Modeling Information Structure for Computational Discourse Processing

ESSLLI 2004 Course Reader

Ivana Kruijff-Korbayová

korbay@coli.uni-sb.de
http://www.coli.uni-sb.de/

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Contents

Background Reading Material

František Daneš. 1974. Functional sentence perspective and the organization of the text. In František Daneš, editor, *Papers on functional sentence perspective*, pages 106–208. Academia, Prague, Czech Republic.

Eva Hajičová. 1993. *Issues of sentence structure and discourse patterns* — Chapters 2 and 3. Volume 2 of *Theoretical and computational linguistics*. Charles University, Prague, Czech Republic.

Michael A. K. Halliday. 1967. Notes on transitivity and theme in English — Part 2. *Journal of Linguistics*, 3(1 and 2):37–81 and 199–244.

Manfred Krifka. 1993. Focus and presupposition in dynamic semantics. *Theoretical Linguistics*, 19:269–300.

Chapter 1

Introduction

[the phenomena at issue here] have to do primarily with how the message is sent and only secondarily with the message itself, just as the packaging of toothpaste can affect sales in partial independence of the quality of the toothpaste inside.

– Wallace L. Chafe

1.1 Overview of the Reader

The goal of this ESSLLI 2004 course on *Modeling Information Structure for Computational Discourse Processing* is to help students and researchers to orient themselves in the large amount of literature on information structure, by providing them with a basic understanding of the various approaches and the notions they work with, and by giving a survey of existing attempts at formalizing IS and employing it in computational discourse modeling.

The next section, partially based on (Kruijff-Korbayová and Steedman, 2003), motivates this goal of the course in more depth. Chapter 2 gives a more detailed overview of the field, with many pointers to literature. Section 2.1 provides a high-level overview and comparison of IS terminology. Some parts of the text are reused from (Kruijff-Korbayová and Steedman, 2003); some parts are based on (Kruijff, 2001)[Section 5.1]. In the following ections, a more detailed overview and comparison of some of the main approaches is given. Parts of Sections 2.2, 2.4 and 2.6 are based on (Kruijff, 2001), Sections 5.2, 5.4 and 5.3, respectively. For other overviews and comparisons, see for example (Vallduví, 1990), (Kruijff-Korbayová, 1998) and (Kruijff-Korbayová and Hajičová, 1997).

After this introductory material, the reader contains some background reading material. I decided to include scanned copies of a selection of older articles, which are hard to get unless one has access to a really well stocked library. Works that are available electronically on the internet are not included in this reader. This holds about most recent works, but also about some older ones. For example, thanks to the ACL Anthology project `http://acl.ldc.upenn.edu`, the ACL Journal, as well as the ACL, COLING and other proceedings are available several decades back. The course webpage course at `http://www.coli.uni-sb.de/~korbay/esslli04/` contains an extensive bibliography list with many pointers to electronically available versions of papers.

1.2 Motivation

Information Structure (IS) concerns utterance-internal structural and semantic properties reflecting the speaker's/writer's communicative intentions and the relation of the utterance to the discourse context, in terms of the discourse status of the content, the attentional states of the discourse participants, and the participants' prior and changing attitudes (knowledge, beliefs, intentions, expectations, etc.) (Kruijff-Korbayová and Steedman, 2003).

Among the dichotomies used by various authors to describe IS at various levels are Theme-Rheme, Topic-Comment or Topic-Focus and Ground-Focus on the one hand, and Given-New, Contextually Bound-Nonbound, Background-Focus or Background-Kontrast on the other hand.

Languages differ in the extent to which they employ various means of IS realization, such as intonation (i.e., accenting, de-accenting, and phrasing), word order, particular syntactic constructions or morphological marking.

For example, (Halliday, 1970) notes a sign in the London Underground with the text "Dogs must be carried", and observes that this text can be pronounced with different intonation patterns, e.g., (1) vs. (2) reflecting different IS.[1] Thereby, different instructions (here, paraphrased in italics) are conveyed to passengers. One supposes that (2) was not the intention of the London Transport Authority.

(1) Dogs must be CARRIED.
H* LL%
If there is a dog, carry it.

(2) DOGS must be carried.
H* LL%
Carry a dog.

The Czech counterparts of (1) and (2), conveying the same instructions to the hearer, are (3) and (4), respectively:

(3) Psa je nutno NÉST.
Dog_{acc} is necessary carry_{inf}
A dog it is necessary to CARRY.

(4) Je nutno nést PSA.
Is necessary carry_{inf} dog_{acc}
It is necessary to carry a DOG.

Over the past two decades, the understanding of IS within the sentence has been enriched by intensive research in formal semantics, addressing association-with-focus phenomena involved in the the interpretation of focus particles ("only", "even", etc.), quantifiers and negation; interpretation of intonation and word order; and reference. It is now widely accepted that IS affects both interpretation and realization, even though there is no uniform account.

Modeling these phenomena and their interaction in the grammar requires understanding IS and its role in discourse. IS is therefore an important aspect of meaning at the interface between utterance and discourse, that computational models of discourse processing should take into account.

Discourse, i.e., a coherent multi-utterance dialogue or monologue text, is more than a sequence of propositions, just as sentences are more than sequences of words. A discourse has rich internal organizational structure, involving informational and intentional relations

[1] Throughout this reader, words bearing a pitch accent are printed in SMALL CAPITALS, and intonation is indicated using the ToBI ("Tones, Breaks and Indices"), cf. *http://www.ling.ohio-state.edu/~tobi/* (Pierrehumbert, 1980; **?**).

between discourse segments, anaphoric relations, modal subordination, discourse topics, thematic progression, etc. In discourse, both explicit and implicit devices signify links between utterances, between groups of utterances, and between elements within them, and in turn, carry additional elements of discourse semantics. However, much less is known about what, if any, use is made of IS beyond clause and sentence boundaries and how IS interacts with other aspects of discourse structure.

The need to model IS in relation to discourse semantics and vice versa is justified not only on theoretical grounds, but it is also an arising challenge for practical systems: experience with applications such as translating telephony and interactive query-answering, as well as written text analysis and generation, makes it painfully clear that a theory relating IS and discourse is essential for accurate natural language processing. For example, in dialog systems with flexible interaction it becomes important to produce and interpret the contextual aspects of utterance realization, in terms of, e.g., choice of syntactic structure and intonation. The generation of contextually appropriate intonation is an important challenge for systems using synthesized speech, because with dynamically produced output, the same sequence of words may appear in different contexts, possibly needing different intonation. For example, the intonation of an answer needs to correspond to the respective question: whereas in (5S) the nuclear intonation center has a "default" placement, in (6S) it does not.

(5) U: What is the status of the stove?
S: The stove is switched ON.
H* LL%

(6) U: Which device is switched on?
S: The STOVE is switched on.
H* LL%

Contextually inappropriate intonation may have negative effect on intelligibility or even lead to confusion; for example, when (5U) is answered with (6S), or (6U) with (5S), a mismatch arises. Similar concerns hold in text processing, especially for languages with higher degree of word order freedom.

Formal accounts addressing various issues involved in modeling IS in relation to discourse structure and semantics have started to emerge, and some have been embodied in computational models of discourse processing involving intonation, e.g., (Hirschberg, 1993; Nakatani et al., 1995; Monaghan, 1994; Prevost, 1995a; Kruijff-Korbayová et al., 2003a), and other aspects of the linguistic realization of IS, such as word order (Hoffman, 1995b) and (Hoffman, 1996), (Komagata, 1999), (Kruijff-Korbayová et al., 2002), as well as non-linguistic reflexes or corelates of IS, e.g., gestures in multimodal conversation (Pelachaud et al., 1998) or turn-taking and gaze behavior (Cassel et al., 1999).

While the phenomena involved in discourse and IS are themselves complex and not yet fully understood, progress in studying their interaction is made even more difficult by proliferating and often under-formalized terminologies, especially in the area of IS. What is needed is further systematization of the diverse terminologies, formalization and computational modelling, and fuller empirical and corpus-based studies.

Chapter 2

Approaches to IS

2.1 Two Dimensions of Information Structure

In general, the purpose of a (declarative) sentence is *to communicate meaning*. As most sentences are uttered in the context of a larger discourse, there is a side-condition on this communication: the sentence's meaning needs to be *coherent* with the preceding context. Arguably, the claim behind IS as a theoretical construct is that it helps us to explain *how* the meaning a sentence conveys can be coherent with respect to a larger discourse.

Similarities The terminology describing IS partitioning and its semantics is at the same time diverse, and under-formalized. Yet it seems that all definitions have some elements in common. They all draw at least one of these distinctions:

- A "theme/rheme" or "topic/comment" distinction between the part of the utterance that relates it to the discourse purpose, and the part that advances the discourse; this distinction is sometimes characterized as one of *abboutness* between a *Relatum* and an *Attributum*, where the relatum serves to relate the utterance meaning to the discourse context explicitly established or implicitly shared between the speaker and the hearer, and the attributum provides some information *about* the relatum. This information may add to or indicate the need to change or modify, some information that had previously been established in the discourse.

- A "background/kontrast" or "given/new" distinction, between parts of the utterance which contribute to distinguishing its actual content from alternatives the context makes available.

The above use of the terms theme and rheme stems from Firbas and Bolinger, rather than Halliday; the theme/rheme dichotomy in Vallduví and Vilkuna's, Steedman's, Firbas' and Bolinger's analyses is straightforwardly comparable to the topic/focus dichotomy in the recent Prague School works (Sgall et al., 1986; Hajičová et al., 1998; Kruijff, 2001). The ground/focus dichotomy employed in (Vallduví, 1990) also more or less aligns with theme/rheme and topic/focus. However, Vallduví analyzes IS at the level of surface syntactic constituents, whereas the Prague School exponents and Steedman ascribe IS partitioning at some level of semantic representation, i.e., logical form or linguistic meaning. (For Steedman,

IS is also directly represented at the level of syntactic derivation and, in English, intonation structure.)

The background/kontrast distinction is closely related to the Hallidean given/new dichotomy and the background/focus distinction of (Dahl, 1969). Background/kontrast partitioning can occur within both rheme and theme. Kontrast within rheme corresponds to what the Praguians call "focus proper", whereas kontrast within theme corresponds to "contrastive Topic" in the most recent Praguian works (Hajičová et al., 1998).[1] In the earlier information packaging terminology of (Vallduví, 1990), kontrast within rheme does not have any particular label, while kontrast within theme is comparable to link as part of ground, and background within theme is comparable to tail as part of ground.

