Chapter 25

Information structure

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Information structure as the hinge between sentence and discourse has been at the center of interest for linguists working in different areas such as semantics, syntax or prosody for several decades. A constraint-based grammar formalism such as HPSG encoding multiple levels of linguistic representation within the architecture of signs opens up the possibility to elegantly integrate such information about discourse properties. In this article, we discuss a number of approaches that have explored how to best integrate information structure as a separate level into the representation of signs. We discuss, which lexical and phrasal priciples have been implemented in these approaches and how they constrain the distribution of the various information structural features. Finally, we discuss how the various approaches are used to formulate theories about the interaction of syntax, prosody and information structure. In particular, we will see several cases where (word order) principles that used to be stipulated in syntax can now be formulated as an interaction of syntax and discourse properties.

1 Introduction

The *information structure* of a sentence captures how the meaning expressed by the sentence is integrated into the discourse. The *information structure* thus encodes which part of an utterance is informative in which way, in relation to a particular context. A wide range of approaches exists with respect to the question what should be regarded as the primitives of the information structure.

It is now commonly assumed that there are three basic dimension of information structure that are encoded in natural languages and that have been assumed as the basic primitives: (i) A distinction between what is new information advancing the discourse (*focus*) and what is known, i.e., anchoring the sentence in

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existing (or presupposed) knowledge or discourse (*background*), (ii) A distinction between what the utterance is about (*topic*, *theme*) and what the speaker has to say about it (*comment*, *rheme*), and (iii) and a dimension referred to as *information status* where entities that have already been mentioned in the discourse *given* ares distinguished from those that haven't been mentioned. (*new*). For all three ways of partitioning the information structure, we find approaches within the HPSG framework. Example (1) illustrated, how one utterance in the context of a question can be structured according to different partitionings of information structure.

(1) Q: What does Sarah drink?

	background		*focus*
A:	Sarah	drinks	TEA.
	topic	*comment*	

The focus/background division with focus as the part of an utterance that is informative with respect to the discourse is one of the most commonly adopted partitioning when studying information structure, and thus many approaches within the HPSG architecture as well assume a division into focus and background, such as the ones that will be discussed in this article: Engdahl & Vallduví (1996), De Kuthy (2002), Webelhuth (2007), Song & Bender (2012), Paggio (2009), Bildhauer (2008). Less common within the HPSG framework are approaches that take topic, i.e. the material that an utterance is about, as the central notion and assume topic and comment (or theme and rheme) as the primitives of the information structure. Most approaches discussed here assume that the background has one designated (mostly referential) element functioning as the topic (or link), among them are Engdahl & Vallduví (1996), De Kuthy (2002), Paggio (2009).

A third aspect of the information structure is captured under the notion of information status with primitives such as new and given. Here the discourse status of referential elements is of interest, i.e. whether they can be linked to previously mentioned items, i.e. whether they are (discourse) old or given, or whether they haven't been mentioned before and are thus (discourse) new. The representation of information status has received comparatively little interest within the HPSG community, the approach by De Kuthy & Meurers (2011) is one of the few approaches that explicitly integrate this dimension into their information structural architecture.

The need to represent discourse properties in a grammar architecture of signs results from the insight that in many, if not all, languages the way utterances are realized via their syntactic structure, morphological patterns and prosody very

often interacts with discourse requirements of these utterances. In other words, approaches dealing with constraints on word order in a particular construction need to encode that this particular word order is only grammatical given a particular context, or a particular accent pattern has to be connected to a particular discourse status of the accented elements. Most of the approaches discussed here include deal with such interface questions, and we therefore discuss the particular word order and phonetic theories that have been implemented in sections 6 and 7 in detail. As a starting point, however, we will first discuss the various architectural designs that have been implemented in order to be able to formulate the specific theories integrating discourse constraints.

2 Information structure in the architecture of signs

Several ways of representing information structure within the architecture of signs have been pursued as part of the HPSG framework: one of the earliest approaches, which is similar to the idea of F-marking as pursued in many syntax-based approaches to information structure in generative grammar (such as Jackendoff (1972),Selkirk (1982)), has been proposed by Manandhar (1994). He assumes that all signs have an additional appropriate feature INFO-STRUC which takes as its value objects of the sort *info-type*. A sign can then be specified for the subtypes of *info-type* shown in Figure 1 as its informational marking.

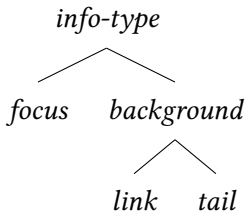

Figure 1: Type hierarchy under *info-type* of Manandhar (1994)

The distribution of the INFO-STRUC values in a sign is determined by the *Focus Inheritance Principle*, which enforces that in every phrase, the INFO-STRUC value of the mother subsumes the values of the INFO-STRUC of all of its daughters. The consequence of this principle is that if one daughter in a phrase is in the focus and the other one in the ground, then the mother's INFO-STRUC value is the smallest common super-type of both, namely *info-type*.

There are two problematic aspects of such an architecture. Firstly, it leads to a proliferation of syntactic markup of non-syntactic properties, in particular once one considers the full range of information structure notions, such as focus and focus projection, multiple foci, and the marking of other discourse functions such as topic. And secondly, the perspective of information structure as resulting from an independent interpretation process of syntactic markup does not support a view of syntax, information structure, and intonation as directly interacting modules, a view that can be nicely implemented in a multi-layer frameworks such as HPSG. More common are thus approaches that encode the information structure as a separate layer, i.e., a feature with its own structural representation.

In the original setup of signs introduced in Pollard & Sag (1994), the feature CONTEXT is introduced as part of *local* objects as a place to encode information relating to the pragmatic context (and other pragmatic properties) of utterances. In Engdahl & Vallduví (1996) it is argued that it would be most natural to also represent information structural information as part of this CONTEXT feature. Engdahl & Vallduví (1996) thus introduce the feature INFO-STRUC as part of the the CONTEXT and since they couch their approach into Vallduví (1992) information packaging account, INFO-STRUC is further divided into FOCUS and GROUND. All INFO-STRUC features take entire signs as their values. The complete specification is shown in Figure 2.

$$\begin{bmatrix} \textit{sign} & \\ \textsc{synsem|local|context|info-struc} & \begin{bmatrix} \textsc{focus} & \textit{sign} \\ \textsc{ground} & \begin{bmatrix} \textsc{link} & \textit{sign} \\ \textsc{tail} & \textit{sign} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Figure 2: Information structure in Engdahl & Vallduví (1996)

Another approach locating the representation of information structure with in the CONTEXT feature is the one by Paggio (2009) as part of a grammar for Danish. The INFOSTR feature TOPIC, FOCUS and BG take as their values list of indices. Since Paggio (2009) includes Minimal Recursion Semantics (MRS, (Copestake et al. 2005)) as the semantic representation[1], these indices can be structure shared with the argument indices of the semantic relations collected on the RELS list of the content of a sign. The basic setup is illustrated in Figure 3.

