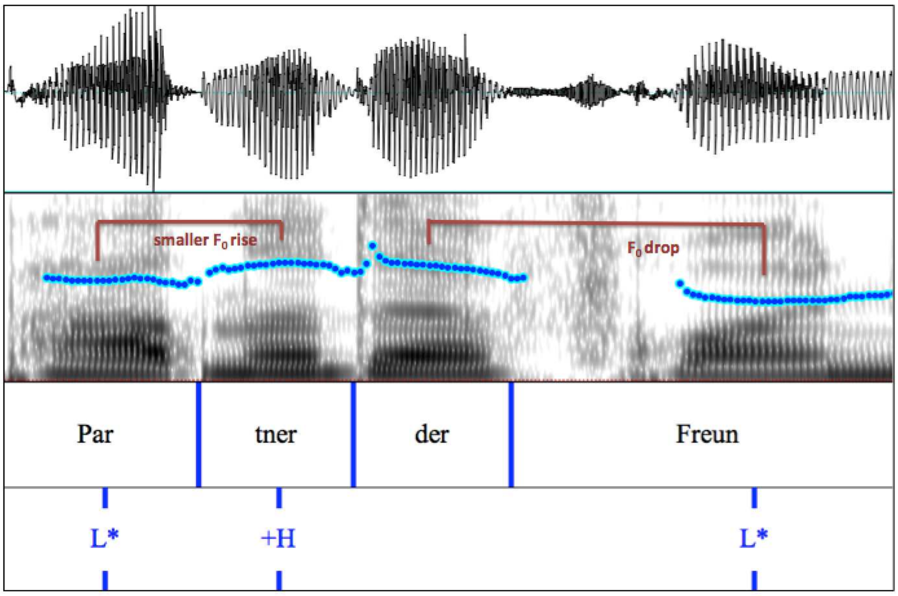

Figure 4: A ‘prototypical’ genitive

All of the above mentioned (‘dative’) indicators are significant for the genitive as well in that they are *not* present. Acoustic cues in the genitive speech signal are the smaller f_0 rise,[6] and the drop in f_0 from the determiner to the first syllable of the second DP.

While all of the indicators found for the dative are significant if measured for all participants, this is certainly not true for each individual speaker. This applies to an even greater extent to the nonsignificant cues found for the genitive. It can thus be concluded, that participants use different acoustic cues and combinations thereof to indicate a particular case construction – and that a significant number of them does not use any discernible cues at all. Speaker variability is thus a very important factor when it comes to modelling these constructions and the interplay between syntax and prosody at the interface.

However, even given speaker variety, the experiment confirmed that a certain combination of acoustic cues can be assumed to indicate the presence of a phonological phrase boundary, as predicted in (4), and repeated in (7).

(7) a. ... dass der Partner)$_{\text{PhP}}$(der Freundin ... $\rightarrow$ *Dative*

b. ... dass der Partner der Freundin ... $\rightarrow$ *Genitive*

To conclude, although prosody usually does not determine syntactic structure, syntactic ambiguities can be resolved with reference to prosody. In the following section, this asymetric relationship between prosody and syntax will be discussed in more detail with reference to the syntax–prosody interface in LFG.

4 The syntax-prosody interface

The modular architecture of LFG distinguishes two syntactic structures. C(onstituent)-structure represents the linear order and the hierarchical organization of words into a syntactic tree (See also Figure 2). F(unctional)-structure, on the other hand, encodes the abstract functional organization and the dependency structures of a sentence in terms of an attribute-value matrix; for the interaction with prosody that particular structure is not important and will therefore not be considered any further in this paper.

Apart from these structures representing the syntactic module, there are further modules representing, among others, s(emantic)-structure, i(nformation)-structure, and p(rosodic)-structure. All structures are placed into correspondence with each other via projection functions that relate specific parts of one structure to specific parts of another structure. The projection function ϕ, for example, relates c- and f-structure and determines that the specifier of IP (in c-structure) corresponds to the subject (in f-structure) (see Dalrymple (2001) for a general overview).

Resolving case ambiguities requires the involvement of at least two modules of grammar: syntax and prosody. While the syntactic structures discussed above are well-established, the prosodic module has received considerably less attention (in LFG, but also elsewhere). While over the last decades, some analyses of phenomena have been presented with reference to prosody and phonology in LFG (Butt and King 1998, O'Connor 2004, Mycock 2006, Bögel et al. 2009, Dalrymple and Mycock 2011), all of these approaches are relatively narrow and cannot account for the full complexity found in relation to the form of a sentence, i.e., the

[6]The rise in f_0 has been compressed to the extent that an L*+H annotation might seem to be uncalled-for. The annotation was left in there because a rise, albeit a small one, is still present.

spoken utterance. Therefore, the paper here presents a new approach to p-structure, which enables a full interaction between p-structure and the other modules of grammar (here: syntax).

The following figure shows the abstract arrangement of modules/structures and projections functions with respect to the prosody–syntax interface, i.e., p-structure and c-structure respectively (see Bögel (2015) for a detailed introduction).