There are further similarities between the various approaches to IS: while some of the theories leave the associated discourse semantics at an intuitive level, the theories which do address formal semantic issues all tend to use some version of "update" semantics of the Kampo-Heimian synthesis (Kamp, 1984; Heim, 1982b) or Alternative Semantics (Rooth, 1985b; Rooth, 1992), further elaborated in (Büring, 1995; Steedman, 2000a), e.g., (Vallduví, 1990; Kruijff-Korbayová, 1998; Hendriks, 1998). For example, (Steedman, 2000a) views context as an updatable database including two Roothian alternative sets, respectively called the "Theme Alternative Set" and the "Rheme Alternative Set" (corresponding also to what is called membership set(s) in (Vallduví and Vilkuna, 1998).

Differences There are differences among the theories of course. Some, like (Halliday, 1967), view the two distinctions as orthogonal, applying at independent levels of structure. Others, both in the Prague School tradition (Mathesius, 1929; Firbas, 1964; Sgall, 1967) and in the Bolingerian tradition (Bolinger, 1965), view them as different aspects of a single level of structure, e.g., (Sgall et al., 1986), (Vallduví, 1990), (Steedman, 2000a). An important issue that further differentiates the Bolingerian theories is that of whether pitch accent corresponds to a single contrastive notion applying to both theme and rheme, i.e., what (Steedman, 1996) calls "focus" and (Vallduví and Vilkuna, 1998) call "kontrast", or whether "contrastive focus" is a distinct notion, applying to explicitly mentioned entities and associated with topic or theme alone.

Another aspect where theories differ is recursivity of IS partitioning. That is, whether IS is a partitioning at the sentence level, clause level or possibly even lower ranks of syntactic structure.[2] Various authors allow various degrees of mild recursivity, e.g., for coordinated and some cases of subordinated clauses within complex sentences (Vallduví and Zacharski, 1994; Koktová, 1995; Hajičová et al., 1998; Kruijff-Korbayová and Webber, 2001). But there are also extreme positions, not allowing any recursivity (Vallduví, 1990; Sgall et al., 1986; Steedman, 2000a) or allowing unlimited recursivity (Partee, 1995).

IS Realization An important issue is how a sentence's surface form realizes the IS of the underlying linguistic meaning. After all, whereas the meaning that is being communicated is by nature *multi-dimensional*, [3] wordforms can only be uttered in a *linear order*. Thus, we

[1] The Praguian distinction between contextually bound and non-bound elements is not so straightforwardly alignable with background/kontrast, although it is usually, but perhaps inaccurately, also compared with Hallidean given/new.

[2] Some argue for utterance as the unit of IS. But more research is needed to clarify what structural units can constitute separate utterances.

[3] In the sense that conceptual structures are not linear.

need to project the complex underlying structures onto a single dimension, and thereby we are constrained by language-specific rules defining grammaticality.

The basic idea is that forms are *iconic* of their informativity - they carry *structural indications of informativity*. It naturally depends on the type of language what means are available to indicate informativity. For example, Slavonic languages like Czech or Russian predominantly use word order, structuring a sentence such that the words realizing the Relatum appear at the beginning, followed by the Attributum - see (7) for some possibilities in Czech, and their English counterparts in (8).

(7) **Czech**

a. (Včera Elijah četl)$_{Theme}$ (Katce knihu)$_{Rheme}$.

b. (Katce Elijah včera četl)$_{Theme}$ (knihu)$_{Rheme}$.

c. (Knihu Elijah včera četl)$_{Theme}$ (Katce)$_{Rheme}$.

"Elijah read a book to Kathy yesterday."

Thus, even though Slavonic languages have a relatively free word order, that word order is by no means arbitrary: It indicates informativity, and therefore the sentence's felicity may vary depending on the context.

On the other hand, a language like English uses predominantly other means, in particular tune. The examples below (8) illustrate the use of tune to realize the same ISs as in (7). Pitch accent is indicated by SMALL CAPS.

(8) **English**

a. (Yesterday Elijah read)$_{Theme}$ (A BOOK TO KATHY)$_{Rheme}$.

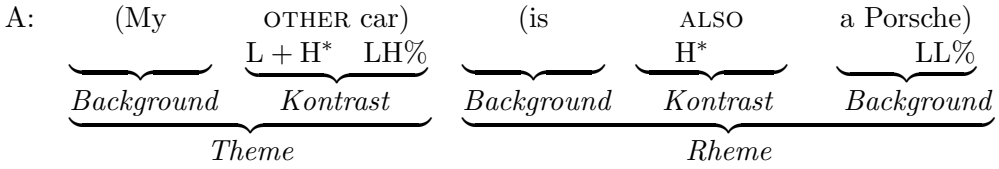
b. (Elijah read)$_{Theme}$ (A BOOK)$_{Rheme}$ (to Kathy yesterday)$_{Theme}$.

c. (Yesterday Elijah read the book)$_{Theme}$ (TO KATHY)$_{Rheme}$.

Intonation has been seen as a reflex of IS since early work of, e.g., (Bolinger, 1965; Jackendoff, 1972b). One of the basic common ideas is that deaccenting is related to givenness (Hirschberg and Pierrehumbert, 1986; Hirschberg, 1993), another is that a marked placement of accent on some word reflects a so-called *narrow focus*, possibly contrast, (as opposed to *broad focus*) (Jackendoff, 1972b). Another (still disputed) issue is whether intonation patterns are related to specific IS-partitioning(s), in particular, whether particular tunes or accent types are used in Theme, and others for Rhemes, e.g., (Steedman, 1996) for English, (Féry, 1993) for German. It is possible that languages differ w.r.t. use and function of different accent types. For more discussion, see, e.g., (Ladd, 1996; Ladd, 2001).

For English, (Steedman, 1996) claims that Information Structure is indicated by Intonation Structure in the following way: the pitch contour described as L+H* LH% in the notation of (Pierrehumbert, 1980) is one of the "theme tunes" that identify an intonational phrase as the topic or theme of this utterance, while H* LL% is a "rheme tune". Within both the theme and the rheme, the presence of one or more pitch accents identifies words which contribute to distinguishing that theme and/or that rheme from other themes and rhemes that the context affords. The following example illustrates this in detail:

(9) Q: I know that THIS car is a PORSCHE.
But what is the make of your OTHER car?



Steedman follows (Bolinger, 1965) and (**?**) in viewing the role of accent in English as a single undifferentiated contrastive meaning applying to both informational components, and captured by the term *kontrast* introduced in (Vallduví and Vilkuna, 1998) to distinguish this narrow accent-related sense of the term from any other.

In (Kruijff-Korbayová and Steedman, 2003), we ventured to suggest that the terminology used in (Vallduví and Vilkuna, 1998), as embodied in the twin dichotomies of *theme/rheme* and *background/kontrast* exemplified above, provides a clear and unambiguous expression of the basic ideas that are common to most approaches to IS.

Finally, there are also languages that have a rich nominal morphology and -hence- a relatively freer word order, which realize IS primarily through affixation. An often-cited example is Japanese, where the *-wa* suffix marks a contextually given item and *-ga* is often associated with newness (though see (Heycock, 1993)). Haiman mentions other languages that have similar constructions (cf. (Croft, 1990),p.10). For example, the Papuan language Hua uses a suffix *-mo* to indicate a sentence's Relatum. Furthermore, although Turkish normally uses word order to indicate IS (Hoffman, 1995b; Hoffman, 1995a) Haiman notes that the *-sA* suffix can mark contrast ("contrastive topic"). Tagalog also uses morphological means to indicate informativity (Kroeger, 1993)(pp.64-69,pp.130-131). Finally, Engdahl and Vallduví mention in (1994) Navajo and Vute, languages in which an Rheme is associated with a particular suffix.

To recapitulate, we see that there is an interesting variety in how languages can *realize* IS, i.e., what types of structural indications of informativity are *predominantly* used, like word order in Czech, tune in English or a dedicated morphological suffix in Japanese. 'Predominantly' should be stressed here, because no language appears to be making *absolute* use of one and only one means.

Nevertheless, many questions concerning the IS partioning, and its realization in different languages await fuller empirical and corpus based studies.

Question Test Example (9) also illustrates the use of question-answer pairs as a common device to explicitly indicate the intended IS partitioning of an utterance under discussion: the question sets the Theme of the answer-utterance, and the Rheme of the answer-utterance is what answers the question (Sgall et al., 1986; Steedman, 2000a). The question can also establish relevant alternatives, and thereby help to make explicit the intended Background/Focus partitioning (Prevost and Steedman, 1993; Prevost and Steedman, 1994; Prevost, 1995b; Büring, 1995; Steedman, 2000a). Question-answer congruence underlies the *question test* as an operational test of IS (Sgall et al., 1986). The question test relies on the observation that exchanging "sentence-variants" which differ in IS as replies to a given question does not always result in a congruent question-answer pair. The idea of the question test has been used to practically evaluate the appropriateness of the intonation of automatically generated responses in spoken dialogs, cf. (Prevost, 1995b; Kruijff-Korbayová et al., 2003b).

A question-answer pair in the question test is of course something else than a question-answer pair in actual dialogue. However, there is an interesting corelation here with Ginzburg's

approach to dialog modeling in terms of *questions under discussion*: each utterance (not only a question) may push one or more QUDs onto a stack, and when subsequent utterances are interpreted, it is tested whether they resolve or address a QUD. The IS of an utterance can then also be motivated by the current QUD. The QUD-based approach to dialog modeling has been implemented in several dialog systems in the TRINDI and SIRIDUS projects (Traum and Larsson, 2003); (Bos, 1999) and (Kruijff-Korbayová et al., 2003a) present implementations of the generation of dialog system responses with contextually varied IS realized through intonation. In relation to Q-A congruence and QUD modelling, many issues are subject of ongoing research: How do QUDs get established? When do QUDs get resolved? For more discussion see, for example, (Roberts, 1998). (Umbach, 2001) addresses the interaction of QUDs and discourse relations.

The diagram in Figure 2.1 is reproduced from (Kruijff-Korbayová and Steedman, 2003) and summarizes the influences and terminological dependencies in theories of IS and the associated discourse semantics.