Several approaches encode infostruc as part of the CONTENT, such as Song

[1] A detailed discussion of the properties and principles of MRS as implemented in HPSG can be found in Koenig & Richter (2019), Chapter 24 of this volume.

$$\begin{bmatrix} \textit{sign} & \\ \textsc{synsem|local|context|infostr} & \begin{bmatrix} \textsc{focus} & \textit{list-of-indices} \\ \textsc{topic} & \textit{list-fo-indices} \\ \textsc{bg} & \textit{list-of-indices} \end{bmatrix} \end{bmatrix}$$

Figure 3: Information structure in Paggio (2009)

(2017) and Song & Bender (2012). Since they also use MRS as the semantic representation language, they enrich the architecture of *mrs* structures. The information structure itself is encoded via a feature ICONS (Individual Constraints), that is introduced parallel to HCONS (handle constraints) as part of the CONTENT.

$$\begin{bmatrix} \textit{sign} & \\ \textsc{synsem|local|content} & \begin{bmatrix} \textit{mrs} & \\ \textsc{hook} & \begin{bmatrix} \textit{hook} & \\ \textsc{icons-key} & \textit{info-str} \\ \textsc{clause-key} & \textit{event} \end{bmatrix} \\ \textsc{rels} & \textit{diff-list} \\ \textsc{hcons} & \textit{diff-list} \\ \textsc{icons} & \langle \ldots, \begin{bmatrix} \textit{info-str} & \\ \textsc{clause} & \textit{individual} \\ \textsc{target} & \textit{individual} \end{bmatrix}, \ldots \rangle \end{bmatrix} \end{bmatrix}$$

Figure 4: Information structure in Song & Bender (2012)

As pointed out by De Kuthy (2002), assuming that the information structure is part of *local* objects (which it is if it is part of the CONTEXT in HPSG as proposed by Engdahl & Vallduví (1996) or part of the CONTENT) is problematic in connection with a trace-based account of unbounded dependencies. Traces should not contribute anything to the information structure of a sentence. If one wants to develop an information structure approach which is independent of the decision of which kind of UDC theory one assumes, the only options for placing the information structure attribute are *synsem* objects or signs.

Information structure as part of *synsem* objects would suggest that it plays a role in syntactic selection. This possibility is assumed in Bildhauer & Cook (2011), and they thus represent INFO-STRUC as a feature appropriate for *synsem* objects (their account will be discussed in more detail in section 6. A third possibility is argued for in De Kuthy (2002) and Bildhauer (2008), namely that information structure should not be part of *synsem* objects. As a result, they encode information structure again as an additional feature of signs (similar to Manandhar (1994)

approach discussed above), but it is argued that the appropriate values should be semantic representations.

In De Kuthy (2002), a tripartite partition of information structure into focus, topic, and background is introduced. As to the question what kinds of objects should be defined as the values of these features, De Kuthy proposes the values of the INFO-STRUC features to be chunks of semantic information. It is argued that the semantic representation proposed in Pollard & Sag (1994) is not appropriate for her purpose, because the semantic composition is not done in parallel with the syntactic build-up of a phrase. Instead, the Montague-style semantic representation for HPSG proposed in Sailer (2000) is adopted, in which CONTENT values are regarded as representations of a symbolic language with a model-theoretic interpretation. As the semantic object language under CONTENT the language Ty2 (cf., Gallin (1975)) of two-sorted type theory is chosen. The resulting feature architecture is shown in Figure 5.

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phon} & \textit{list} \\ \textsc{synsem} & \textit{synsem} \\ \textsc{info-struc} & \begin{bmatrix} \textit{info-struc} & \\ \textsc{focus} & \textit{list-of-mes} \\ \textsc{topic} & \textit{list-of-mes} \end{bmatrix} \end{bmatrix}$$

Figure 5: The structure of INFO-STRUC in De Kuthy (2002)

The information structure is encoded in the attribute INFO-STRUC that is appropriate for signs and has the appropriate features FOCUS and TOPIC, with lists of so-called meaningful expressions (semantic terms, cf. Sailer (2000)) as values.

3 Information structure principles

The above sketched approaches all assume that signs contain some kind of structural representation of information structure, with the consequence that they need to introduce principles that constrain the values of the information structural features. Most approaches thus formulate two types of principles as part of their grammar fragment, one set of principles on the lexical level tying information structure to word level properties such as accents, and another set of principles on the phrasal level determining the distribution of information structure values between mother and daughters in a phrase.

3.1 Instantiating information structure on the word level

In the approach of Engdahl & Vallduví (1996) prosodic properties of English, in particular accent placement, are tied to specific information structural properties of words and phrases. On the word level, they thus introduce two principles that instantiate the information structure FOCUS and LINK when the word has a particular accent. The two principles are shown in Figure 6. Words with an A accent

$$word \rightarrow \boxed{1}\begin{bmatrix}\text{PHON|ACCENT} & A\\ \text{INFO-STRUC|FOCUS} & \boxed{1}\end{bmatrix}$$

$$word \rightarrow \boxed{1}\begin{bmatrix}\text{PHON|ACCENT} & B\\ \text{INFO-STRUC|GROUND|LINK} & \boxed{1}\end{bmatrix}$$

Figure 6: Information structure of words

always contribute focal information, i.e. the entire sign is structure-shared with the INFO-STRUC|FOCUS value, words carrying a B accent contribute link information, i.e. the entire sign is structure-shared with the INFO-STRUC|GROUND|LINK value.

A similar set of word level principles is introduced in the approach of De Kuthy (2002), where the information structure of utterance in German is also tied to words carrying particular accent patterns. The phonology of signs is altered as shown in Figure 7 to include an ACCENT attribute to encode whether a word receives an accent or not, and whether it is a rising or a falling accent in case it receives one.

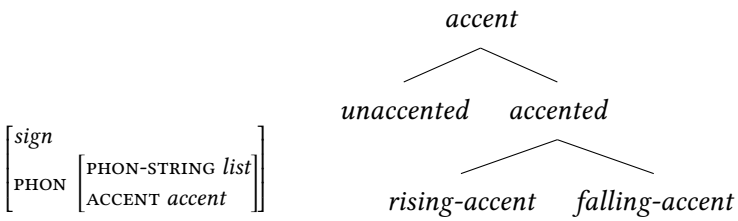

Figure 7: Representing pitch accents

The information structure of words is defined through the principle shown in Figure 16 which assigns the semantic contribution of the word to the focus or topic specification in the information structure representation of that word, depending on the type of accent the word receives.

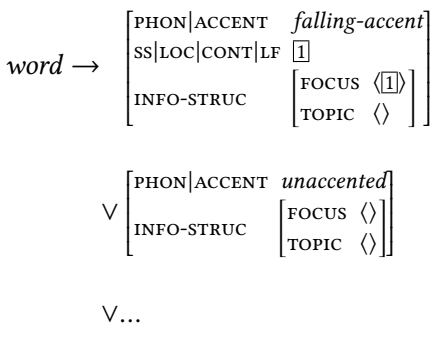

Figure 8: Relating intonation and information structure

3.2 Information structure principles on the phrasal level

3.2.1 Information packaging (Engdahl & Vallduví 1996)

One of the first approaches integrating an explicit representation of information structure into the HPSG architecture, Engdahl & Vallduví (1996) encode the information structure as part of the CONTEXT of signs with the help of an additional feature INFO-STRUC. As discussed above, on the lexical level the instantiation of these features can be triggered by phonetic properties, such as certain accents, for intonation languages like English. Phrasal signs must then satisfy the INFO-STRUC instantiation constraints in (2).