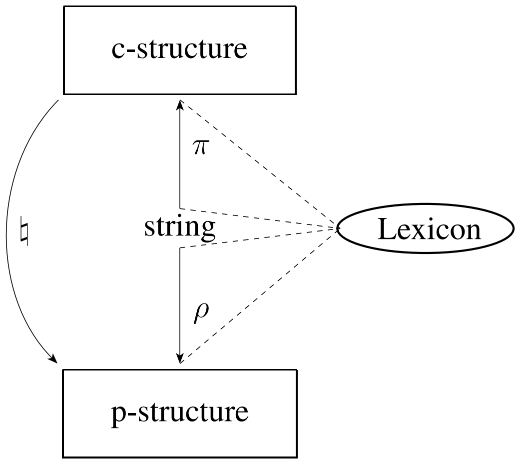

Figure 5: An abstract representation of the syntax–prosody interface

C-structure is represented by a syntactic tree (Figure 2). P-structure is represented via the p-diagram, a compact, syllable-based model imitating the linear nature of the speech signal over time. For this purpose, each syllable receives a feature vector associating the syllable with a number of attributes, which each assign a specific value to that particular syllable. In the following figure, the DP *der Freundin* (‘the (female) friend’) is encoded in a p-diagram. Each syllable is assigned a vector (S_i) and a number of attribute-value pairs. The attribute SEGMENTS, for example, associates the value /deᵊ/ with the syllable representing *der* ‘the’.

ATTRIBUTE$_3$	...	...	...	...	
ATTRIBUTE$_2$	...	...	...	...	
SEGMENTS	...	/deɐ/	/fʁɔœ̯n/	/dɪn/	
VECTORINDEX	$\mathbf{S_3}$	$\mathbf{S_4}$	$\mathbf{S_5}$	$\mathbf{S_6}$	

Figure 6: The p-diagram: a compact syllable-based model of p-structure

Three levels can be distinguished within the p-diagram, each with a unique set of attributes: The *lexical level* stores lexical information that is associated with each syllable and applies only during production. The *signal level* records information associated with each syllable in the speech signal and occurs only during comprehension. The *interpretation level*, finally, interprets and abstracts away from both the *lexical* and the *signal level* during production and comprehension.

Because of the distinct nature of each level, only specific attributes can be associated with it: While the signal level will naturally contain attributes like DURATION, PAUSE, and FUNDAMENTAL FREQUENCY (f_0), the lexical level is concerned with attributes like LEXICAL STRESS and SEGMENTS.[7] The interpretation level builds on the different values given in the lexical or the signal level and interprets them in terms of PROSODIC PHRASING or GTOBI annotations, e.g., it determines on the basis of the values given for DURATION, PAUSE, and FUNDAMENTAL FREQUENCY if a phonological/intonational phrase boundary is present after a specific syllable, or if a high tone is given on the basis of the development of f_0.

Two levels of information transfer are assumed at the syntax–prosody interface, i.e., between c- and p-structure: the *transfer of vocabulary* and the *transfer of structure*.

4.1 The *transfer of vocabulary*: information exchange at the lexical level

The *transfer of vocabulary* operates at the word-level and lower with reference to the string via the projection functions ρ and π (Figure 5). Each element of the string is related to its associated morphosyntactic and phonological information in the lexicon, projecting this information to the respective structures (c-structure or p-structure).

LFG supports the strong lexicalist hypothesis (Lapointe 1980) and the *principle of lexical integrity* (Bresnan and Mchombo 1995) in that only morphologically complete words can enter the syntactic module. The lexicon in LFG is thus a rich and complex structure whose output consists of fully-fledged wordforms.[8] Each lexical entry has three dimensions: The *concept* which includes all semantic information associated with that particular form,[9] the *s(yntactic)-form* including all morphosyntactic information on, e.g., case, number, or gender, and the *p(honological)-form* which contains all information associated with segmental and suprasegmental (word-level) phonology (c.f. Levelt et al. 1999). In the following table, the lexical entries for the determiner *der*[10] 'the' and the noun *Freundin* 'friend' are given.

concept	**s-form**		**p-form**	
FREUNDIN	N	($\uparrow$ PRED) = 'Freundin' ($\uparrow$ NUM) = sg ($\uparrow$ GEND) = fem	SEGMENTS METRICAL FRAME	/f ʁ ɔ͡œ n d i n/ $(\acute{}\sigma\sigma)_\omega$
DETERMINER	D	($\uparrow$ PRED) = 'der' ($\uparrow$ NUM) = sg ($\uparrow$ GEND) = fem ($\uparrow$ CASE) = {gen | dat}	SEGMENTS METRICAL FRAME	/d e ɐ/ σ

Table 3: (Simplified) lexical entries for *der* and *Freundin*.

Besides information on number and gender, the s-form of the determiner *der* also encodes the inherent case ambiguity between genitive and dative within the multidimensional lexicon using

[7]In fact, the attribute SEGMENTS occurs with both, lexical and signal level. However, while the value represents the underlying segments as they are stored in the mental lexicon at the lexical level (feature bundles, as suggested by Lahiri and Reetz (2002, 2010) and indicated by slashes / /), the SEGMENTS attribute at the signal level encodes the segments as given in the speech signal, including possible variations or coarticulation phenomena (represented by square brackets [ ]).

[8]These wordforms are assumed to be generated dynamically within the lexicon and its associated structures, e.g., lexical phonology and morphology (Kiparsky 1982, Mohanan 1982, Meinzer et al. 2009, a.o.).

[9]The *concept* is not of relevance for the current discussion and will therefore be omitted from depictions of the lexicon following Table 3.