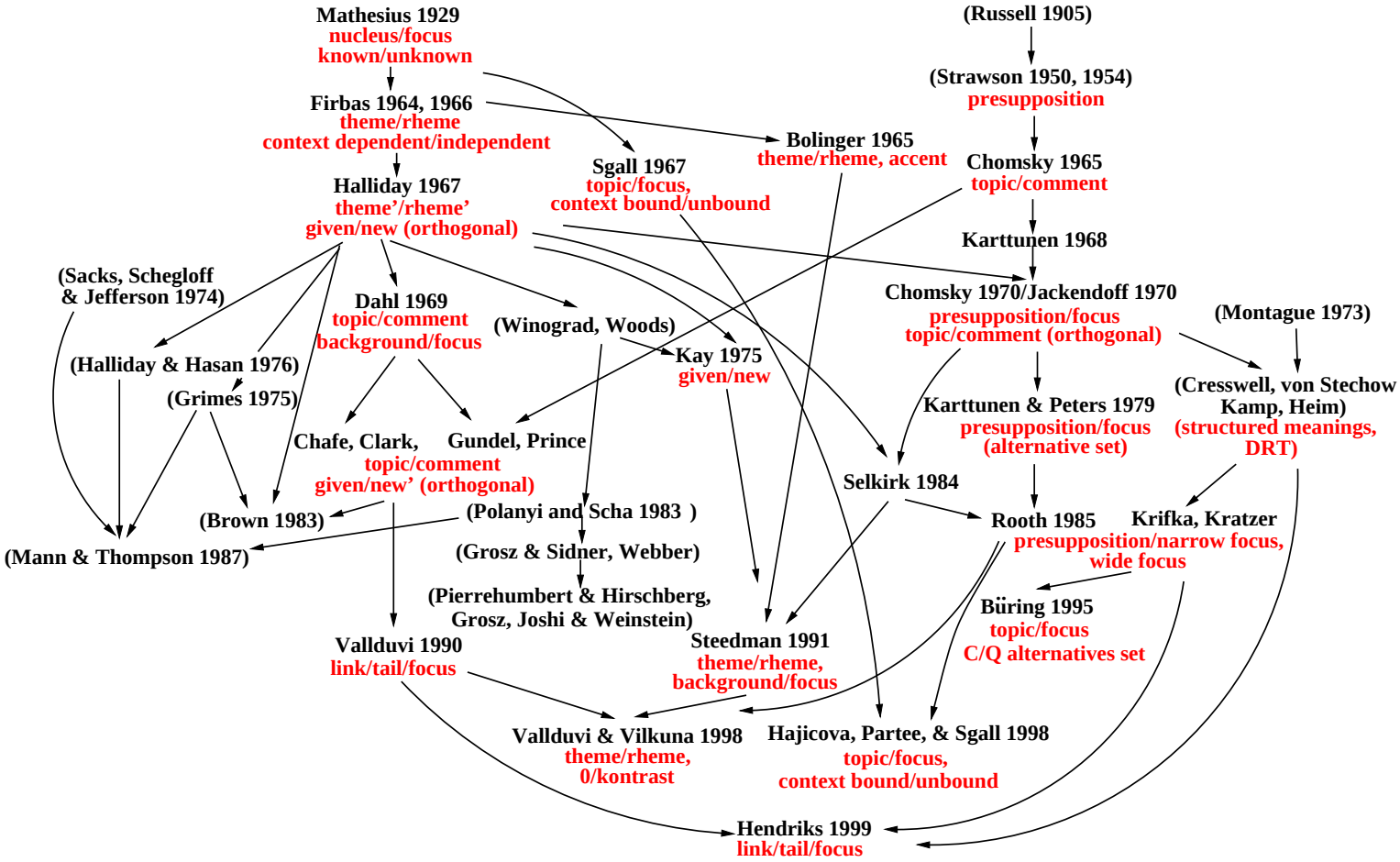


Figure 1. Information Structure Terminologies and their Dependencies

2.2 Information structure in the Prague School

Information structure has since long been an essential ingredient of the view on language developed in the Prague School of Linguistics. The concepts of *Thema* and *Rhema* developed here can be traced back to Weil's work in the nineteenth century (Weil, 1844). Weil's work was resumed by several German linguists in the decades around the turn of the last century. Subsequently, the Prague School of Linguistics started paying systematic attention to issues of IS, pioneered by (Mathesius, 1936; Mathesius, 1975). Mathesius studied the *Thema/Rhema* dichotomy and its relation to syntax from the viewpoint of a structural comparison of Czech and English, and recognized that this dichotomy was important to problems ranging from tune to word order(cf. also (Sgall et al., 1986),p.175)). Among Mathesius' followers, Firbas studied further the interplay of syntax and word order, as means to realize the *functional sentence perspective*, and showed that it involves not only a dichotomy, but a whole scale of *communicative dynamism* (cf. (Firbas, 1992) for a comprehensive recent account). Daneš explored the relationships of *Theme* and *Rheme* to word order and intonation as well as to the structure of text, giving a thorough analysis of *thematic progressions*, i.e., the types of relations a Theme bears to the preceding context, and more subtle aspects of text connectedness (Daneš, 1970; Daneš, 1974). (Korbayová and Kruijff, 1996) adapt Daneš's proposal to define *topic chains* in the FGD-based TFA terms (see below), and (Kruijff-Korbayová, 1998) spells this proposal out in DRT terms.

Sgall, Hajičová and their collaborators introduced the terms *topic* and *focus*, and incorporated *topic-focus articulation* (TFA) into a formal description of syntax and sentence meaning in the framework of the Functional Generative Description of language (FGD) (Sgall, 1967; Hajičová and Sgall, 1980; Sgall et al., 1986; Petkevič, 1987; Petkevič, 1995). (Hajičová, 1993) gives an informal summary of the various threads of TFA reaseach in FGD, including (Sgall et al., 1973; Sgall et al., 1980; Sgall et al., 1986) and various articles primarily by Sgall and Hajičová. A recent dialogue examining TFA and its relation to formal semantics can be found in Hajičová, Partee, and Sgall (Hajičová et al., 1998).

There are three principal ingredients to the Praguian theory of TFA:

i. the *topic* and *focus* dichotomy that divides a sentence's linguistic meaning into a contextually given topic (the Relatum) and a focus that is *about* the topic (the Attributum);

ii. *contextual boundness*, a characterization of an individual head's or dependent's informativity, being either *contextually bound* or contextually nonbound; and,

iii. *communicative dynamism*, which is a relative ordering over the heads and dependents making up a sentence's linguistic meaning indicating how informative they are relative to one another.

An important characteristic of FGD's TFA is that the terms topic and focus are *not* primary notions, like their counterparts in other theories. Rather, topic and focus are based on the structural notion of contextual boundness.[4] Each dependent and each head in a sentence's linguistic meaning is characterized as being either contextually bound or contextually nonbound. Intuitively, items that have been activated in the preceding discourse may function as contextually bound (CB), whereas non-activated items are always contextually nonbound

[4]To quote Sgall *et al.*: "If the notions of topic and focus (as parts of a tectogrammatical representation) are characterized on the basis of contextual boundness, then we don't have to worry about questions whether topic and focus are a single (deep or surface) constituent [...]." (Sgall et al., 1986)(p.188).

(NB) (Sgall et al., 1986)(p.54ff,p187ff). Mostly, an item is activated by introducing it explicitly into the discourse. Important about contextual boundness is, though, that it is a *linguistic* opposition, reflected in the structuring of linguistic meaning and its realization - it is not precise to equate contextual boundness to the discourse (or cognitive) opposition of given/new. For example, a previously mentioned item (CB) may occur in a contrastive focus, and we can present items as CB if they are activated by the situation of the discourse or can be activated indirectly by for example association (Hajičová et al., 1998)(p.59). In other words, contextual boundness is an issue of linguistic presentation.

More detailed discussion concerning TFA and the CB/NB opposition, and the activation (or *salience*) of items in the *Stock of Shared Knowledge* between the speaker and the hearer can be found in (Hajičová and Vrbová, 1981; Hajičová and Vrbová, 1982; Hajičová, 1993) and in (Hajičová, 2003). Salience-tracking in discourse and its relation to anaphora resolution is discussed in (Hajičová et al., 1990; Hajičová et al., 1992; Hajičová et al., 1995a; Hajičová et al., to appear). For a comparison to Centering Theory see (Kruijff-Korbayová and Hajičová, 1997)).

Given the above characterization, and the internal structure of the sentence's linguistic meaning, the TFA can be derived as follows (Sgall et al., 1986, p.216):

Definition 1 (FGD's Topic-Focus Articulation). *Given a tectogrammatical representation of a sentence's linguistic meaning,*

- *the main verb belongs to the focus if it is contextually nonbound, and to the topic if it is contextually bound;*
- *the contextually nonbound nodes depending on the main verb belong to the focus, and so do all nodes (transitively) subordinated to them;*
- *if some of the elements of the tectogrammatical representation belong to its focus according to either of the above points, then every contextually bound daughter of the main verb together with all nodes (transitively) subordinated to it belong to the topic;*
- *if no node of the tectogrammatical representation fulfills the first two points above, then the focus may be more deeply embedded; special rules for the determination of focus are applied in these cases.*

In FGD, the *scale of communicative dynamism* defines a (partial) order over the nodes in a sentence's linguistic meaning, after Firbas's original notion of communicative dynamism (see Firbas (1992) for a recent formulation). If we project the linguistic meaning's tree to a line, then we obtain a reflection of that order. The *topic proper* and the *focusproper* are the least respectively most communicatively dynamic elements in a sentence's linguistic meaning. In the projected (deep) order, the topic proper corresponds to the leftmost item, whereas the focusproper is identified by the the rightmost element.

TFA and word order are discussed in detail in (Hajičová and Sgall, 1987), and more recently in (Hajičová et al., 1998)(p.56ff), Hajičová and Sgall address the strong correspondence between communicative dynamism and word order (and, indirectly, tune). This certainly holds for languages like Czech. Dependents that are contextually nonbound are considered to be communicatively more dynamic, and occur prototypically *after* the head, whereas contextually bound dependents are less dynamic and should occur before the modified head. The mutual ordering of contextually nonbound dependents thereby follows what is called

the *systemic ordering*, the canonical ordering in which complement types occur in a given language (Sgall et al., 1986; Sgall et al., 1995). On the other hand, FGD considers the order of contextually bound complements to be only determined by their mutual communicative dynamism. The examples in (10) give a brief illustration of the above ideas (recall also the earlier (8)).

(10) a. **Czech**
Co Elijah udělal? (**English** What did Elijah do?)
Elijah koupil knihu.
Elijah-CB bought-NB book-NB.
"Elijah bought a BOOK."
Topic={**Actor**:Elijah}, Focus={buy, **Patient**:book}

b. **Czech**
Co Elijah koupil? (**English** What did Elijah buy?)
∅ koupil knihu.
he-CB bought-CB book-NB
"He bought a BOOK."
Topic={**Actor**:he, buy}, Focus={**Patient**:book}

An algorithm for TFA identification during parsing, which is based on theDefinition 1 is described in (Hajičová et al., 1995b).

Definition 1 also covers cases where the focus is deeper embedded. Thus, the dependent(s) constituting the focus do not modify the main verbal head but (transitively) one of its dependents. In the example in (11), only the dependent realized as *s kapsami* (**English** "with pockets") belongs to the focus, the rest of the sentence's linguistic meaning constitutes the topic. Consider also (12).