(2) INFO-STRUC *instantiation principles for English:*

Either (i) if a DAUGHTER's INFO-STRUC is instantiated, then the mother inherits this instantiation (for narrow foci, links and tails),

or (ii) if the most oblique DAUGHTER's FOCUS is instantiated, then the FOCUS of the mother is the sign itself (wide focus).

As a result, the resulting structure including a wide VP focus with the relevant INFO-STRUC values is shown in Figure 9.

According to the principle in (2), since the rightmost NP daughter carries an A accent, the entire sign is structure-shared with the focus value (or, in Engdahl and Valluvi's terms the focus value "is instantiated"), the second clause of the principle in (2) applies and the focus value of the VP mother is the sign itself, which is then inherited by the sentence itself.

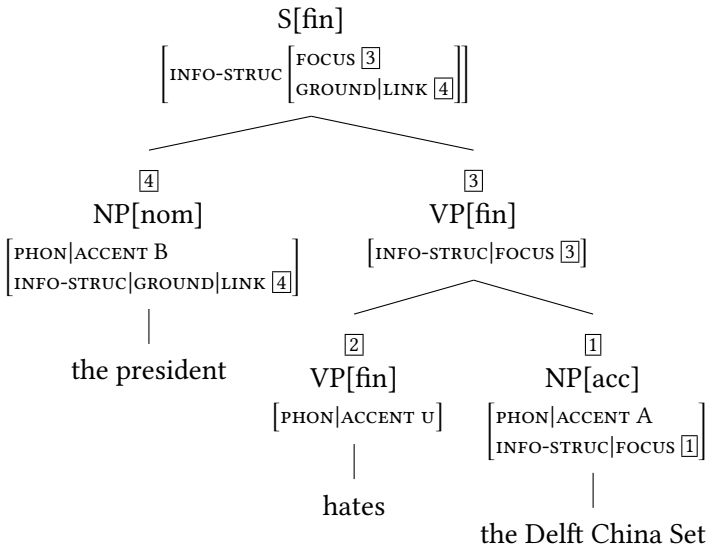

Figure 9: An example for VP focus in Engdahl & Vallduví (1996)

3.2.2 Information structure as structured meanings (De Kuthy 2002)

The structured meaning approach (von Stechow 1981; Jacobs 1983; Krifka 1992) provides a compositional semantic mechanism based on separate representations of the semantic contribution of the focus and that of the background. De Kuthy (2002) and Webelhuth (2007) worked out how such a structured meaning approach can be integrated into the HPSG architecture.

As discussed above, in De Kuthy (2002), the information structure is encoded in the attribute INFO-STRUC that is appropriate for signs and has the appropriate features FOCUS and TOPIC, with lists of so-called meaningful expressions as values. The background of a sentence in De Kuthy's approach is then defined to be that part of the logical form of the sentence which is neither in focus nor in topic. This characterization of background closely resembles the definition of background employed by the so-called *structured meaning* approaches to focus of von Stechow (1981), Jacobs (1983), or Krifka (1992). The INFO-STRUC value of a simple sentence with the focus as indicated in 3 is thus structured as shown in Figure 10.

The information-structure values of phrases are constrained by principles such as the one in Figure 11. The simplest case are those sentences where the focus or the topic does not project, i.e., only the words bearing an accent are in the topic

(3) Peter [[liest ein BUCH.]]$_F$
Peter reads a book

$$\begin{bmatrix} \text{S|LOC|CONT|LF } \exists x[book'(x) \wedge read'(p,x)] \\ \text{INFO-STRUC} \begin{bmatrix} \text{FOCUS } \langle \lambda y \exists x[book'(x) \wedge read'(y,x)] \rangle \\ \text{TOPIC } \langle\rangle \end{bmatrix} \end{bmatrix}$$

Figure 10: A sign representation including information structure

or in the focus of an utterance. In this case, the mother of a phrase just collects

$$\textit{phrase} \rightarrow \begin{bmatrix} \text{INFO-STR|FOCUS } \boxed{1} \oplus \text{COLLECT-FOCUS}\left(\boxed{2}\right) \\ \text{HEAD-DTR|INFO-STR|FOCUS } \boxed{1} \\ \text{NON-HEAD-DTRS } \boxed{2} \end{bmatrix}$$

$$\vee \begin{bmatrix} \text{PHON|PHON-STR } \boxed{1} \oplus \boxed{2} \\ \text{SS|LOC} \begin{bmatrix} \text{CAT|HEAD } \textit{noun} \vee \textit{prep} \\ \text{CONT|LF } \boxed{3} \end{bmatrix} \\ \text{INFO-STR|FOCUS } \langle \boxed{3} \rangle \\ \text{ANY-DTR}\left(\begin{bmatrix} \text{PHON|PHON-STR } \boxed{2} \\ \text{SS|L|CONT|LF } \boxed{4} \\ \text{INFO-STR|FOCUS } \langle \boxed{4} \rangle \end{bmatrix}\right) \end{bmatrix}$$

$$\vee \begin{bmatrix} \text{SYNSEM|LOC} \begin{bmatrix} \text{CAT|HEAD } \textit{verb} \\ \text{CONT|LF } \boxed{3} \end{bmatrix} \\ \text{INFO-STR|FOCUS } \langle \boxed{3} \rangle \\ \text{NON-HEAD-DTRS } \langle .., \begin{bmatrix} \text{SYNSEM} \begin{bmatrix} \text{FPP } \textit{plus} \\ \text{LOC|CONT|LF } \boxed{4} \end{bmatrix} \\ \text{INFO-STR|FOCUS } \langle \boxed{4} \rangle \end{bmatrix}, ... \rangle \end{bmatrix}$$

$$\vee ...$$

Figure 11: Extended focus projection principle

the focus values of all her daughters as ensured by the principle in Figure 11 [2]. A similar principle is needed to determine the TOPIC value of phrases.

For cases of so-called focus projection in NPs and PPs, it is assumed in De Kuthy (2002) that it is sufficient to express that the entire NP (or PP) can be focused if the rightmost constituent in that NP (or PP) is focused, as expressed by the second disjunct of the principle in Figure 11. If focus projection is possible in a

[2] The presentation differs from that in De Kuthy (2002), it is the one from De Kuthy & Meurers (2003). Definitions of the auxiliary relations:

certain configuration then this is always optional, therefore the focus projection principle for nouns and prepositions is formulated as a disjunct. The second disjunct of the principle in Figure 11 ensures that a phrase headed by a noun or a preposition can only be in the focus (i.e., its entire logical form is token identical to its focus value) if the daughter that contributes the rightmost part of the phonology of the phrase is entirely focused itself. Again, a similar principle needs to be provided for the TOPIC value of nominal and prepositional phrases.