[10]Note that the lexical entry for *der* is restricted to the feminine form here. Further morphosyntactic information could be included based on the syncretism with the masculine and the plural forms, but was left out for reasons of simplification.

the formal disjunction operator {gen | dat}. The p-form entries, on the other hand, provide information on the individual segments associated with that entry, the number of syllables (σ), stress distribution (ˈ) among these syllables, and the prosodic domain: a prosodic word (ω) for *Freundin*, but no domain for the function word *der* (c.f. Selkirk 1995, a.o.). Note that the segments are not associated with syllables as of yet. This is assumed to be a dynamic process which is also determined by preceding and following words and postlexical phonological processes, e.g., resyllabification. A function word without prosodic word status might be prosodically grouped with the preceding prosodic word. If that 'host' is terminated by a consonant and the function word starts with a vowel, a majority of the languages will apply onset maximisation, drawing the final consonant of the host into the onset of the following function word. It is therefore crucial to only associate segments with syllables once the context is given as well (see also Levelt et al. (1999) for a further discussion of the topic).

This strict separation of module-related information within the multi-dimensional lexicon is in line with a modular view of grammar (c.f. Fodor (1983), see also Scheer (2011) for an overview). Each lexical dimension can only be accessed by the related module of language: c-structure can access only information associated with the s-form, and p-structure can only access information stored within the p-form. However, once a lexical dimension (e.g., s-form) is triggered, the related dimensions (e.g., p-form) can be accessed as well and the information can be instantiated to the related modules, i.e., c-structure can relate to a specific s-form in the lexicon which activates the associated lexical p-form whose information then becomes available to p-structure and vice versa. The multidimensional lexicon therefore adopts a translatory function at the phonological and morphosyntactic word-level and below, thus enabling the *transfer of vocabulary* between c- and p-structure.

4.2 The *transfer of structure*: information exchange on constituents

The *transfer of structure* directly associates c- and p-structure via the projection function $\natural$ (Figure 5) and exchanges information on syntactic and (higher) prosodic constituency. The assumptions made here roughly follow Selkirk (2011)'s *Match Theory* for the higher constituents,[11] in that each IP/CP is assumed to match an intonational phrase (IntP/ι) and each XP corresponds to a phonological phrase (PhP). The prosodic domain information associated with a specific syntactic node by means of an annotation is related to p-structure via the correspondence function $\natural$. The following figure shows a sample *transfer of structure* between the syntactic CP node and p-structure, relating the CP to an intonational phrase.

[11]Note, however, that the model presented here is not limited to this approach. In principle, any assumption concerning the correspondence between syntactic and prosodic constituents (e.g., the *end-based approach* (Selkirk 1986, Chen 1987)) might be more suitable for another language and can be implemented into this model as well.

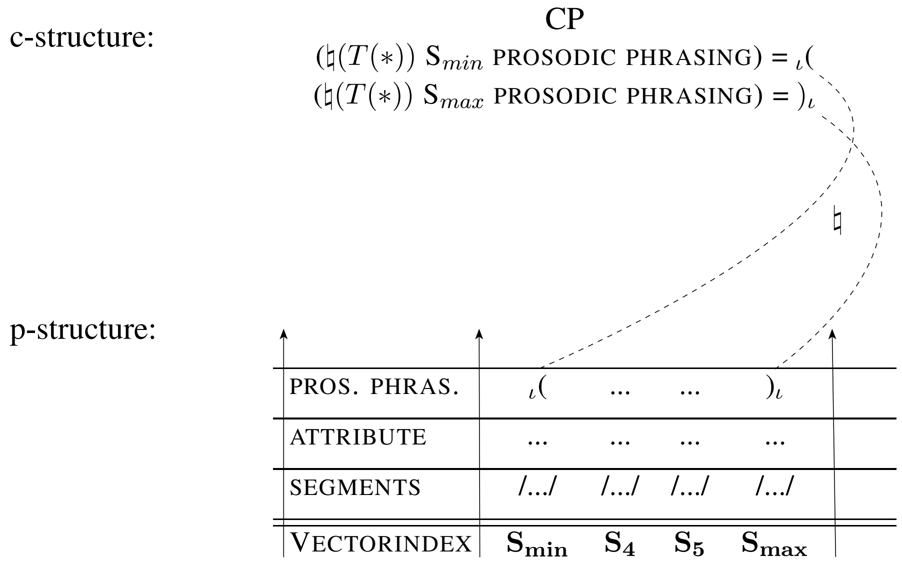

Figure 7: The *transfer of structure*

The annotations to the CP node can be read as follows: For every terminal node *T* of the current node * (here referring to each terminal node belonging to the CP), take the corresponding string in p-structure (related via ♮, which associates the CP and its terminal nodes to all syllables of which the terminal nodes consist of in the p-diagram). For the syllable with the lowest index (S_{min}, i.e., the first syllable of the string representing the CP) and the one with the highest index (S_{max}, i.e., the last syllable of the string representing the CP) insert an intonational phrase boundary (ι) as the value of the attribute PROSODIC PHRASING (from hence on shortened to PHRASING).

The *transfer of structure* thus effectively allows for the formal determination of prosodic phrasing on the basis of syntactic phrasing, relating the CP to an intonational phrase that contains all the segmental material corresponding to the terminal nodes underneath the CP.[12] Thus, in constrast to the *transfer of vocabulary* , which operates on the wordlevel and below, the *transfer of structure* only relates information on higher syntactic and prosodic constituents (XP/PhP and above). Taken together, the two transfer processes complement each other and provide for a complete transfer of all necessary information at the interface between syntax and prodody.