(11) **Czech** Jaké nosí krtek kalhotky?
(**English** "What trousers does the mole wear?")
Krtek nosí kalhotky s kapsami.
mole-CB wears-CB trousers-CB with pockets-NB
"The mole wears trousers WITH POCKETS."
Topic={**Actor**: mole,wear,**Patient**: trousers}, Focus={**GenRel**:pockets}
(Kruijff-Korbayová, 1998)(p.27)

(12) **English**
(What teacher did you meet yesterday?)
$[(\text{Yesterday})_{cb}\ (\text{I})_{cb}\ (\text{met})_{cb}\ (\text{the teacher})_{cb}]_T\ [\ (\text{of CHEMISTRY})_{nb}.]_F$
– cf. (Sgall et al., 1986), (Hajičová et al., 1998)(p.135)

Thus, the primary notions contextually bound and contextually nonbound are *recursive* in the sense that contextually nonbound items can be embedded under contextually bound items and *vice versa*.

In the general case, neither topic nor focus is a single item, as (11) or (13) show.

(13) **English**
(What happened to Jim?)

A burglar INJURED him.
Topic={**Patient**:he}, Focus={**Actor**: burglar, injure} (Hajičová, 1993)

Petkevič notes in (Petkevič, 1987; Petkevič, in prep) that Definition 1 does not cover some special cases of topic-focus articulation that he calls "split semantemes". The topic-focus articulation of a sentence is represented at the level of linguistic meaning, and at that level we do not have separate nodes for function words or even more local aspects of form, such as tense or modality. A sentence's linguistic meaning only has nodes that represent what in FGD are called auto-semantic units or semantemes. However, from the viewpoint of a sentence's topic-focus articulation it is not only the whole semanteme as such that can be determined as either contextually bound or contextually nonbound. Petkevič illustrates the need for a more refined assignment by examples like (14).

(14) **English**

a. I SHALL do it, not that I HAVE already done it.

b. I saw not only a single mouse there but several MICE.

For example, Petkevič argues that in (14a) the specifications of the verbal Tense of both occurrences of *do* belong to the focus, whereas both occurrences of the head *do* belong to the topic. A similar picture arises from (14b), only then for the specification of number.

Over time, several proposals have been made how to formalize FGD's theory of TFA. In general, these proposals either focus on the (truth-theoretic) interpretation of a sentence's topic-focus articulation, or have as their main concern the grammar's representation of a topic-focus articulation.

Both represent rather long traditions. FGD received its first formalization in Sgall *et al*'s (1969), where the authors were concerned with providing a "mathematically -thus linguistically- interesting description of (linguistic) meaning."[5] Sgall (Sgall, 1980) presents the first formalization of FGD's TFA. Sgall first constructs an automaton (roughly a complex pushdown store automaton) that is able to generate representations of a sentence's linguistic meaning, including marking of contextual boundness. Subsequently, a transducer is given that completes the representation -as it were- by deriving the sentence's topic-focus articulation, based on the contextual boundness marking. Petkevič extends this type of description in (Petkevič, 1987; Petkevič, 1995; Petkevič, in prep). Petkevič's formalization is couched in a larger reformulation of FGD's generative description of linguistic meaning.

After Sgall *et al* argued the importance of distinguishing a sentence's topic-focus articulation from the felicity of its linguistic meaning *in a given context*, various attempts have been made towards the clarification of this view in *logical* terms. One group of such contributions was carried out within the framework of an intensional logic, namely Tichý's transparent intensional logic. The basic issues involved in formulating TFA in transparent intensional logic were discussed by Materna and Sgall (1980) and by Materna, Sgall and Hajičová (1987). Vlk (1988) provided a procedure for translating the tectogrammatical representations generated by FGD into Materna *et al*'s logical representations of transparent intensional logic.

Other, more recent developments are based on Partee's *tripartite structures* or on a logical dynamic perspective as arising from *dynamic semantics*. (See (Muskens et al., 1996) for

[5]The kind of grammar that Sgall *et al* present in (Sgall et al., 1969) still employs phrase structure-based notions, contrary to the later work (Sgall et al., 1986).

a general description of logical dynamics and its use in describing natural language interpretation.)

Formalizations of TFA in dynamic-semantic terms are proposed in (Peregrin, 1995) and in (Kruijff-Korbayová and Kruijff, 1997; Kruijff-Korbayová, 1998; Kruijff and Kruijff-Korbayová, 2001). Peregrin (1995) is the first attempt to construct a more dynamic account of TFA. Following an approach that essentially goes back to (Jackendoff, 1972b), Peregrin formalizes the intuition that the focus says something *about* the topic as a λ-term. The topic is modeled as an abstraction, to which the focus-term then can be applied.

To provide an account of the semantic effects of IS, Peregrin provides an extensional theory of the truth of a sentence's topic-focus articulation. In this theory, $\| X \|$ stands for the extension of an expression 'X', whereby $\| X \|$ is a truth value if 'X' is a sentence, an individual if 'X' is a term, and a class of individuals if 'X' is a unary predicate. Then, a proposition whose extension is denoted by $| X |$ is associated with every expression X (understood as a presupposition associated with X) as given in (15).

$$
\begin{array}{rrll}
 & | X | & = & \| X \| \qquad\qquad\qquad\qquad \text{if } X \text{ is a sentence} \\
(15) & & = & \| \exists y.y = X \| \qquad\qquad\quad \text{if } X \text{ is a term} \\
 & & = & \| \exists y.X(y) \| \qquad \text{if } X \text{ is a unary predicate}
\end{array}
$$

The semantics of a formula $F\{T\}$, as the predication of F corresponding to the focus-part over a sentence's topic-part T, is defined in (16), cf. (Peregrin, 1995)(p.240). Note that $F(T)$ is (the β-normalization of) the standard application of F to T.

$$
\begin{array}{rrlll}
 & \| F\{T\} \| & = & \text{true} & \text{iff } | T | = \text{true } \& \ \| F(T) \| = \text{true} \\
(16) & & = & \text{false} & \text{iff } | T | = \text{true } \& \ \| F(T) \| = \text{false} \\
 & & = & \text{false} & \text{iff } | T | = \text{false}
\end{array}
$$

The simple examples in (17) illustrate the basic idea.

(17) a. John WALKS: **Walk**{ **John** }
b. JOHN walks: $\lambda f.f($**John**$)$ { **Walk** }

Peregrin works out an extensional account of negation, basic quantification, and focus as exhaustive listing. On the basis of the definitions in (15) and (16) Peregrin defines a more dynamic account of $\{\cdot\}$. Dynamically, a predication $P(S)$ is true can be modeled as a statement saying that there exists an assignment of a value to a variable x such that $P(x)$ & $x = S$ is true. A similar construction can be defined for Peregrin's new mode of predication, $\{\cdot\}$. Given a concatenator $\}\&$, T $\}\&$ F has a truth value if and only if T has a truth value, and it is true if and only T & F is true (in the sense of $P\&S$ as above).

Besides a dynamic account, Peregrin also briefly discusses the possibility to model TFA in terms of tripartite structures. The idea of using tripartite structures was first put forward by Partee in (Partee, 1991), and is substantiated to a larger degree in Hajičová *et al*'s (1998). In the latter work, the authors discuss in Chapter 2 how a tripartite structure constisting of an *Operator*, a *Restrictor*, and a *Nuclear Scope* could model a sentence's IS when it involves a focus-sensitive operator.

As Peregrin observes, the definition he gives for the truth of a statement T $\}\&$ F cannot be applied recursively. In (Kruijff-Korbayová, 1998) Peregrin's proposal has been extended to an

intensional approach by weaving an intensional (typed) theory of TFA into a discourse representation theory to create TF-DRT. The TF-DRT definitions in (Kruijff-Korbayová, 1998) can be applied recursively (see p.78ff).

Finally, (Kruijff, 2001) provides a new formalization of the Praguian notion of linguistic meaning, including TFA, in terms of Dependency Grammar Logic, a categorial-modal logical framework.

For more thorough discussions of TFA see Chapter 3 of (Sgall et al., 1986), and Hajičová *et al*'s discussion in (Hajičová et al., 1998). In recent years, the Prague Dependency Treebank project (PDT) includes the annotation of TFA as part of the tectogrammatical tree representations (Buráňová et al., 2000; Hajičová and Sgall, 2001). This enables, among oher things, the assessment of various hypotheses developed earlier, by considering large corpus data (e.g., (Hajičová et al., 2003)).

2.3 Halliday's Two Dichotomies

Halliday, inspired by the Prague School works, distinguishes between two dimensions of clause organization: one is the Theme/Rheme partitioning he calls *thematic structure*, the other is the Given/New distinction he calls *information structure* (Halliday, 1967; Halliday, 1970; Halliday, 1985).

According to Halliday, the thematic structure and information structure of a clause are closely related but not the same. Halliday's information structure concerns the distinction between the *Given* as "what is presented as being already known to the listener", and the *New* as "what the listener is being invited to attend to as new, or unexpected, or important" (Halliday, 1985)[p.59]. In Halliday's original approach, the root assumption for English is that ordering, when not grammatically constrained, is iconic with respect to "newsworthiness": under the scale from Given to New, the "newer" elements would come towards the end of the information unit; the "newest" element would be the bearer of nuclear stress. This position is indeed very close to that pioneered in the Prague School.

With respect to the thematic structure, Halliday's view differs from streamline current IS research, in that Theme in Halliday's approach has a *textual function*, it is concerned primarily with textual organization. Central to Halliday's approach is the notion that many languages *grammaticize* this particular textual function: that of signposting the intended development or "scaffolding" that a writer employs for structuring an extended text. In the grammar of English this textual function is realized in the first position in the clause and Halliday calls this textual function 'Theme': "The Theme is the element which serves as the point of departure of the message; it is that with which the message is concerned. [...] and the [thematic] structure is expressed by the order - whatever is chosen as the Theme is put first" (Halliday, 1985, p.37).

Halliday's use of the term Theme for a textual notion, which we henceforth refer to as **Theme**$_{SFG}$, needs to be understood in relation to the thematic structure. The specialized textual role of Theme$_{SFG}$ was originally identified empirically in (Fries, 1981) and has since been applied in many (SFG-based) analyses of extended texts (e.g., (Halliday, 1993; Ventola, 1995; Matthiessen, 1995). For example, it is a matter of a global text organization strategy that a biography can be organized along the dates when or the places where important events in one's life happened. These dates or places are not "given" information individually, but they are nevertheless broadly "predictable" from the knowledge of the text

type. Such strategies then guide the choice of Theme$_{SFG}$. This line of research is very similar to the earlier mentioned work of Daneš on "thematic progressions" and other aspects of text connectedness (Daneš, 1970; Daneš, 1974).

Although the claim of this special role for the first position in the clause has been questioned or rejected in various works (Lyons, 1977; Huddleston, 1988; Bolinger, 1989; Steedman, 1996; Steedman, 2000b), these critiques miss the point that it is the larger **textual organization** to which Theme$_{SFG}$ contributes, not the local sentence-by-sentence organization found in dialogue or as highlighted by question tests. Most non-Hallidayan uses of the term Theme refer to properties that have to do with information structure (not thematic structure in Halidayan sense), and also Halliday attributes them to what he calls information structure.