For the verbal domain, the regularities are known to be influenced by a variety of factors, such as the word order and lexical properties of the verbal head (cf., e.g., von Stechow & Uhmann 1986). Since verbs need to be able to lexically mark which of their arguments can project focus when they are accented, De Kuthy & Meurers (2003) introduce the boolean-valued feature FOCUS-PROJECTION-POTENTIAL (FPP) for objects of type *synsem*. Figure 12 shows the relevant part of the lexical entry of the verb *lieben* (love) which allows projection from the object but not the subject:

$$\left[\begin{array}{l} \textsc{phon}|\textsc{phon-str}\ \langle \textit{lieben} \rangle \\ \textsc{arg-s}\ \left\langle \left[\begin{array}{l} \textsc{loc}|\textsc{cat}|\textsc{head}\ \left[\begin{array}{ll} \textit{noun} & \\ \textsc{case} & \textit{nom} \end{array}\right] \\ \textsc{fpp}\ \textit{minus} \end{array}\right], \left[\begin{array}{l} \textsc{loc}|\textsc{cat}|\textsc{head}\ \left[\begin{array}{ll} \textit{noun} & \\ \textsc{case} & \textit{acc} \end{array}\right] \\ \textsc{fpp}\ \textit{plus} \end{array}\right] \right\rangle \end{array}\right]$$

Figure 12: The focus projection potential of *lieben*

The third disjunct of the principle in Figure 11 then specifies under which circumstances focus can project in the verbal domain: a phrase headed by a verb can only be in the focus (i.e., its entire logical form is token identical to an element of its focus value) if the daughter that has the focus projection potential (FPP *plus*) is entirely focused itself.

3.2.3 Information structure inheritance in MRS

As introduced above, in the MRS based approach of Paggio (2009) the information structure is part of the CONTEXT, consisting of FOCUS, TOPIC and BACKGROUND features which are structure shared with the respective INDEX values

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$$\textsc{any-dtr}\left(\boxed{1}\right) := \left[\textsc{head-dtr}\ \boxed{1}\right].$$
$$\textsc{any-dtr}\left(\boxed{1}\right) := \left[\textsc{non-head-dtrs}\ \textit{element}\left(\boxed{1}\right)\right].$$

$$\textsc{collect-focus}\left(\langle\rangle\right) := \langle\rangle.$$
$$\textsc{collect-focus}\left(\left\langle \left[\textsc{info-struc}|\textsc{focus}\ \langle\boxed{1}\rangle\right] \mid \boxed{2}\right\rangle\right) := \left\langle \boxed{1} \mid \textsc{collect-focus}\left(\boxed{2}\right)\right\rangle.$$

of the semantic representation of a phrase. Paggio (2009) connects the distribution of information structure values to particular clausal types and introduces new phrasal subtypes which constrain the distribution of information structure in the respective phrase. One example for such a new phrasal subtype is the *focus-inheritance* as defined in figure 13, which then has to be cross-classified with every basic phrasal subtype (such as *hd-comp, hd-spec, had-adj*, etc.) in order to constrain the distribution of focus values across all phrasal subtypes.

$$\left[\begin{array}{ll} \textit{focus-inheritance} & \\ \textsc{synsem|loc|context} & \left[\begin{array}{ll} \textsc{focus} & \langle \boxed{2}, \boxed{1} \rangle \\ \textsc{bg} & \boxed{3} \end{array}\right] \\ \textsc{hd|synsem|loc|context} & \left[\begin{array}{ll} \textsc{focus} & \boxed{1} \\ \textsc{bg} & \boxed{3} \end{array}\right] \\ \textsc{non-hd} & \left[\begin{array}{ll} \textsc{synsem|loc|context|focus} & \langle \boxed{2} \rangle \\ \textsc{accent} & \textit{true} \end{array}\right] \end{array}\right]$$

Figure 13: focus-inheritance in Paggio (2009)

The principle in 13 ensures that the list of focus values of the mother is the list of focus values of the head daughter plus the focus value of the non-head daughter, in case it is accented. Similar principles are defined for the inheritance of background values, also depending on the accent status of the non-head daughter. Paggio further assumes that each phrasal subtype has further subtypes connecting it to one of the information structure inheritance phrasal types. For examples, she assumes that there is a phrasal subtype *focus-hd-adj* that is a subtype both of *hd-adj* and of *focus-inheritance*. Finally, clausal types are introduced that account for the information structure values at the top level of a clause. For example, the *decl-main-all-focus* as shown in figure 14, is a clause, in which both the background and the topic values are empty and the mother collects the focus values from the head and the non-head daughter.

Different from Paggio's approach, Song (2017), Song & Bender (2012) locate the representation of information structure within the MRS based CONTENT value of signs. The list elements of information structural values build up for a phrase consists of focus, background or topic elements co-indexed with the semantic INDEX values of the daughters of that phrase. The main point of their approach is that they want to be able to represent underspecified information structural values, since very often a phrase, for example with a certain accent pattern, is ambiguous with respect to the context in which it can occur and thus is ambiguous with respect to its information structure values. An example they discuss is the one in (4), where the first sentence could be an answer to the question

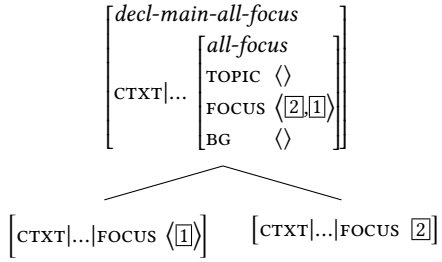

Figure 14: Declarative all-focus construction

What barks? and thus signal narrow focus, whereas the second utterance could be answer to the question *What happened?* and signal broad focus.

(4) a. [[The DOG]]$_F$ barks.
b. [[The DOG barks]]$_F$.

The approach pursued in Song & Bender (2012) thus assumes, that the two possible readings in (4) are further specializations of one MRS which is associated with one syntactic structure and includes underspecified values, in particular the type of the ICONS element for the constituent *barks*, leaving it open whether it is part of the focus or not. Unfortunately they don't specify how a potential focus projection or focus instantiation principle for a non-ambiguous phrase could look like in their approach. They only mention that "it at least plausible that MRS and ICONS will contain enough information to calculate the range of fully-specified information structures for each sentence".

4 Topics

Most HPSG approaches are based on a focus/background division of the information structure. To capture aspects of a topic vs. comment distinction, or to be able to specify topics as a special element in the background, they include an additional feature or substructure for topics. Engdahl & Vallduví (1996), for example, divide the GROUND into LINK and TAIL, where the link is a special element of the background linking it to the previous discourse, just like topics. In the approaches of De Kuthy (2002), Song & Bender (2012), Paggio (2009), and additional feature TOPIC is introduced, parallel to FOCUS and BACKGROUND, in order to distinguish discourse referents as topics from the rest of the background.