5 Case ambiguities at the interface: *production* and *comprehension*

Having established the underlying architecture, the following sections will analyse the dative-genitive case ambiguities at the interface in more detail. As mentioned above (Figure 1), the syntax–prosody interface is assumed to be placed between two reference points: form and meaning. *Production* is the process of creating speech starting from meaning and assigning it

[12]This first indication of prosodic phrasing on the basis of syntactic phrasing is taken to only be the initial input to p-structure. The full model assumes generative power within p-structure as well in the sense that prosodic rephrasing may happen purely on the basis of prosodic constraints, e.g., function words have to be prosodically grouped with a host. As a p-structure internal rearrangement of prosodic units is not relevant for the present analysis, it has been excluded here. The interested reader is referred to Bögel (2015, ch. 4-6) for further reading.

a particular form which the recipient can understand. *Comprehension*, on the other side, takes form as an input and assigns meaning to it. Depending on the type of process, the interface thus has to be interpreted either from syntax to prosody (production) or from prosody to syntax (comprehension), with prosody having a less strong effect on syntactic phrasing[13] compared to syntax' influence on prosody (cf. the discussion in Section 2).

5.1 Case in *production*

In a production process, the concept of what the speaker intends to say is first encoded in syntax/c-structure. As was shown in the experiment described above, a significant number of speakers insert a phonological phrase boundary between the two DPs to indicate a dative object interpretation of the second DP. This information on phrasing is related from syntax to p-structure via the *transfer of structure*, as shown in the following model of a complete syntax-to-prosody interface for a dative construction in production.

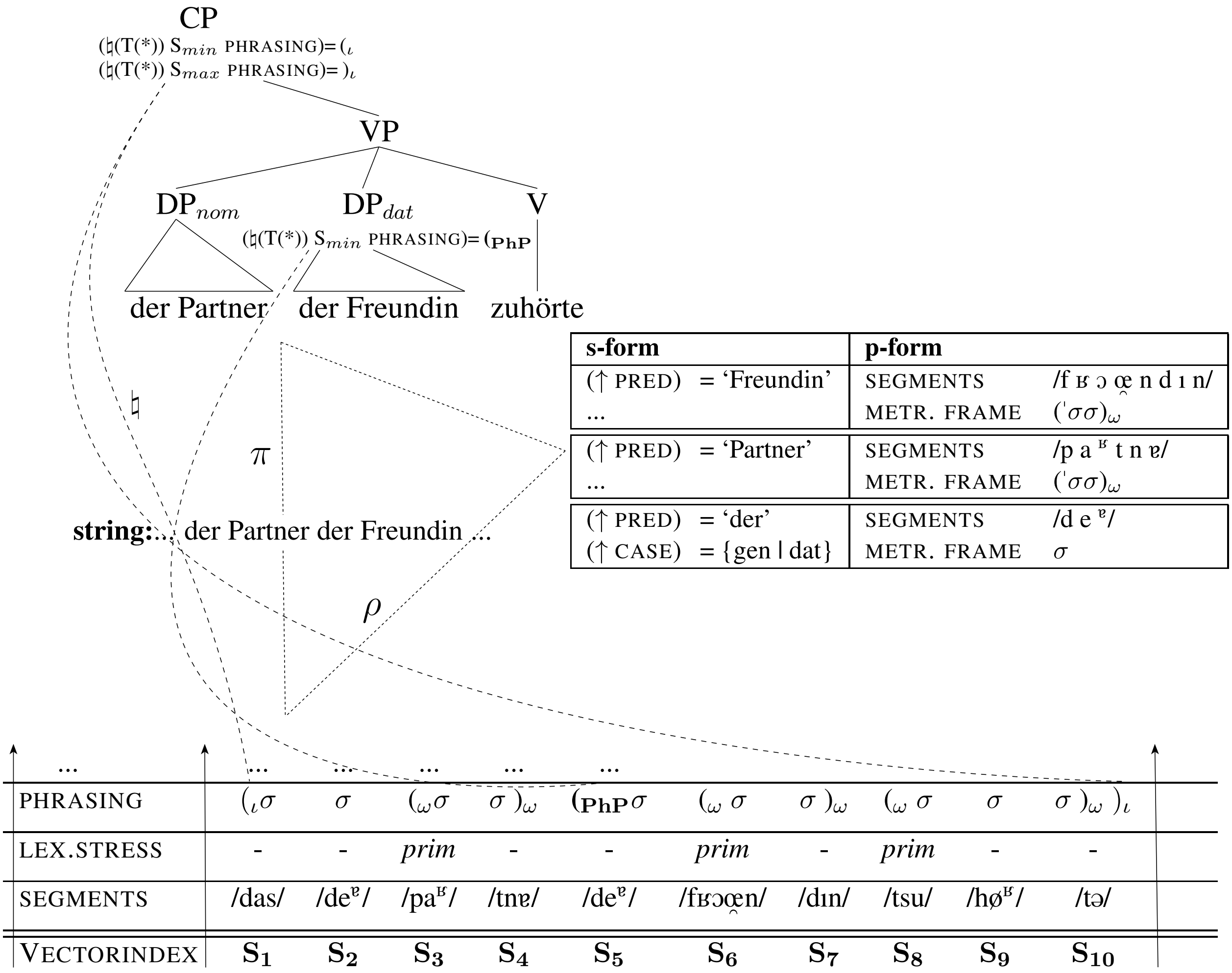

Figure 8: The production of a dative construction at the syntax–prosody interface

[13]This is certainly true for German and English, but this might be different in other languages.