An approach to word order generation which synthesises a Hallidayan and Praguian perspective is presented in (Kruijff-Korbayová et al., 2002): it combines Halliday's IS/TS dichotomies with the Prague School insights concerning the relationship between communicative dynamism, contextual boundness and word order. This synthesis is motivated by observations of ordering in written instructions for software products, where we encountered regular thematization of (i) the location where actions are performed (19,(ii) the particular action that the user is instructed to perform, or (iii) the goal that the user wants to achieve. For example, consider (19) which demonstrates thematization of action location which appear repeatedly in the English, Czech, Bulgarian and Russian versions of the AutoCAD user guide. This particular occurrence was preceded only by the respective language counterpart of (18).

(18) First open the Multiline styles dialog box using one of the following methods.

(19) **Cz** Z menu `Data` vyberte `Multiline Style`.
Ru В меню `Data` выберите `Multiline Style`
Bu От менюто `Data` изберете `Multiline Style`
En From the `Data` menu choose the `Multiline Style`.

The preceding context does not refer to the `Data` menu or make it salient in any way. Working only with the Praguian notion of information structure discerning CB (Given) and NB (New) elements, one is thus unable to explain the WO. The notion of Theme$_{SFG}$ as a reflex of a global text organization strategy makes such explanation possible.

2.4 Vallduví's Information Packaging

The term information packaging can be traced back to Chafe.[6] Starting with Vallduví (1990), various researchers have contributed to the *information packaging* perspective on IS, both in its aspects of discourse interpretation and grammatical realization.

Vallduví characterizes information packaging as a division of a sentence's surface form into *Focus* and *Ground*, further subdivided into *Link* and *Tail*. Cross-linguistic justification of this view using examples from various languages is presented in (Vallduví, 1990); (Vallduví and Engdahl, 1996) offer an additional indepth study of how a large number of languages may employ different strategies to realize information packaging, using examples from English, German, Dutch, Swedish, Catalan, Hungarian, Turkish, and Japanese. Consider the following examples for Catalan and English (20)-(22) from (Vallduví and Engdahl, 1996)(p.42), which illustrate the four abstract realizations of IS that Vallduví distinguishes.

[6] Cf. the quote on page 2, which originates from (Chafe, 1976, p.28).

(20) *Link-focus sentences*: typical topic-comment structures, predicate-focus structures, categorical judgments.

a. The president [$_F$ hates CHOCOLATE].
El president$_1$ [$_F$ odia la XOCOLATA t_1].

b. The president [$_F$ CALLED].
El president$_1$ [$_F$ ha TRUCAT t_1].

c. The president$_1$ [$_F$ (I) wouldn't BOTHER t_1].
El president$_1$ [$_F$ no l'EMPRENYARIA t_1 *pro*].

(21) *All-focus sentences*: (a) neutral descriptions, news sentences, sentence-focus structures, thetic judgments; (b) *there*-sentences; (c) predicate-focus sentences where the locus of update is inherited.

a. [$_F$ The PRESIDENT called].
[$_F$ Ha trucat el PRESIDENT].

b. [$_F$ There are protests in the STREETS.]
[$_F$ Hi ha protestes als CARRERS.]

c. [$_F$ (He) HATES (it).]
[$_F$ L$_2$ 'ODIA e$_2$ *pro*.]

(22) *Link-focus-tail sentences* and *focus-tail* sentences: narrow focus, constituent focus, typical open-proposition structures.

a. The president [$_F$ HATES] chocolate.
El president$_1$ [$_F$ l$_2$'ODIA t$_2$ t$_1$,] la xocolata$_2$

b. The president hates [$_F$ CHOCOLATE.]
El president [$_F$ t$_v$ la XOCOLATA t$_1$,] odia$_v$.

Vallduví reflects in Chapter 3 of (Vallduví, 1990) on various approaches to what he calls 'informational articulation'. Vallduví divides these approaches into *topic/comment* approaches and *focus/ground* approaches. Both (types of) approaches split a sentence, or rather its meaning, in two parts. The topic/comment approach splits the meaning into a part that the sentence is about, which is usually realized sentence-initially, and a comment. To follow Halliday, this 'topic' is the point of departure for what the sentence conveys.[7]

According to what Vallduví terms the focus/ground approaches, the sentence is divided into 'focus' and a 'ground', with the 'focus' being the informative part of the sentence's meaning. The ground anchors the sentence's meaning to what the speaker believes the hearer already knows. The 'focus' expresses what the speaker believes to contributes to the hearer's knowledge. The 'ground' is also known as 'presupposition' or 'open proposition' - the latter being explainable, at least formally, by Jackendoff's λ-term representation mentioned earlier.

Vallduví argues that both traditions suffer from various problems. Aside from terminological confusion, both traditions suffer from the fundamental problem (according to Vallduví) that they are incomplete in their empirical coverage, *necessarily so* because "a binomial informational division of the sentence is simply not enough." (Vallduví, 1990)(p.54) For example, consider the example in (23) adapted from Dahl (1974).

[7]Note that Halliday (1985) calls this 'topic' the Theme, (Halliday, 1985)(p.59).

(23) a. What about John? What does he do?

$$\overbrace{\underbrace{John}_{ground}}^{topic}\ \overbrace{\underbrace{drinks\ beer}_{focus}}^{comment}$$

b. What about John? What does he drink?

$$\overbrace{John}^{topic}\ \overbrace{drinks\ beer}^{comment}$$

$$\underbrace{John\ drinks}_{ground}\ \underbrace{beer}_{focus}$$

The fact that the two perspectives partition (23b) *differently* is taken to show that "neither of them is by itself capable of capturing all the informational distinctions present in the sentence" (Hendriks, 1994)(p.93). Vallduví notices that there is a certain overlap in how the two perspectives divide (23b), and proposes to conflate the two perspectives into a single, hierarchically structured trichotomy of a sentence's surface form, centered around a binary division according informativity, in the sense of the 'focus/ground' tradition: The *ground* anchors the sentence's meaning into the preceding discourse, and a *focus* that specifies the 'new' information. In addition, the ground is further divided into a *link* and a *tail*. According to Vallduví, the link specifies *where* to anchor the information specified by the focus, and the tail indicates *how* it fits there (Vallduví, 1994)(p.5). Unlike is the case with FGD's contextually bound/contextually nonbound-distinction or Steedman's focus/background, Vallduví's primary notions are not (entirely) recursive.

Originally, Vallduví (1990) proposed to integrate information packaging into a GB-style architecture, with information structure as a *autonomous* stratum, next to deep structure (DS), logical form (LF), phonological form (PF), and surface structure (SS). (Engdahl and Vallduví, 1994; Vallduví and Engdahl, 1996; Engdahl, 1999) elaborate a different approach, making use of HPSG.

Subsequently, Vallduví's theory of information packaging has found its way primarily into HPSG– for example, see (Manandhar, 1994; Kolliakou, 1998; Alexopoulou, 1999). Hendriks proposes in (1994; 1996; 1997) a Lambek-style categorial grammar, based on Moortgat and Morrill's D calculus (Moortgat and Morrill, 1991), in which he tries to capture various insights of information packaging.

In (Vallduví, 1990), the interpretation of a sentence's link, tail, and focus in the larger context of a discourse, is defined as "a small set of instructions with which the hearer is instructed by the speaker to retrieve the information carried by the sentence and enter it into her/his knowledge store." (p.66) Vallduví defines the dynamical potential that the discerned components of a sentence's meaning have in terms of *operations on file cards*, based on Heim's file metaphor from File-Change Semantics (Heim, 1982b). Thus, a link is associated with a GOTO instruction - GOTO(fc) specifying "go to the file-card signified by the link's meaning". If a sentence has a tail, then the tail indicates a record on the identified file-card that has to be *modified* by the information specified by the focus. Vallduví associates the instruction UPDATE-REPLACE with a link; if the sentence does not have a tail, then the focus is simply added to the current location, using UPDATE-ADD.

According to Vallduví, there are altogether four possible combinations of link, tail, and focus - the focus being the only obligatory part. These four possible combinations lead to four abstract (in the sense of language-universal) sentence types, (24).

(24) a. focus

b. link-focus
c. focus-tail
d. link-focus-tail

The combinations in (24) do not necessarily correspond to continuous segments of a sentence, in the order as given: They may be discontinuous, and depending on the individual language, appear in different orders. The instruction sequences that result from these combinations are given in (25). Here, I_S is the information specified by the sentence's focus.

(25) a. UPDATE-ADD(I_S)
b. GOTO(fc)(UPDATE-ADD(I_S))
c. UPDATE-REPLACE(I_S,RECORD(fc))
d. GOTO(fc)(UPDATE-REPLACE(I_S,RECORD(fc)))

Vallduví's rather literal use use of the file metaphor in (Vallduví, 1990; Vallduví, 1994) has been criticized by Dekker and Hendriks in their argument against treating links as ushers to a file-location (Dekker and Hendriks, 1994; Hendriks and Dekker, 1995); see also (Kuboň, 1998).

2.5 IS in the Generative Grammar Tradition

In (Chomsky, 1965) and the subsequent generative grammar works, IS phenomena are pursued in to orthogonal dimensions, namely the *topic-comment* dichotomy and the *background-focus* dichotomy (cf. (Lambrecht, 1994) for a detailed overview). The latter has attracted considerable research interest in formal semantics, starting essentially with (Jackendoff, 1972b), who successfully argued that focus has not only pragmatic import, but also both truth-conditional and semantic import, and laid out a research program for the theory of focus. Various researchers have since then addressed the main two issues pointed out by Jackendoff: Given a prosodically marked element (the prosodic focus), how can the syntactic focus be derived, and given a syntactic focus, how can the semantic and pragmatic import of it be computed? The seminal paper on syntactic focus projection is (Selkirk, 1984). Steedman then advocates a categorial grammar approach, arguing for an isomorphism between intonation, syntactic a semantic structure (Steedman, 2000b). (Engdahl and Vallduví, 1994) show how to model focus projection in HPSG.

The relation between syntactic and semantic focus has been explored to great detail in formal semantics research. The precursors of the current formal accounts of the meaning of IS were, e.g., (Lakoff, 1971; Dretske, 1972). One branch of approaches to the semantics of focus (von Stechow, 1990; Jackendoff, 1990; Krifka, 1992) works with *structured meanings* introduced by (Cresswell, 1985), where sentence meaning is represented by a pair of lambda-terms, one representing the focus and the other the ground. In (Krifka, 1992), this approach is applied to sentences with multiple focussing operators, and shown to preserve compositionality, while dealing with rather complex cases. In (Krifka, 1993), structured meanings are combined with a framework of dynamic interpretation, and a detailed discussion of the relation between focus, anaphora and presupposition is given. In a different vein, (Rooth, 1985b; Rooth, 1992) proposes a *alternative semantics* approach in which each expression has two semantic values: its truth-conditions and its focus value. The notion of alternative set is also

closely related to Hamblin's *set of potential answers* (Hamblin, 1973) and Karttunen's notion of *secondary denotation* (Karttunen and Peters, 1979b). Rooth shows how this focus value can be used to capture various constructs involving focussing, such as contrast, question-answer pairs, implicatures and focussing operators. (Büring, 1995; Büring, 1999) develops the alternative semantics approach further to handle theme-focus. It can be said that Steedman's work discussed below synthesizes both views, by working with IS-partitioned logical forms not unsimilar to the structured meanings, and assigning them interpretations in terms of presupposed alternative sets.