Most approaches don't introduce separate mechanisms for the distribution of

TOPIC values, but assume that similar principles as the ones introduced for focus can constrain topic values, as mentioned above for the approach of De Kuthy (2002). A more specific example can be found in Paggio (2009), where a constraint on topicalization constructions including a topic-comment partitioning is formulated, as illustrated in Figure 15. This *inv-topic-comment* phrasal type con-

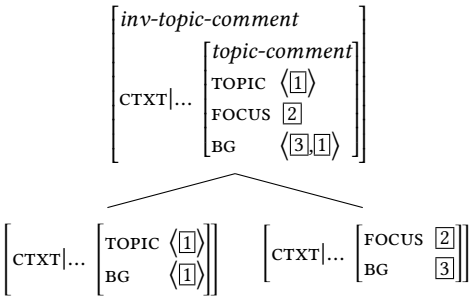

Figure 15: Topicalization construction with extracted topic

strains the information structure values of topicalization constructions in Danish characterized by subject verb inversion, where the topic corresponds to the topicalized complement, as illustrated by the example in (5) from Paggio (2009).

(5) og [i det nederste vindue]$_T$ [tager man og saetter urtepotten]$_F$
and in the lowest window takes one and puts flowerpot.DEF
'And in the lowest window you put the flowerpot.'

5 Givenness

In De Kuthy & Meurers (2011), it is shown how the HPSG approach to information structure of De Kuthy (2002) and colleagues can be extended to capture givenness and to make the right predictions for so-called *deaccenting*, which has been shown to be widespread (Büring 2006). In contrast to Schwarzschild (1999), who spells out his approach in the framework of alternative semantics Rooth (1992), they show how the notion of givenness can be couched in a standard structured meaning approach – thereby preserving the explicit, compositional representations of focus.

The example in in (6) illustrated the necessity to include information about the givenness into information structural setup.

(6) The conference participants are renting all kind of vehicles. Yesterday, Bill came to the conference driving a red convertible and today he's arrived with a blue one.
   a. What did John rent?
   b. He (only) rented [[a GREEN convertible]]$_F$.

The context in (6) introduces some conference participants, Bill, the rental of vehicles, and red and blue convertibles into the discourse. Based on this context, when considering the question (6a) asking for the object that John is renting as the focus, one can answer this question with sentence (6b), where *a green convertible* is the focus: Out of all the things John could have rented, he picked a green convertible. In this focus, only *green* is new to the discourse, whereas convertibles were already given in the context, and still the entire NP is in the focus

To capture such cases of focus projection, an additional feature GIVEN is introduced as part of the setup of De Kuthy (2002) as already discussed in section 3.2.2. The relation between pitch accents and the information structure of words is still defined by the principle shown in Figure 16 depending on the type of accent the word receives.

$$\textit{word} \rightarrow \left[\begin{array}{ll} \textsc{phon}|\textsc{accent} & \textit{accented} \\ \textsc{ss}|\textsc{loc}|\textsc{cont}|\textsc{lf} & \boxed{1} \\ \textsc{struc-meaning} & \left[\begin{array}{ll} \textsc{focus} & \langle \boxed{1} \rangle \\ \textsc{given} & \langle\rangle \end{array}\right] \end{array}\right] \vee \left[\begin{array}{ll} \textsc{phon}|\textsc{accent} & \textit{unaccented} \\ \textsc{struc-meaning} & \left[\begin{array}{ll} \textsc{focus} & \langle\rangle \\ \textsc{given} & \langle\rangle \end{array}\right] \end{array}\right] \vee \ldots$$

Figure 16: Relating intonation and information structure for words

We extend the Focus Projection Principle of De Kuthy & Meurers (2003) with a disjunct capturing focus projection in the presence of givenness. Figure 17 shows the resulting principle.

The fourth disjunct of the Focus Projection Principle[3] captures the previously unaccounted cases where given material in a focused phrase is deaccented. Focus in those examples can project from a focused daughter in a position which normally does not allow focus projection. This only is an option if all other daughters

[3]The auxiliary relations are defined as:

$$\textsc{dtrs-list}\left(\left\langle \boxed{1} | \boxed{2} \right\rangle\right) := \left[\begin{array}{ll} \textsc{head-dtr} & \boxed{1} \\ \textsc{non-hd-dtrs} & \boxed{2} \end{array}\right]$$

$$\textsc{given-sign-list} := \langle\rangle.$$

$$\textsc{given-sign-list} := \left\langle \left[\begin{array}{ll} \textsc{ss}|\textsc{l}|\textsc{cont}|\textsc{lf} & \boxed{1} \\ \textsc{struc-meaning} & \left[\textsc{given} \left\langle \boxed{1} \right\rangle\right] \end{array}\right] \middle| \textsc{given-sign-list} \right\rangle.$$

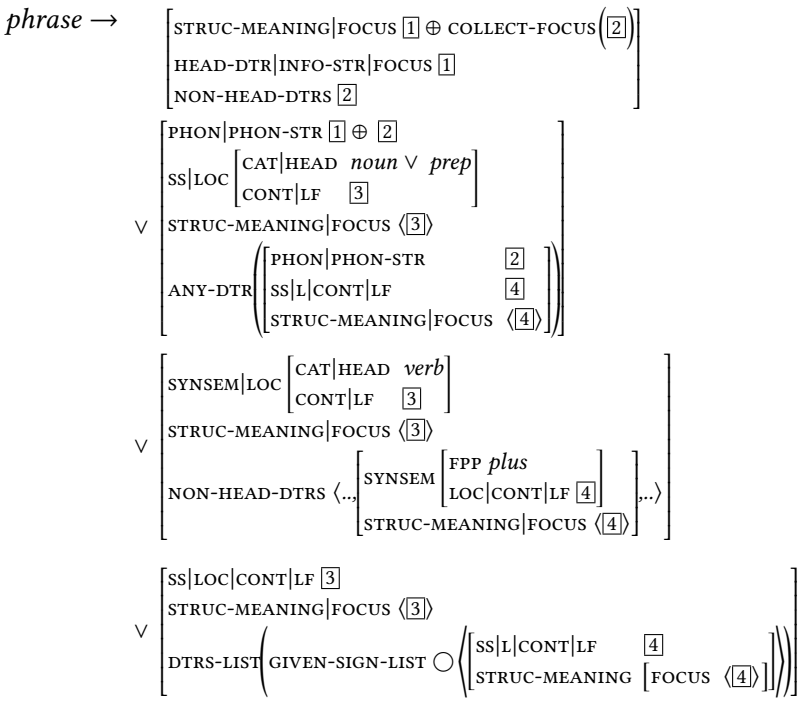

Figure 17: Focus Projection Principle

in that focused phrase are *given*. Spelling this out, the fourth disjunct of the principle in Figure 17 specifies that the mother of a phrase can be in the focus (i.e., the entire LF value of the mother's CONTENT is token identical to an element on the mother's FOCUS list) if it is the case that the list of all daughters (provided by *dtrs-list*) consists of *given* signs into which a single *focused* sign is shuffled (◯).[4] As before, a sign is focused if its LF value is token identical to an element of its FOCUS value; and a sign is given if its LF value is token identical to an element of its GIVEN value.

The pitch accent in this example is on the adjective *green* so that the principle in Figure 16 licenses structure sharing of the adjective's content with its FOCUS value. In the context of the question (6a), the entire NP *a green convertible* of example (6b) is in the focus. In the phrase *green convertible*, the clause licensing focus projection in NPs does not apply since the adjective *green*, from which

[4]If only binary structures are assumed, as in the examples in this paper, the principle can be simplified. We here kept the general version with recursive relations following De Kuthy & Meurers (2003), which also support flatter structures.

the focus has to project in this case, is not the rightmost element of the phrase. What does apply is the fourth disjunct of the principle licensing focus projection in connection with givenness. Since the noun *convertible* is given, the adjective *green* is the only daughter in the phrase that is not given and focus is allowed to project to the mother of the phrase. In the phrase *a green convertible*, focus projection is again licensed via the clause for focus projection in noun phrases, since the focused phrase *green convertible* is the rightmost daughter in that noun phrase.