First, the *transfer of vocabulary* (ρ) builds up the fundamental structure of the p-diagram by associating each separate morphosyntactic item with its respective p-form via the multidimensional lexicon. The information encoded within the p-form is transferred to the p-diagram syllablewise, reflecting lexical phonological information associated with each syllable, e.g., lexical stress or segments. Following the experimental results discussed above, the *transfer of structure* (♮) determines that a phonological phrase boundary is placed with the first syllable of the DP *der Freundin*, prosodically indicating a dative construction. In addition, following the assumptions made by *Match Theory* (Selkirk 2011), the CP projects an intonational phrase (ι) to p-structure that wraps all phonological material associated with the subordinate clause.

Together, both transfer structures provide an initial input to p-structure. Further prosodic (re-)phrasing and completion of prosodic domains follows according to p-structure-internal constraints (e.g., if there is an intonational phrase boundary, there will also be a phonological phrase boundary according to the *Strict Layer Hypothesis* (Selkirk 1995)). The output of the phonological module will thus consist of a complete underlying phonological/prosodic model of the string. In a further step, this information is then 'transformed' into spoken language via the phonetic module, which would encode concrete acoustic realisations of, e.g., a phrase boundary, or determines coarticulation of the different segments, but is also dependent on non-linguistic factors like the gender of the speaker. As these considerations go far beyond the production of a dative construction at the syntax-prosody interface, they are not further discussed here. The paper will, however, briefly touch on the phonetics–phonology interface in the section on *comprehension* below.

A genitive in production is very similar to a dative, except that there is no information on phonological phrase boundaries as these are only associated with a DP in a dative object position.

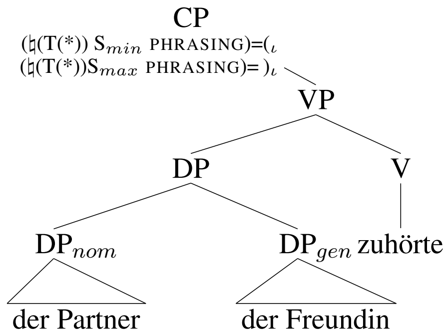

Figure 9: P-structure annotation in the c-structure relating to a genitive construction

Apart from the missing phonological phrase boundary, the p-diagram and the lexicon of the genitive construction are identical to a dative in production. The interface model proposed here thus allows for a very straightforward and uniform phonological/prosodic description of different syntactic structures, where the difference in prosodic phrasing can be modelled by simply adjusting annotations relating to the *transfer of structure*.

5.2 Case in *comprehension*

As discussed above, the p-diagram during production leaves out explicite phonetic details as it is concerned with the underlying phonological categories, and not with the surface form realisation (even though this can, in principle, be included as well, as part of the phonology-phonetics interface). However, during comprehension, phonetic details are included in the model, in order to show how the results gained through the experiment reported above can inform the phonological categories relevant at the interface. In order to show this distinction between the phonetic and the phonological module, the p-diagram during comprehension is split into two levels, the *signal* level and the *interpretation* level. While information stored in the signal level is taken directly from the speech signal, the interpretation level abstracts away from the concrete data to a more categorical representation. Figure 10 shows the p-diagram of a concrete speech signal of *der Partner der Freundin* representing dative case.

...	...	...	...	...	...		**interpretation**
PHRASING	-	-	$)_{PhP}$	$(_{PhP}$	-	-	↓
SEMIT_DIFF	...	-1	6.8	-4.3	-1.9	2.6	
GTOBI	-	L*	+H H-	-	L*	+H	
BREAK_IND	-	-	3	-	-	-	
...	...	...	...	...	...	...	**signal**
P_DURATION	-	-	0.07	-	-	-	↓
DURATION	0.15	0.25	0.25	0.13	0.31	0.19	
FUND. FREQ.	192	181	269	209	188	218	
SEGMENTS	[deᵄ]	[paʶ]	[tnɐ]	[deᵄ]	[fʁɔœ̯n]	[dɪn]	
VECTORINDEX	$\mathbf{s_1}$	$\mathbf{s_2}$	$\mathbf{s_3}$	$\mathbf{s_4}$	$\mathbf{s_5}$	$\mathbf{s_6}$	

Figure 10: P-diagram for the speech signal of a dative construction.

Figure 10 includes several attributes whose values allow for a prosodic interpretation. At the signal level, the attributes SEGMENTS, DURATION of the syllable, P(AUSE) DURATION, and the syllable's mean FUNDAMENTAL FREQUENCY (f_0) value have been included. A further attribute-value pair left out here could be, e.g., INTENSITY. On the basis of these concrete values the interpretation level allows for an abstract representation of the speech signal. For example, on the basis of f_0 values, semitone differences can be calculated (SEMIT_DIFF), where negative values are associated with a fall and positive values indicate a rise in f_0. The resulting abstract contour representation allows for the interpretation in terms of prosodic phrasing and low and high tones (represented via GTOBI, Grice and Baumann (2002)): the strong rise in pitch to the otherwise unstressed second syllable of *partner* and the following drop, for example, are likely to indicate a phonological phrase boundary. Further indicators for such a boundary are pauses and syllable duration. Concrete signal information on pauses can be recoded as break indices (Silverman et al. 1992) (BREAK_IND), indicating the length of a pause after a specific syllable (here: after the first DP). In addition, the relatively long duration of the unstressed second syllable of *partner* (DURATION) also indicates the presence of a phonological phrase domain boundary after the first DP.