2.6 Steedman's Two Dimensions of IS

Steedman (1996; 2000b; 2000a) develops a theory of grammar in which syntax, information structure, and intonational prosody are integrated into one system. Steedman's main aim is to provide an IS-sensitive compositional analysis of English phrased as a Combinatory Categorial Grammar. In Combinatory Categorial Grammar ((Steedman, 2000a)), Information Structure and the associated structured meanings are associated directly with surface syntactic derivational structure, uniting Information Structure, Intonation Structure, and Surface Syntax in a single module of Grammar.

Steedman recognizes two independent dimensions of IS, both of which are relevant to its realization (Steedman, 2000a)(p.655). The first dimension defines a partitioning into a *Theme* and *Rheme*. This distinction is similar to the one proposed by Mathesius and to the Praguian topic-focus articulation. Steedman's Theme/Rheme indicates how, informally put, the utterance relates to the preceding discourse context.

Steedman also defines a second dimension of IS, the background/focus-partitioning of Themes and Rhemes. This partitioning is related to Halliday's *Given-New* dichotomy (Halliday, 1970; Halliday, 1985). It concerns the distinction between elements in the sentence's meaning which contribute to distinguishing the Theme and the Rheme from other *alternatives* that the context makes available, in the sense of Rooth's alternative sets (Steedman, 2000a)(p.656). The focus of a Rheme is that 'information' that is marked in the surface form, whereas the background of the Rheme is its unmarked part. In English, this corresponds to the focus being marked by a pitch accent, whereas the background is unmarked by either a pitch or a boundary. In a similar move Steedman divides the Theme into a focus and a background, with that difference to the Rheme that the Theme's focus is *optional*. There can, but need not, be a marked element in the Theme's surface realization.

The examples below illustrate Steedman's characterization of IS in more detail. Steedman formalizes the Theme of a sentence as a λ-term involving a functional abstraction, similarly to (Jackendoff, 1990; Krifka, 1993; Peregrin, 1995). The Rheme is a term that can be applied to that abstraction, after which we obtain a proposition. As CCG is a categorial grammar combining a λ-calculus to represent linguistic meaning, this proposition has the same predicate-argument structure as the composition of the canonical sentence would have resulted in. For example, consider the example in (26a) and the representation of its Theme in (26b).

(26) **English**

a. (What did Kathy prove?)
(Kathy proved)$_{theme}$(P=NP)$_{rheme}$.

b. $\lambda x.prove' x Kathy'$

Because the functional abstraction is closely related to the existential operator $\exists$, the context of (26a) could instantiate the existential as in (27).

(27) $\left\{ \begin{array}{c} \textit{prove' undecidability' Kathy'}, \\ \textit{prove' canonicity' Kathy'}, \\ \textit{prove' infatomability' Kathy'} \\ \textit{prove' P=NP' Kathy'} \end{array} \right\}$

The set in (27) is an alternative set, i.e. a set of potential alternative instantiations. Steedman calls it the *rheme alternative set*, and it holds that the Theme *presupposes* the rheme alternative set whereas the Rheme *restricts* it.[8] The distinction of a focus and a background in the Rheme, and possibly in the Theme, helps to set it apart from other alternatives available in the context. In particular, we have that the focus within the Rheme restricts the Rheme alternative set presupposed by the Theme.

Furthermore, we can consider the situation in which a Theme indeed does have a focus, realized by a marked form. Steedman gives in (Steedman, 2000a)(p.659) the following example, (28).

(28) **English**
(I know that Marcel likes the man who wrotes the muscial.
But who does he ADMIRE?)
(*Marcel* ADMIRES)(*the woman who*DIRECTED *the musical*)
background *focus* *background* *focus* *background*
Theme *Rheme*

Steedman argues that the significance of having a pitch accent on "admire" seems to be in the context offering alternatives that only differ in the relation between Marcel and x. A marked Theme is represented as in (29).

(29) $\exists x. * admires'\ x\ marcel'$

The utterance of (28) would be infelicitous if the context would *not* contain an alternative, like the $\exists x.likes'\ x\ marcel'$ we have here. The set of alternative Themes provided by the context of (28) is given in (30).

(30) $\left\{ \begin{array}{c} \exists x.admires'\ x\ marcel', \\ \exists x.likes'\ x\ marcel' \end{array} \right\}$

The kind of alternative set given in (30) is what Steedman calls the *Theme alternative set*. The Theme presupposes also this set, and it is the Theme's focus that restricts it.

In summary, elaborating on the alternative semantics of focus in (Rooth, 1992) and contrastive themes in (Büring, 1999), Steedman assigns the following semantics to IS (cf. (Steedman, 2000a)):

[8] As Steedman notes himself, for examples in (Steedman, 2000a)(p.10), alternative sets are used for reasons of exposition rather than presenting the only possible means of formalization. For example, it is not difficult to see how alternative sets in a sense 'extensionalize' accessibility in a modal logic's frame.

- Theme presupposes a *Rheme-alternative set* (ρ-*AS*).
- Focus within Rheme restricts the ρ-AS to the singleton set corresponding to the asserted proposition.
- Theme also presupposes a *Theme-alternative set* (θ-*AS*).
- Focus within Theme restricts the θ-AS to the singleton set corresponding to Theme.

ρ-AS corresponds to what Rooth calls the *contextual alternative set* (Rooth, 1985b; Rooth, 1992). θ-AS is a set of alternative themes with respect to the context (cf. (Büring, 1995)), corresponding to what Rooth calls the *question alternative set*. ρ-AS is a subset of the propositions supported by the context, whose characteristic function is obtained systematically from the IS-partitioned logical form. As noted in (Steedman, 2000a, p.10), alternative sets may not be exhaustively known to hearers, and in practice one would want to compute with a more abstract form.

Although Steedman does not discuss recursivity of focus and background, they appear to be recursive in the same sense as FGD's contextually bound/contextually nonbound distinction.

In (Steedman, 1996; Steedman, 2000b) and in (Steedman, 2000a) Steedman elaborates a grammar that shows how the above kinds of IS-enriched representations of a sentence's linguistic meaning are related to English tune. Hoffman worked out in (Hoffman, 1995b; Hoffman, 1995a) a version of CCG that models Turkish free word order. Hoffman coupled that to a slightly different theory of IS that stands inbetween Steedman's account and Vallduví's information packaging. (Kruijff and Baldridge, 2004) present a CCG account of how word order, intonation, and their interaction can help realize information structure, combining the insights from Hoffman and Steedman.

There appear to be various correspondences between Steedman's approach and FGD regarding IS. Both place it at the level of linguistic meaning. They both employ primitive notions that are recursive (CB/NB, focus/background). Also, they allow for a moderate form of recursivity where it concerns Theme/Rheme or topic/focus: information structure(s) can be embedded when it concerns embedded clauses (Hajičová et al., 1998)(p.160), (Steedman, 2000b)(§5.7.2).[9] Finally, it seems plausible to consider the contrastive topic marker *c* (Hajičová et al., 1998) as the counterpart of Steedman's Theme-focus, and the focusproper as the counterpart of Steedman's Rheme-focus.

However, Steedman's approach and FGD differ substantially in their view on the grammar, and in the way they describe IS and its realization. An approach to modeling IS that combines FGD's view on IS and its realization as an interaction between different means, and the categorial approach to formalizing the relation between surface form and underlying linguistic meaning has been presented in DGL(Kruijff, 2001). This can be argued to combine the best of the two worlds.

2.7 IS and Common Ground

It is clear from the overview in the preceding sections that some notion of *"givenness"* is involved in most approaches to IS. In the Praguian approach, the dichotomy of *contex-*

[9]For an earlier discussion of recursivity of TFA in FGD, see (Sgall et al., 1986)(§3.11).

tual boundness/non-boundness is used as basic (Sgall et al., 1986), and it is seen a linguistic signal of an item being considered activated in the common ground assumed by the speaker to be shared with the hearer; in (Firbas, 1992) *retrievability* is among the factors involved in IS, in Halliday's approach, the *Given/New* distinction constitutes a separate dimension (Halliday, 1967; Halliday, 1970; Halliday, 1985). The *Background/Focus* distinction in (Steedman, 2000a; Steedman, 2000b), where Focus marks those parts of a Theme/Rheme that distinguish it from alternatives that a context makes available, is also described by Steedman as being close to Halliday's Given/New. And finally, givenness is commonly appealed to when explaining *deaccenting*, e.g., (Hirschberg and Pierrehumbert, 1986; Hirschberg, 1993).

However, different authors agree that givenness is not as simple as "previous mention". So, we can ask how to define givenness, and how is it related to linguistic form. These questions have been addressed extensively in the literature, and different authors have proposed various taxonomies of (their notion) "givenness", also in relation to reflexes is linguistic form. (Prince, 1981) critically reviews several earlier approaches and proposes her taxonomy of *familiarity status*, where the main categories are *new, inferrable, given* (from the hearer's point of view). Two dimensions of *speaker given/new* vs. *hearer given/new* are discussed in (Prince, 1992). Various authors look in more detail at the discourse-given status, and propose more finegrained distinctions according to different degrees of *activation* that entities may be assumed to have in the hearer's consciousness (or: in a discourse model), e.g., (Chafe, 1976) (see also (Lambrecht, 1994)[Chapter 3]), (Gundel et al., 1993). Another approach to distinguishing different degrees of activation and linking them to the ways reference is realized linguistically is the Centering Theory (Grosz et al., 1995), which has been also applied computationally in both generation and analysis. What is of interest in the comparison to other approaches to givenness are the *forward-looking centers* and their *ordering*. Various proposals for center ordering have been made for various languages, using e.g., grammatical roles (Grosz et al., 1995), theta-roles (Hoffman, 1998), word order (Rambow, 1993), and Prince's familiarity status (Strube and Hahn, 1999). See (Grosz et al., 1995) and (Walker et al., 1998) for more details and references. Unlike the works above which use a taxonomy with a small number of givenness categories, Hajičová et al. et al.'s work on tracking salience assumes a continuous scale of activation (Hajičová and Vrbová, 1981; Hajičová and Vrbová, 1982), (Hajičová et al., 1990; Hajičová et al., 1992), (Hajičová et al., 1995a) and with reference to the Prague Dependencty Treebank, (Hajičová and Sgall, 2001). Moreover, this is the only approach that takes IS into account, rather than only some of its (more or less direct) surface reflexes. A comparison of Hajičová et al.'s model of tracking salience and the Centering model can be found in (Kruijff-Korbayová and Hajičová, 1997).