6 Information structure and word order

The explicit representation of information structure as part of signs in HPSG opens up the possibility of providing explanations for constraints previously stipulated in syntax, such as word order constraints, by deriving the constraints from the nature of the integration of a sentence into the discourse. Many of the approaches discussed in the previous section employ the information structural architecture exactly in this way and formulate principles linking word order to discourse properties.

One first such approach is presented in Engdahl & Vallduví (1996), where word order constraint for Catalan are couched into the information structure set up discussed in section 3.2. The basic observation is that in Catalan the word order within the sentential core is VOS and that every constituent within this sentential core is interpreted as focal. If an argument of the main verb of a sentence is to be interpreted as non-focal, it mus be clitic-dislocated. The example in 7 from Engdahl & Vallduví (1996) illustrated such two cases.

(7) a. Ahir [[va tornar a Barcelona el PRESIDENT.]]$_F$
yesterday return to Barcelona the president

b. A Barcelona$_1$ [[hi$_1$ va tornar el PRESIDENT.]]$_F$
to Barcelona returned the president

c. [[Hi$_1$ va tornar el PRESIDENT]]$_F$a Barcelona.
'Yesterday, the president returned to Barcelona.'

With respect to modelling this within the HPSG account, they assume that phrases associated with a LINK interpretation should be constrained to be left dislocated whereas phrases associated with a TAIL interpretation should be right attached. They thus introduce the following ID schema for Catalan:

(8) *Head-Dislocation Schema for Catalan:*
The DTRS value is an object of sort *head-disloc-struc* whose HEAD-DTR|SYNSEM|LOCAL|CATEGORY value satisfies the description $\left[\text{HEAD } \textit{verb}\left[\text{VFORM } \textit{finite}\right], \text{SUBCAT } \langle\rangle\right]$, and whose DISLOC-DTRS|CONTEXT|INFOSTRUC value is instantiated and for each DISLOC-DTR, the HEAD-DTR|SYNSEM|LOCAL|CONTENT value contains an element which stands in a *binding* relation to that DISLOC-DTR.

The principle requires that the information structure value dislocated daughters of a finite sentences has to be GROUND. An additional LP statement then captures the relation between the directionality of the dislocation and a further restriction of the GROUND value, as illustrated in Figure 18. This LP statement is

LINK > FOCUS > TAIL

Figure 18: LP constraint on information structure in Catalan

meant to ensure that link material must precede focus material and focus material must precede tails. By this, Engdahl & Vallduví (1996) want to ensure that left-detached constituents are always interpreted as links and right-detached constituents as tails.

The insights from Engdahl and Vallduvi's approach are the basis for an approach accounting for clitic left dislocation in Greek presented by Alexopoulou & Kolliakou (2002). The representation of information structure with the features FOCUS, and GROUND (further divided into LINK and TAIL, is taken over as well as the phonological constraints on words and the information-structure instantiation principle. In order to account for clitic left dislocation, as illustrated in example 9, an additional feature CLITIC is introduced as appropriate for *nonlocal* objects.

(9) a. Pii simetehoun s' afti tin paragogi?
b. Tin parastasi *ti* skinothetise o Karolos KOUN ...
the performance directed the Karolos Koun

The Linkhood Constraint shown in Figure 19 ensures that links (i.e. elements whose INFOSTRUC|LINK value is instantiated) can only be fillers that are "duplicated" in the morphology by a pronominal affix, i.e. it is required that there is an element on the CLITIC list of the head daughter.

The Linkhood Constraint thus has two purposes, it ensures clitic doubling and it connects the particular word order of left dislocated phrase to discourse properties by requiring the filler daughter to be the link of the entire clause.

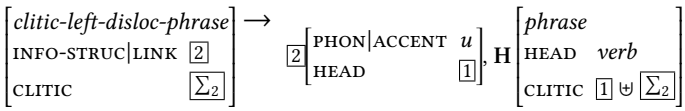

Figure 19: The Linkhood Constraint for clitic left dislocation phrases

The approach of De Kuthy (2002) relates the occurrence of discontinuous NPs in German to specific information-structural contexts, and De Kuthy & Meurers (2003) show that the realization of subjects as part of fronted non-finite constituent and its constraints can be accounted for based on independent information-structure conditions.

Based on the setup discussed in section 3.2.2 above, constraints are formulated that constrain the occurrence of discontinuous NPs and fronted VPs based on their information structure properties. The type of discontinuous NPs that are at the center of De Kuthy's approach are so-called NP-PP split construction, in which a PP occurs separate from its nominal head, as exemplified in (10).

Example (10) illustrated the type of discontinuous NPs

(10) a. *Über Syntax* hat Max sich [ein Buch] ausgeliehen.
about syntax has Max self a book borrowed
'Max borrowed a book on syntax.'

b. [Ein Buch] hat Max sich *über Syntax* ausgeliehen.
a book has Max self about syntax borrowed

The information structure propertied of discontinuous noun phrases are summarized in De Kuthy (2002) in the following principle:

> In an utterance, in which a PP occurs separate from an NP, either the PP or the NP must be in the focus or in the topic of the utterance, but they cannot both be part of the topic or the same focus projection.

The last restriction can be formalized as: they cannot be part of the same meaningful-expression on the FOCUS list or the TOPIC list of the INFO-STRUC value of the utterance.

As discussed in De Kuthy & Meurers (2003), it has been observed that in German it is possible for ergative and unergative verbs to realize a subject as part of a fronted non-finite verbal constituent. This is exemplified in (11).

(11) a. [Ein Fehler unterlaufen] ist meinem Lehrer noch nie.
an$_{nom}$ error crept in is my teacher still never
'So far my teacher has never made a mistake.'

b. [Haare wachsen] können ihm nicht mehr.
hair$_{nom}$ grow can him not anymore
'His hair cannot grow anymore.'

c. [Ein Außenseiter gewonnen] hat hier noch nie.
an$_{nom}$ outsider won has hier still never
'An outsider has never won here yet.'