Taken together, the drop in f_0, the pause, and the syllable duration value clearly indicate a phonological phrase boundary after the first DP, which is consequently encoded as a value of PHRASING. During the *transfer of structure*, this boundary indication is then the sole relevant value for the correct intepretation of ambiguous syntactic phrasing.

As discussed above, the relation between prosodic and syntactic structure is asymmetric in that prosody cannot alter an unambiguous syntactic structure during comprehension, while syntax is much more influential when it comes to prosodic phrasing during production. This difference, however, only applies to the *transfer of structure*. The *transfer of vocabulary* works equally from both sides: During production, c-structure terminal nodes correspond to s-forms, which activate the associated p-forms in the multidimensional lexicon, thus making them available to p-structure. During comprehension, on the other hand, segmental chunks of the signal are matched against the lexicon's p-form (see also McQueen (2005)) and if a match is made, the associated s-form information becomes available to c-structure. While the segmental level is always given during comprehension, prosodic phrasing can be quite erratic.[14] It is therefore necessary to constrain this part of the information transfer in the sense that syntax is independent of prosody, *except* in cases where syntactic phrasing is ambiguous and can be disambiguated via prosody. As a consequence, information on prosodic phrasing is not automatically projected from p-structure to c-structure. Instead, the *transfer of structure* only requests information on prosodic phrasing if syntactic ambiguities are identified. Formally, this is achieved by adding a constraint to the annotation associated with the dative object DP ((8)), which effectively prevents the syntactic structure from being parsed unless the required value is present.

(8) $(\natural(T(*))\mathrm{S}_{min}$ PHRASING) $=_\mathbf{c}$ $(_{PhP}$
which reads as: The value of PHRASING for the first syllable of the phonological string corresponding to the current syntactic node must be equal ($=_\mathbf{c}$) to a phonological phrase boundary.[15]

The following figure shows a dative construction in comprehension, where the p-diagram reflects a concrete speech signal at the signal level and its abstract representation in prosodic terms at the interpretation level. The DP annotation is not a projection of information *to* p-structure, but a constraint as to what p-structure should look like in order for this syntactic interpretation to obtain.

[14]For example, a long pause might just be caused by a distraction of the speaker, or a particular prosodic pattern might only be relevant for information structure, but not syntax.

[15]In principle, the annotation does not have to refer to the PHRASING attribute, but could refer to any attribute-value given in the p-diagram's *interpretation* level. However, it seems that it is mostly prosodic phrasing that is relevant for syntax. For information structure, on the other hand, the relevant information mostly seems to be information on the pitch of a clause (in particular the nature and the distribution of high and low tones).