References

Theodora Alexopoulou. 1999. *The Syntax of Discourse Functions in Greek: A Non-Configurational Approach*. Ph.D. thesis, Department of Linguistics, University of Edinburgh, Edinburgh, United Kingdom, March.

Dwight Bolinger. 1965. *Forms of English*. Harvard University Press, Cambridge, MA.

Dwight Bolinger. 1989. *Intonation and its Uses*. Stanford University Press.

Johan Bos. 1999. The treatment of focussing particles in Underspecified Discourse Representations. In Bosch and van der Sandt (Bosch and van der Sandt, 1999), pages 121–141.

Peter Bosch and Rob van der Sandt, editors. 1999. *Focus: Linguistic, Cognitive and Computational Principles*. Natural Language Processing. Cambridge University Press, Cambridge.

Gillian Brown. 1983. Prosodic structure and the given/new distinction. In Anne Cutler, D. Robert Ladd, and Gillian Brown, editors, *Prosody: Models and Measurements*, pages 67–77. Springer-Verlag, Berlin.

Eva Buráňová, Eva Hajičová, and Petr Sgall. 2000. Tagging of very large corpora: Topic-focus articulation. In *Proceedings of COLING'2000*, pages 139–144.

Daniel Büring. 1995. *The 59th Street Bridge Accent: On the Meaning of Topic and Focus*. Ph.D. thesis, Universität Tübingen. Publ. as (Büring, 1997).

Daniel Büring. 1997. *The Meaning of Topic and Focus: The 59th Street Bridge Accent*. Routledge, London.

Daniel Büring. 1999. Topic. In Bosch and van der Sandt (Bosch and van der Sandt, 1999), pages 142–165.

Justine Cassel, Obed. E. Torres, and Scott Prevost. 1999. Turn taking vs. discourse structure: How best to model multimodal conversation. In Y. Wilks, editor, *Machine Conversations*. Kluwer.

Wallace Chafe. 1976. Givenness, contrastiveness, definiteness, subjects, topics and points of view. In Charles Li, editor, *Subject and Topic*, pages 25–55. Academic Press, New Tork.

Noam Chomsky. 1965. *Aspects of the Theory of Syntax*. MIT Press, Cambridge, MA.

Noam Chomsky. 1971. Deep structure, surface structure, and semantic interpretation. In Danny Steinberg and Leon Jakobovits, editors, *Semantics*, pages 183–216. Cambridge University Press, Cambridge.

Herbert Clark and Susan Haviland. 1977. Comprehension and the given-new contract. In R. Freedle, editor, *Discourse Production and Comprehension*, pages 1–40. Ablex, Norwood, NJ.

M.J. Cresswell. 1973. *Logics and Languages*. Methuen, London.

M.J. Cresswell. 1985. *Structured Meanings*. MIT Press, Cambridge, MA.

William Croft. 1990. *Typology and Universals*. Cambridge Textbooks in Linguistics. Cambridge University Press, Cambridge, United Kingdom.

Östen Dahl. 1969. *Topic and Focus: a Study in Russian and General Transformational Grammar*. Elandres Botryckeri, Göteborg.

Östen Dahl. 1974. Topic-comment structure revisited. In Östen Dahl, editor, *Topic and Comment, Contextual Boundedness and Focus*, number 6 in Papers in Text Linguistics. Helmut Buske, Hamburg, Germany.

František Daneš. 1970. Zur linguistischen [a]nalyse der [t]extstructur. *Folia Linguistica*, 4:72–78.

František Daneš. 1974. Functional sentence perspective and the organization of the text. In František Daneš, editor, *Papers on functional sentence perspective*, pages 106–208. Academia, Prague, Czech Republic.

Paul Dekker and Herman Hendriks. 1994. Files in focus. In Elisabet Engdahl, editor, *Integrating Information Structure into Constraint-based and Categorial Approaches*, DYANA-2 Deliverable R1.3.B., pages 41–79. Institute for Logic, Language and Computation (ILLC), Amsterdam, The Netherlands.

F. Dretske. 1972. Contrastive statements. *Philosophical Review*, pages 411–437.

Elisabeth Engdahl and Enric Vallduví. 1994. Information packaging and grammar architecture: A constraint-based approach. In Elisabet Engdahl, editor, *Integrating Information Structure into Constraint-based and Categorial Approaches*, DYANA-2 Deliverable R1.3.B., pages 41–79. Institute for Logic, Language and Computation (ILLC), Amsterdam, The Netherlands.

Elisabet Engdahl. 1999. The choice between *bli*-passive and *s*-passive in Danish, Norwegian, and Swedish. NORDSEM project report, Department of Linguistics, Göteborg University, June. Available from http://www.ling.gu.se/research/projects/nordsem/reports.html.

Carolin Féry. 1993. *German Intonational Patterns*. Niemeyer, Tübingen.

Jan Firbas. 1964. On defining the theme in functional sentence analysis. *Travaux Linguistiques de Prague*, 1:267–280.

Jan Firbas. 1966. Non-thematic subjects in contemporary english. *Travaux Linguistiques de Prague*, 2:229–236.

Jan Firbas. 1992. *Functional Sentence Perspective in Written and Spoken Communication*. Cambridge University Press, Cambridge, United Kingdom.

Peter H. Fries. 1981. On the status of theme in English: Arguments from discourse. *Forum Linguisticum*, 6(1):1 – 38.

Joseph Grimes. 1975. *The Thread of Discourse*. Mouton.

Barbara Grosz and Candace Sidner. 1986. Attention, intention and the structure of discourse. *Computational Linguistics*, 12:175–204.

Barbara Grosz, Aravind Joshi, and Scott Weinstein. 1995. Centering: a framework for modeling the local coherence of discourse. *Computational linguistics*, 21(2):203–226.

Jeanette Gundel, Nancy Hedberg, and Ron Zacharski. 1993. Cognitive status and the form of referring expressions in discourse. *Language*, (69):274–307.

Janet Gundel. 1974. *The Role of Topic and Comment in Linguistic Theory*. Ph.D. thesis, University of Texas, Austin.

Eva Hajičová and Petr Sgall. 1980. A dependency based specification of topic and focus. *Statistical methods in linguistics*, 1(2):93–140.

Eva Hajičová and Petr Sgall. 1987. The ordering principle. *Journal of Pragmatics*, 11(4):435–454.

Eva Hajičová and Petr Sgall. 2001. Topic-focus and salience. In *Proceedings of the 39th Annual Meeting of the Association for Computational Linguistics*.

Eva Hajičová and Jarka Vrbová. 1981. On the salience of the elements of the stock of shared knowledge. *Folia linguistica*, (15):291–303.

Eva Hajičová and Jarka Vrbová. 1982. On the role of the hierarchy of activation in the process of natural language understanding. In Ján Horecký, editor, *Proceedings of COLING 1982*, pages 107–113, Prague, Czechoslovakia. Academia.

Eva Hajičová, Petr Kuboň, and Vladislav Kuboň. 1990. Hierarchy of salience and discourse analysis and production. pages 144–148.

Eva Hajičová, Vladislav Kuboň, and Petr Kuboň. 1992. Stock of shared knowledge - a tool for solving pronominal anaphora. pages 127–133.

Eva Hajičová, Petr Sgall, and Hana Skoumalová. 1993. Identifying topic and focus by an automatic procedure. In *Proceedings of the conference of the European Association of Computational Linguistics, April 1993, Utrecht, the Netherlands*. ACL.

Eva Hajičová, Tomáš Hoskovec, and Petr Sgall. 1995a. Discourse modelling based on hierarchy of salience. *Prague Bulletin of Mathematical Linguistics*, 64:5–24. Charles University, Prague, Czech Republic.

Eva Hajičová, Petr Sgall, and Hana Skoumalová. 1995b. An automatic procedure for topic-focus identification (a revised version of (Hajičová et al., 1993)). *Computational linguistics*, 21(1):81–94.

Eva Hajičová, Barbara H. Partee, and Petr Sgall. 1998. *Topic-Focus Articulation, Tripartite Structures, and Semantic Context*. Studies in Language and Philosophy. Kluwer Academic Publishers, Dordrecht, Boston, London.

Eva Hajičová, Jiří Havelka, and Petr Sgall. "to appear". Topic and focus, anaphoric relations and degrees of salience. In *Prague Linguistic Circle Papers 5*. John Benjamins.

Eva Hajičová. 1993. *Issues of sentence structure and discourse patterns*, volume 2 of *Theoretical and computational linguistics*. Charles University, Prague, Czech Republic.

Eva Hajičová. 2003. Aspects of discourse structure. In Wolfgang Menzel and Cristina Vertan, editors, *Natural Language Processing between Linguistic Inquiry and System Engineering*, pages 47 – 54. Editura Universitatii Alexandru Ioan Cuza, Iasi.

Eva Hajičová, Petr Sgall, and Eva Buráňová. 2003. Topic-focus articulation and degrees of salience in the prague dependency treebank. In *Formal Approaches to Function in Grammar. In honor f Eloise Jelinek, Arizona*, pages 165–177. John Benjamins.

Eva Hajičová. 1993. *Issues of sentence structure and discourse patterns*, volume 2 of *Theoretical and Computational Linguistics*. Charles University Press, Prague, Czech Republic.

Michael Halliday and Ruqaiya Hasan. 1976. *Cohesion in English*. Longman.

Michael A. K. Halliday. 1967. Notes on transitivity and theme in English — parts 1 and 2. *Journal of Linguistics*, 3(1 and 2):37–81 and 199–244.

Michael A.K. Halliday. 1970. *A Course in Spoken English: Intonation*. Oxford Uniersity Press, Oxford.

Michael A.K. Halliday. 1985. *Introduction to Functional Grammar*. Edward Arnold, London, U.K.

M.A.K. Halliday. 1993. The construction of knowledge and value in the grammar of scientific discourse: Charles Darwin's *The Origin of the Species*. In M.A.K. Halliday and J.R. Martin, editors, *Writing Science: literacy and discoursive power*, pages 86–105. The Falmer Press, London.

C. Hamblin. 1973. Questions in Montague english. *Foundations of Language*, pages 41–53.

Irene Heim. 1982a. *The semantics of definites and indefinite noun phrases in English*. Ph.D. thesis, University of Massachussetts, Amherst.

Irene Roswitha Heim. 1982b. *The Semantics of Definite and Indefinite Noun Phrases*. Ph.D. thesis, Graduate School of the University of Massachusetts, Amherst, Massachusetts.