In order to account for the context-sensitive occurrence of such fronted verbal constituents, specific information structure properties of fronted verb phrases need to be expressed in a principle expressing what De Kuthy and Meurers refer to as Webelhuth's generalization: In an utterance in which a verb phrase occurs as a fronted constituent (i.e., the filler of a head-filler phrase) this entire verb phrase must be in the focus of the utterance (i.e., the FOCUS value of the fronted constituent must be identical to its semantic representation). Figure 20 shows the formalization of this principle.

$$\begin{bmatrix} \textit{head-filler-phrase} \\ \text{NON-HEAD-DTR|SYNSEM|LOC|CAT|HEAD} \;\; \textit{verb} \end{bmatrix} \rightarrow \begin{bmatrix} \text{INFO-STRUC|FOCUS} \left\langle \boxed{1} \right\rangle & \\ \text{NON-HEAD-DTR} & \begin{bmatrix} \text{INFO-STRUC|FOCUS} & \left\langle \boxed{1} \right\rangle \\ \text{SYNSEM|LOC|CONT|LF} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Figure 20: Webelhuth's generalization

Combining the new lexical specifications, the focus projection rule for the verbal domain, and the partial fronting focus requirement with the basic setup of De Kuthy (2002) one obtains a theory which predicts that subjects can only be part of a fronted verbal projection if they can be the focus exponent. The sketch of an analysis for an example such as (**??**) is illustrated in Figure 21. The entry of *gewinnen* (to win) (the base form of the verb *gewonnen* in example (11c) in figure 22 encodes the lexical property that the subject of this intransitive verb has focus projection potential.

Under the assumption that in example (11c) the noun *Außenseiter* carries a pitch accent, the information-structure principle for words in Figure 16 ensures that the noun contributes its LOGICAL-FORM value to its FOCUS value. The focus projection principle of Figure 11 ensures that the focus can project over the entire NP *ein Außenseiter*, i.e., its FOCUS element is identical to its LF value. Since *ein Außenseiter* as the subject of *gewonnen* in the tree in Figure 21 is lexically marked

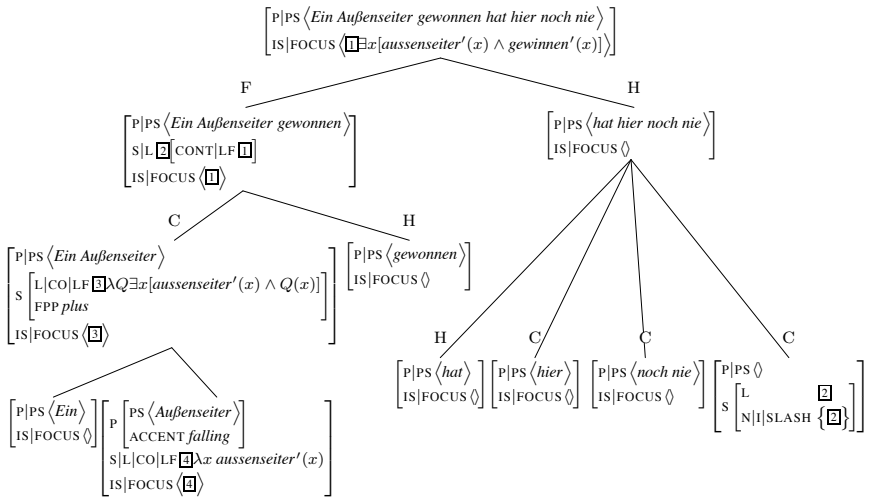

Figure 21: Partial VP fronting in De Kuthy & Meurers (2003)

$$\begin{bmatrix} \textsc{phon} & \langle \textit{gewinnen} \rangle \\ \textsc{arg-s} & \left\langle \begin{bmatrix} \textsc{fpp} & \textit{plus} \\ \textsc{loc|cat|head|case} & \textit{nom} \end{bmatrix} \right\rangle \end{bmatrix}$$

Figure 22: The lexical entry of *gewinnen* (to win)

as FPP *plus*, the principle governing focus projection in the verbal domain in Figure 11 licenses the focus to project over the entire fronted verbal projection *ein Außenseiter gewonnen*. The fronted constituent thus contributes its LF value to its FOCUS value. In this example, the focus does not project further so that in the head-filler phrase the focus values of the two daughters are simply collected as licensed by the first disjunct of the focus principle in Figure **??**. As a result, the FOCUS value of the fronted verbal projection is the FOCUS value of the entire sentence. Finally, note that the example satisfies Webelhuth's generalization, which requires a fronted verbal projection to be the focus of the utterance as formalized in Figure 20.

In the same spirit, Bildhauer & Cook (2010) show that sentences in which multiple elements have been fronted are directly linked to specific types of information structure. In German as a V2 language, normally exactly one constituent oc-

curs in the position before the finite verb in declarative sentences. But so-called multiple fronting examples with more than one constituent occurring before the finite verb have been well attested in naturally occurring data, two examples from Bildhauer & Cook (2010) are shown in (12).

(12) a. [Dem Saft] [eine kräftige Farbe] geben Blutorangen.
to.the juice a more.vivid colour give blood.oranges
'What give the jiuce a more vivid colour is blood oranges.'

b. [Stets] [einen Lacher] [auf ihrer Seite] hatte die Bubi Ernesto Familie.
always a laugh on their side had the Bubi Ernesto Family
'Always good for a laugh was the Bubi Ernesto Family.'

But, as discussed by Bildhauer and Cook, such multiple fronting examples seem to require very special discourse conditions in order to be acceptable. Just like the fronted verb phrases discussed in De Kuthy & Meurers (2003) above, Bildhauer & Cook (2010) propose to analyze multiple fronting constructions in German as head-filler phrases, which in this case introduce a topic shift. Following the approach by Müller (2005), multiple fronting configurations can be identified via the filler daughter which must have a HEAD|DSL (double shlash) value of type *local*. As introduced above, Bildhauer & Cook (2010) assume that an information structure attribute is specified in *symsem* objects, with the features FOCUS and TOPIC taking lists of *elementary predications* as their values. In general, multiple fronting *head-filler* phrases are restricted by the constraint in 23.

$$\begin{bmatrix} \textit{head-filler-phrase} \\ \text{NON-HEAD-DTRS} \ \langle [\text{HEAD|DSL} \ \textit{local}] \rangle \end{bmatrix} \rightarrow \begin{bmatrix} \text{IS} \ \textit{pres} \vee \textit{a-top-com} \vee \ldots \end{bmatrix}$$

$$\begin{bmatrix} \textit{head-filler-phrase} \\ \text{IS} \ \textit{pres} \end{bmatrix} \rightarrow \begin{bmatrix} \text{SS|LOC|CAT|HEAD|DT} \ \langle [\text{LOC|CONT|RELS} \ \boxed{1}] \rangle \\ \text{HD-DTR|SS|IS|FOCUS} \ \langle \boxed{1} \rangle \end{bmatrix}$$

Figure 23: Relating multiple fronting to focus

The first constraint ensures that *head-filler* phrases that are instances of multiple frontings are restricted to have an *is*-value of an appropriate type[5] The second

[5]Bildhauer & Cook (2010) assume that the type *is* as the appropriate value for IS has several subtypes specifying specific combinations of TOPIC and FOCUS values, such as *pres* for presentational focus or *a-top-com* for assessed-topic-comment.

constraint then ensures that in presentational multiple frontings the designated topic of the non-head daughter (i.e. the verbal head of the *head-filler* phrase) must be focused. The feature DT lexically specifies which element, if any, is normally realized as the Topic for a particular verb. This constraint thus encoded what Bildhauer & Cook (2010) call "topic shift": the non-fronted element in a multiple fronting construction that would preferably be the topic is realized as a focus. A similar constraint is introduced for another instance of multiple frontings, which is called *propositional assessment* multiple frontings. Here it has to be ensured that the designated topic must be realized as the topic somewhere in the head-daughter and the head-daughter must also contain a focused element.