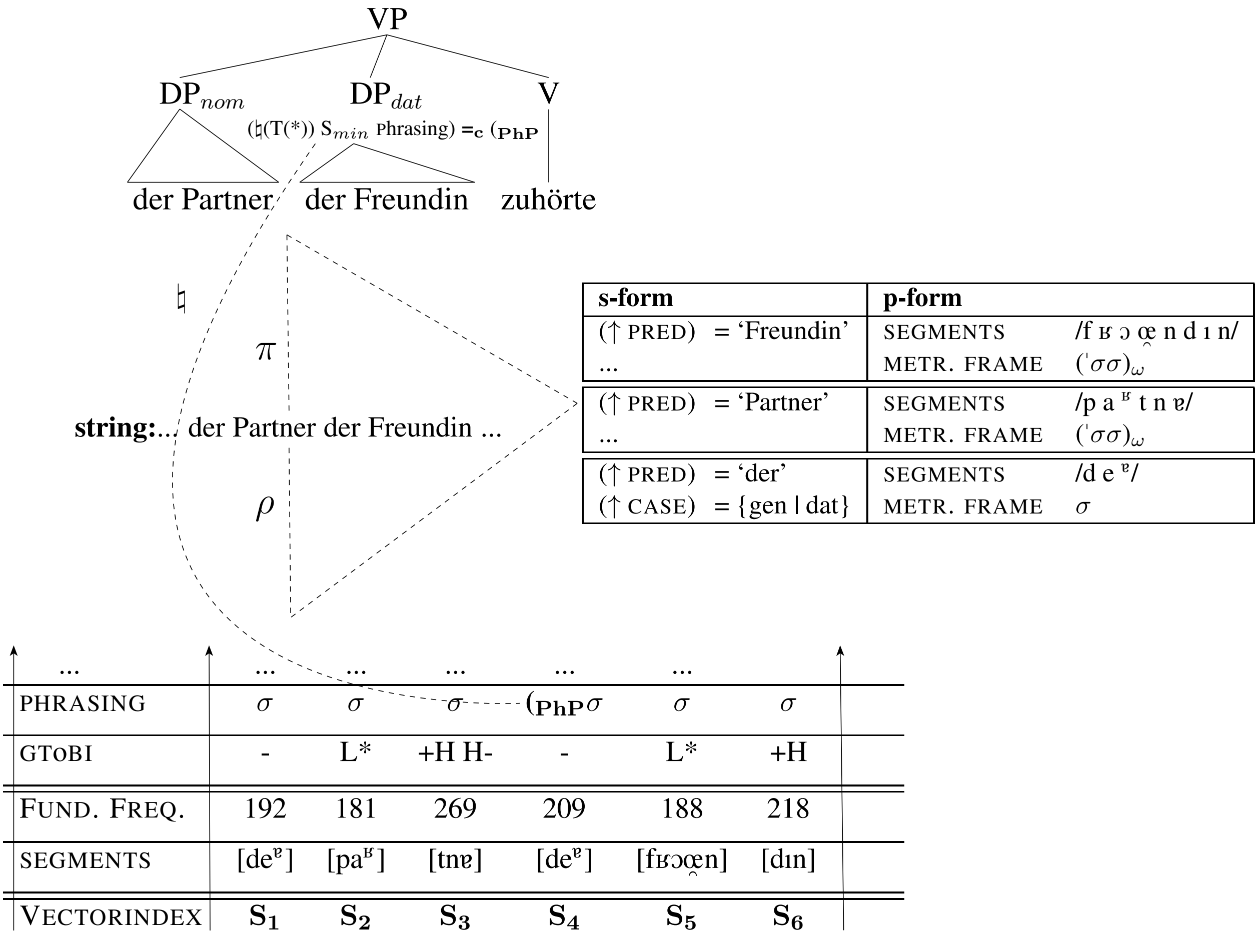

Figure 11: The comprehension of a dative construction at the prosody–syntax interface

As a result, the syntactic structure relating to the interpretation of the second DP as a dative object can only be parsed if it is preceded by a phonological phrase boundary in p-structure.

The same constraint annotation can be employed with a speech signal indicating a genitive construction, with a constraint annotation to the genitive DP indicating that a phonological phrase boundary *must not* be present preceding the second DP in p-structure ($\neq$ ($_{PhP}$).

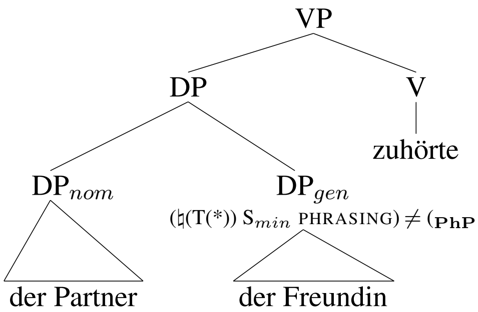

Figure 12: P-structure annotation in the c-structure relating to a genitive construction

These constraints effectively prevent syntax from trying to interpret every possible prosodic boundary, while at the same time enabling the syntactic constituent to rely on prosody in case of multiple syntactic phrasing options, thus reflecting the asymetric relationship between prosody and syntax.

5.3 Accounting for speaker variability

As described in Section 3, speakers show great variability with respect to the realisation of case. While some acoustic cues are applied by several speakers, others are less common. Furthermore, some speakers do not apply any features at all and seemingly do not differentiate between the two options dative and genitive by means of prosody. It is therefore essential that constraints (as in (8)) are not strictly implemented as 'hard' constraints, but allow for some speaker variability.

To account for data like this, OT-like constraints can be implemented in the c-structure rule annotation (originally proposed by Frank et al. (1998), see also Crouch et al. (2015) for an extension). 'OT-like' in this context means that the notion of constraints is not understood as in general Optimality Theory (Prince and Smolensky 2004) or in OT-LFG (Bresnan 2000) in that the underlying assumption is not the existence of a (close to) infinite set of candidates that are ranked according to OT constraints. Instead, the OT-*like* constraints are added to fully-constrained grammars that nevertheless allow for more than one analysis of an input candidate – as it is the case with the dative/genitive ambiguity. The OT-like marks thus rank the different, but syntactically correct analyses of one common input string. On the basis of information coming from other modules or known to the researcher to exist outside of the scope of grammar, e.g., the frequencies across speakers reported above, an OT-like mark can be added to a specific c-structure annotation. In contrast to classic OT rankings, which indicate *dispreference* for certain constructions, the constraints used here can also indicate a *preference*, thus allowing for a constraint that, e.g., expresses the preference for the presence of a prosodic phrase boundary at a certain position.

This system of OT-like constraints enables the softening of 'hard constraints' and allows for the implementation of phenomena, whose analysis cannot be easily divided into 'correct' and 'incorrect', as it is the case with the missing phonological phrase boundaries between the two DPs in a dative construction. That is, in order to account for speaker variability, the constraint that a syntactic dative construction only applies if there is a phonological phrase boundary after the first DP cannot be analysed as a hard constraint, but must be implemented as a soft constraint via OT-like constraints. The following example shows the syntactic rule for the dative including a disjunctive reference to p-structure and a OT-like mark for the member of the disjunction where a phonological phrase boundary is given.

(9) Dative: $\text{VP} \rightarrow \text{DP}_{nom} \quad \begin{array}{c} \text{DP}_{dat} \\ \{\ (\natural(T(*))\ \text{S}_{min}\ \text{PHRASING}) =_c (_{PhP} \\ \text{PHPBREAK} \in \text{o*} \\ \mid (\natural(T(*))\ \text{S}_{min}\ \text{PHRASING}) \neq (_{PhP}\ \} \end{array} \quad \text{V}$

The $\natural(T(*))$ in the second conjunct of (9) refers to the (set of) terminal nodes connected with the DP and the projection between c-structure and p-structure as described above. S_{min} PHRASING $=_c (_{PhP}$ requires that there is a phonological phrase boundary to the left of that DP.

The OT-like constraint PHPBREAK $\in$ o* indicates that the constraint PHPBREAK is part of the optimality structure (o*), where its nature (preference or dispreference) is defined also with reference to other constraints that are positioned higher or lower. In the following optimalityorder, the positive (+) CONSTRAINT_1 is ranked above +PHPBREAK which in turn is ranked above +CONSTRAINT_2.

(10) OPTIMALITYORDER +CONSTRAINT$_1$ +PHPBREAK +CONSTRAINT$_2$

Coming back to example (9), if the constraint cannot be fulfilled, then the structure is still valid as indicated by the second disjunct which allows for the phonological phrase to be absent ($\neq$ ($_{PhP}$). This means that the dative construction is preferably parsed if a boundary is present, but if that information is not given, then the dative structure is parsed nevertheless. This seems redundant, but given the fact that 30% of the speakers do not indicate a phonological phrase boundary in the dative, it is crucial that the constraint requesting a boundary is not a hard constraint, but rather indicates a 'preferred' structure (but does not discard a dative structure per se). The genitive rule, on the other hand, explicitely excludes the presence of a boundary and is thus parsed along with the unmarked dative in (9), resulting in syntactic ambiguity.[16]

(11) Genitive: DP $\rightarrow$ DP$_{nom}$ DP$_{gen}$
($\natural(T(*))$ S$_{min}$ PHRASING) $\neq$ ($_{PhP}$

The OT-like ranking of constraints allows for a detailed representation of variation and frequency of acoustic cues indicating a particular syntactic construction, as it only indicates a preference when specific information is present, but does not automatically prohibit the rule from firing if the relevant information is *not* present. In a sense, OT-like constraints thus enable the implementation of factors that are part of what is generally considered as *performance*, for example the frequency of a specific prosodic cue used by a group of speakers. In that sense, OT-like constraints are the pivot between real-case performance results and the rules and constraints of the 'core' grammar.

6 Conclusion

This paper showed a new approach to the syntax–prosody interface, distinguishing between two different processes: *production*, where a speaker produces an utterance, going from meaning to form (from syntax to prosody), and *comprehension*, where another's utterance is parsed by the recipient (from form to meaning, thus from prosody to syntax). In doing so, the interface combines three modules of grammar: a) syntax, which represents the linear and the hierarchical structure of the string (c-structure in LFG), b) a multidimensional lexicon which represents lexical phonological and morphosyntactic information of each word, and c) phonology/ prosody (p-structure) in form of the p-diagram, which allows for a compact, syllablewise representation of the speech signal at several levels.

The communication between c-structure and p-structure was defined on the basis of two transfer processes: the *transfer of vocabulary* and the *transfer of structure*. The *transfer of vocabulary* exchanges phonological and morphosyntactic information at the word-level and below via the multidimensional lexicon. Each dimension can only be accessed by the respective associated structure, i.e., information stored within the p(honological)-form is only available to p-structure, while s(yntactic)-form information is associated with syntactic structure. However, once a lexical dimension is triggered, other dimensions become available as well. In a sense, the

[16]As mentioned before, the exact prosodic structure of a genitive construction is left for further research with a homogeneous group of verbs. If significant prosodic indicators for a genitive interpretation were found, these constraints could be added to the rule in (11), indicating a preference for the genitive structure.

lexicon therefore functions as a kind of translator between lexical phonology and the terminal nodes of syntax.

This lower-level transfer process is complemented by the *transfer of structure* which exchanges information on syntactic and prosodic phrasing. The relationship between prosody and syntax is asymetric in the sense that prosody can disambiguate syntax, but cannot alter an unambiguous syntactic phrase, while syntactic phrasing always has a certain influence on prosody. The correspondence between the modules reflects this asymmetry: the *transfer of structure* always projects information on syntactic phrasing to p-structure during production, but, during comprehension, p-structure only supplies information on prosodic phrasing to syntax if there is a syntactic ambiguity (that is, if syntax requests this information).

This approach to the interface was tested by means of a concrete example: a production study on syntactic ambiguity caused by syncretic case forms in German and its possible disambiguation by means of prosodic phrasing. As was reported in Section 3, German speakers can indeed disambiguate dative and genitive case ambiguities by employing prosodic cues. During the *production* of a case structure, syntax therefore projects different phrasing possibilities to p-structure, respectively for the genitive and the dative. During *comprehension*, phonological phrase boundaries are calculated and encoded in p-structure on the basis of the concrete acoustic cues given in the speech signal. This information on prosodic domains is in turn available at the interface and can be used to disambiguate syntactic phrasing.

However, it was also noted in the production experiment that some acoustic cues indicating a certain syntactic interpretation are more common across speakers in comparison to other cues, and that up to 33% of the speakers do not apply any prosodic phrasing for the disambiguation of syntactic structures. To account for this variability, the paper employs OT-like soft constraints which allow for a syntactic structure to be preferred if a prosodic cue is given. However, if all prosodic indicators are absent from the speech signal, the multiple syntactic structures are nevertheless parsed, resulting in a true (and justified) syntactic ambiguity.

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