Webelhuth (2007) provides another account of the special information structural requirements of fronted constituents, in this case of predicate fronting in English that is based on the interaction of word order and information structural constraints.

(13) I was sure that Fido would bark and *bark he did*.

The principles part of Webelhuth's account require that in such cases of predicate fronting the auxiliary is focussed and the remainder of the sentence is in the background. The interaction of the two principles in Figure 24. The first

$$\begin{bmatrix} \textit{aux-wd} \\ \text{ARG-S} \ \langle \textit{NP}, \textit{gap-ss} \rangle \end{bmatrix} \rightarrow \begin{bmatrix} \text{SS|STATUS} \ \textit{foc} \\ \text{ARG-S} \quad \langle \left[\text{STATUS} \ \textit{bg} \right], \textit{gap-ss} \rangle \end{bmatrix}$$

$$\left[\textit{PRED-PREPOS-PH} \right] \rightarrow \begin{bmatrix} \textit{HD-FILL-PH} \\ \text{NON-HD-DTR} \ \left[\text{SS|STATUS} \ \textit{bg} \right] \end{bmatrix}$$

Figure 24: Predicate preposing phrases

constraint ensure that auxiliary words whose predicate complement could be preposed (i.e. is of type *gap-ss* have the information status *focus*, whereas the status of the first argument (the subject) is *background*. Additional constraints then ensure that auxiliary words with a gapped second argument can only occur in predicate preposing phrases, and vice versa, that predicate preposing phrases contain the right kind of auxiliary.

7 Information structure and prosody

A lot of languages mark information structure prosodically, as for example English and German, where pitch accents of various shapes are used to mark focus.

Accordingly, several of the above discussed approaches include a component, which enriches the phonology representation of signs such that is allows the integration of the necessary prosodic aspects, as for example accents.

Engdahl & Vallduví (1996) assume, that signs can be marked for particular accents signalling focus or links in English, so-called A and B accents. In a similar way, De Kuthy (2002) extend the PHON value such that it includes a feature ACCENT, in order to formulate constraints on the connection between accents and information structure markings. Since most of the above discussed approaches don't include a detailed analysis of the prosodic properties of the respective language that investigated with respect to discourse properties, most approaches don't go beyond the postulation of one or two particular accents, that are somehow encoded as part of the PHON value. These accents then more or less serve as an illustration how lexical principles can be formulated within a particular theory that constrain the distribution of information structural values on the lexical level. The more articulate such a representation of PHON values including accent pattern, intonation contours, boundary tone etc is, the more detailed the principles could be that are needed to connect information structure to prosodic patterns in languages that signal discourse properties via intonation contours.

In Bildhauer (2008) such a detailed account of the prosodic properties of Spanish is developed together with a proposal how to integrate prosodic aspects into the PHON value, also allowing a direct linking of the interaction of prosody and information structure. In his account, the representation of PHON values in HPSG is enriched to include four levels of prosodic constituency, i.e., phonological utterance, intonational phrases, phonological phrases and prosodic words. The lowest level, prosodic words of type *pwrd*, include the features SEGS, which correspond to the original PHON value assumed in HPSG, and additional features such as PA for pith accents or BD for boundary tones, to encode whether a boundary tone is realized on that word. The additional features UT (phonological utterance), IP (intonational phrase) and PHP (phonological phrase) encode via the the typ EPR (edges and prominence) which role a prosodic word plays in higher level constituents. For examples, the feature DTE (designated terminal element) specifies, whether the word is the most prominent in a phonological phrase. A sign's PHON list then contains all *pwrd* objects and relational constraints define the roles each prosodic word plays in the higher prosodic constituents. This flat representation of prosodic constituency still allows to express constraints about intonational contours associated with certain utterance types. One example discussed in Bildhauer's work is the contour associated with broad focus declaratives in Spanish, which can be decomposed into a sequence of late-rise (L*H) prenuclear accents,

followed by an early-rise nuclear accent (LH*), followed by a low boundary tone (L%). The constraint introduced to model this contour for declarative utterances thus instantiates the BD value (boundary tone) of the last PWRD in the PHON list to low, instantiates a nuclear pitch accent *low-hig-star* on this rightmost prosodic word and ensures that the a prenuclear pitch accent *low-star-high* is instantiated on every preceding compatible prosodic word. The resulting constraint is shown in Figure 25.

$$\textit{DECL-TUNE}\left(\boxed{1}\right) \leftrightarrow \boxed{1} = \boxed{2} \oplus \left\langle \begin{bmatrix} \text{PA} & \textit{low-high-star} \\ \text{BD} & \textit{low} \end{bmatrix} \right\rangle \wedge$$
$$\boxed{2} = \text{LIST}\left(\begin{bmatrix} \text{BD} & \textit{none} \end{bmatrix}\right) \wedge$$
$$\boxed{2} = \text{LIST}\left(\begin{bmatrix} \text{PA} & \textit{none} \end{bmatrix}\right) \bigcirc \text{LIST}\left(\begin{bmatrix} \text{PA} & \textit{low-star-high} \end{bmatrix}\right)$$

$$\begin{bmatrix} \textit{SIGN} \\ \text{EMBED} & - \end{bmatrix} \rightarrow \begin{bmatrix} \text{PHON} & \boxed{1} \end{bmatrix} \wedge \text{DECL-TUNE}\left(\boxed{1}\right)$$

Figure 25: Intonational contour of Spanish declarative utterances

The second constraint in Figure 25 ensure that only unembedded utterances can be constrained to the just described declarative tune. That this specific contour is then compatible with a broad focus reading is ensured by an additional principle expressing a general focus prominence constraint for Spanish, namely that focus prominence has to fall on the last prosodic word in the phonological focus domain, which in the case of a broad focus can be the entire utterance. Figure 26 shows the resulting principle in Bildhauer's account. Since only words

$$\begin{bmatrix} \textit{sign} \\ \text{CONT} & \boxed{1} \\ \text{FOC} & \boxed{1} \end{bmatrix} \rightarrow \left[\text{PHON} \; \text{LIST} \oplus \left\langle \left[\text{UT}|\text{DTE} \; + \right] \right\rangle \right]$$

Figure 26: Focus Prominence in Spanish

that are the designated terminal element (DTE) can bear a pitch accent, the interplay of the two above principles ensures, that in utterances with a declarative contour the entire phrase can be in the focus. These principles thus nicely illustrate, how not only lexical elements can contribute to the information structure via their prosodic properties, but how entire phrases with specific prosodic properties can be constrained to have specific information structural properties.

8 Conclusion

We have discussed various possibilities of how to represent information structure within the HPSG's sign-based architecture. Several approaches from the HPSG literature were presented which all have in common that they introduce a separate feature INFO-STRUC into the HPSG setup, but they differ in (i) where they locate such a feature, (ii) what the appropriate values are for the representation information structure, and (iii) how they encode principles constraining the distribution and interaction of information structure with other levels of the grammatical architecture. Finally, we discussed a number of theories in which phenomena such as word order are constrained to be only well-formed in case they exhibit specific information structural properties.

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Part IV

Other areas of linguistics