Herman Hendriks and Paul Dekker. 1995. Links without locations. information packaging and non-monotone anaphora. In Paul Dekker and Martin Stokhof, editors, *Proceedings of the*

10th Amsterdam Colloquium, pages 339–358. Institute of logic, language and computation, Department of Philosophy, Universiteit van Amsterdam.

Herman Hendriks. 1994. Information packaging in a categorial perspective. In Elisabet Engdahl, editor, *Integrating Information Structure into Constraint-based and Categorial Approaches*, DYANA-2 Deliverable R1.3.B., pages 41–79. Institute for Logic, Language and Computation (ILLC), Amsterdam, The Netherlands.

Herman Hendriks. 1996. Intonation, derivation, information. A proof-theoretic framework for the representation of information packaging. In V.M. Abrusci and C. Casadio, editors, *Proofs and Linguistic Categories: Applications of Logic to the Analysis and Implementation of Natural Language (Roma 1996 Workshop)*.

Herman Hendriks. 1997. The logic of tune. In Geert-Jan M. Kruijff, Glyn V. Morrill, and Richard T. Oehrle, editors, *Formal Grammar 1997*, Aix en Provence, France, August 9-10.

H. Hendriks. 1998. Links without locations. In F. Hamm and E. Zimmermann, editors, *Linguistische Berichte, Sonderheft 9/1998: SEMANTIK*. Westdeutscher Verlag, Opladen.

Caroline Heycock. 1993. Focus projection in Japanese. In Merceí González, editor, *Proceedings of NELS*, volume 24, pages 159–187.

Julia Hirschberg and Janet Pierrehumbert. 1986. Intonational structuring of discourse. In *Proceedings of the 24th Annual Meeting of the Association for Computational Linguistics, New York*, pages 136–144, San Francisco, CA. Morgan Kaufmann.

Julia Hirschberg. 1993. Pitch accent in context: Predicting intonational prominence from text. *Artificial Intelligence*, (63):305–340.

Beryl Hoffman. 1995a. *Computational Analysis of the Syntax and Interpretation of "Free" Word-Order in Turkish*. Ph.d. thesis, ircs report 95-17, University of Pennsylvania.

Beryl Hoffman. 1995b. Integrating "free" word order syntax and information structure. In *Proceedings EACL'95*, Dublin, March.

Beryl Hoffman. 1996. Translating into free word order languages. In *Proceedings of the International Conference on Computational Linguistics (COLING-96), Copenhagen*, pages 556–561, Copenhagen, Denmark. Center for Sprogteknologi.

Beryl Hoffman. 1998. Word order, information structure, and centering in turkish. In Marilyn Walker, Ellen Prince, and Aravind Joshi, editors, *Centering Theory in Discourse*, pages 253–271. Oxford University Press, Oxford.

R.D. Huddleston. 1988. Constituency, multi-functionality and grammaticalization in Halliday's Functional Grammar. *Journal of Linguistics*, 24.

Ray Jackendoff. 1972a. *Semantic Interpretation in Generative Grammar*. MIT Press, Cambridge, MA.

Ray Jackendoff. 1972b. *Semantic Interpretation in Generative Grammar*. The MIT Press, Cambridge Massachusetts.

Ray Jackendoff. 1990. *Semantic Structures*. MIT Press, Cambridge.

Hans Kamp. 1984. A theory of truth and semantic representation. In Jeroen Groenendijk, Theo Janssen, and Martin Stokhof, editors, *Truth, Interpretation, and Information*, pages 1–41. Foris, Dordrecht.

Lauri Karttunen and Stanley Peters. 1979a. Conventional implicature. In Choon-Kyu Oh and David Dinneen, editors, *Syntax and Semantics 11: Presupposition*, pages 1–56. Academic Press, New York.

Lauri Karttunen and Stanley Peters. 1979b. Conventional implicature. In Choon-Kyu Oh

and David A. Dinneen, editors, *Syntax and Semantics: Presupposition*, volume 11, pages 1–56. Academic Press.

Lauri Karttunen. 1968. What makes definite noun phrases definite? Technical report, Rand Corporation.

Martin Kay. 1975. Syntactic processing and functional sentence perspective. In Roger Schank and Bonnie Nash-Webber, editors, *Theoretical Issues in Natural Language Processing, (Supplement)*, pages 12–15, MIT, June.

Eva Koktová. 1995. Wh-extraction and the topic-focus articulation of the sentence. In Barbara H. Partee and Petr Sgall, editors, *Discourse and Meaning: Papers in Honor of Eva Hajičová*, pages 255–271. John Benjamins, Amsterdam, The Netherlands.

Dimitra Kolliakou. 1998. Linkhood and multiple definite marking. In Gosse Bouma, Geert-Jan M. Kruijff, and Richard T. Oehrle, editors, *Proceedings Joint Conf. on Formal Grammar, HPSG and CG*, pages 14–24, Saarbrücken, Germany, August. DFKI.

Nobo Komagata. 1999. *Information Structure in Texts: A Computational Analysis of Contextual Appropriateness in English and Japanese*. Ph.D. thesis, University of Pennsylvania.

Ivana Korbayová and Geert-Jan Kruijff. 1996. Identification of topic-focus chains. In S. Botley, Glass J., T. McEnery, and A. Wilson, editors, *Approaches to Discourse Anaphora: Proceedings of the Discourse Anaphora and Anaphora Resolution Colloquium (DAARC96)*, number 8 in Technical papers, pages 165–179, Lancaster, U.K., jul. University Centre for Computer Corpus Research on Language, University of Lancaster.

Angelika Kratzer. 1991. The representation of focus. In Arnim von Stechow and Dieter Wunderlich, editors, *Semantics: An International Handbook of Contemporary Research*, pages 825–834. de Gruyter, Berlin.

Manfred Krifka. 1991. A compositional semantics for multiple focus constructions. *Cornell Working Papers in Linguistics*, 10:127–158.

Manfred Krifka. 1992. A compositional semantics for multiple focus constructions. In J. Jacobs, editor, *Informationsstruktur und Grammatik*, Linguistische Berichte, Sonderheft 4, pages 17–53.

Manfred Krifka. 1993. Focus and presupposition in dynamic semantics. *Theoretical Linguistics*, 19:269–300.

Paul Kroeger. 1993. *Phrase Structure and Grammatical Relations in Tagalog*. Dissertations in Linguistics. CSLI Press, Stanford, CA.

Geert-Jan M. Kruijff and Jason M. Baldridge. 2004. Generalizing dimensionality in combinatory categorial grammar. In *Proceedings of COLING'2004*.

Geert-Jan Kruijff and Ivana Kruijff-Korbayová. 2001. A hybrid logis formalization of information structure sensitive discourse interpretation. In Václav Matoušek, Pavel Mautner, Roman Mouček, and Karel Taušer, editors, *Proceedings of the Conference on Text, Speech and Dialogue (TSD'01), Železná Ruda, Czech Republic, September 11-13 2001*, Leture Notes in omputer Science, pages 31–38. Springer-Verlag. `http://www.coli.uni-sb.de/~korbay/Publications/tsd01.ps.gz`.

Ivana Kruijff-Korbayová and Eva Hajičová. 1997. Topics and centers: a comparison of the salience-based approach and the centering theory. *Prague Bulletin of Mathematical Linguistics*, (67):25–50. url.

Ivana Kruijff-Korbayová and Geert-Jan Kruijff. 1997. TFA in SDRT. In Paul Dekker, Martin Stokhof, and Yde Venema, editors, *Proceedings of the 11th Amsterdam Colloquium*,

pages 43–48. Institute of logic, language and computation, Department of Philosophy, Universiteit van Amsterdam.

Ivana Kruijff-Korbayová and Mark Steedman. 2003. Discourse and information structure. *Journal of Logic, Language and Information: Special Issue on Discourse and Information Structure*, 12(3):249–259.

Ivana Kruijff-Korbayová and Bonnie Webber. 2001. Concession, implicature, and alternative sets. In Harry Bunt, editor, *Proceedings of the International Workshop on Computational Semantics IWCS-4*, pages 227–248, Tilburg, the Netherlands, January 10-12. http://www.coli.uni-sb.de/ korbay/Publications/iwcs-2001.ps.gz.

Ivana Kruijff-Korbayová, John Bateman, and Geert-Jan M. Kruijff. 2002. Generation of contextually appropriate word order. In Kees van Deemter and Rodger Kibble, editors, *Information Sharing*, Lecture Notes, pages 193–222. CSLI. http://www.coli.uni-sb.de/publikationen/softcopies/Kruijff-Korbayova:1999:GCA.pdf http://www.coli.uni-sb.de/publikationen/softcopies/Kruijff-Korbayova:1999:GCA.ps.

Ivana Kruijff-Korbayová, Stina Ericsson, Kepa Joseba Rodríguez, and Elena Karagjosova. 2003a. Producing contextually appropriate intonation is an information-state based dialogue system. In *Proceedings of the 10th Conference of the European Chapter of the Association for Computational Linguistics (EACL)*, pages 227–234. ACL.

Ivana Kruijff-Korbayová, Stina Ericsson, Kepa Joseba Rodríguez, and Elena Karagrjosova. 2003b. Producing contextually appropriate intonation is an information-state based dialogue system. In *Proceedings of the 10th Conference of the European Chapter of the Association for Computational Linguistics (EACL)*, page to appear, Budapest, Hungary, April 12–17. ACL.

Ivana Kruijff-Korbayová. 1998. *The Dynamic Potential of Topic and Focus: A Praguian Discourse Representation Theory*. unpublished Ph.D. thesis, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic.

Geert-Jan M. Kruijff. 2001. *A Categorial-Modal Logical Architecture of Informativity: Dependency Grammar Logic and Information Structure*. Ph.d. dissertation, Institute of Formal and Applied Linguistics (ÚFAL), Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic.

Petr Kuboň. 1998. Information repackaging. In Gosse Bouma, Geert-Jan M. Kruijff, and Richard T. Oehrle, editors, *Proceedings of the Joint Conference on Formal Grammar, Head-Driven Phrase Structure Grammar, and Categorial Grammar*, Saarbrücken, August.

D. Robert Ladd. 1996. *Intonational Phonology*. Cambridge University Press, Cambridge.

D. Robert Ladd. 2001. Intonational universals and intonational typology. In Martin Hapselmath, Ekkehard König, Wulf Oesterreicher, and Wolfgang Raible, editors, *Handbook on Language Typology and Language Universals*. De Gruyter, Berlin.

Robin Lakoff. 1971. The role of deduction in grammar. In Charles J. Fillmore and D. Terence Langedoen, editors, *Studies in Linguistic Semantics*, pages 62–70. Holt, Rinehart and Winston, Inc.

Knud Lambrecht. 1994. *Information Structure and Sentence Form*. Cambridge University Press, Cambridge, U.K.

John Lyons. 1977. *Semantics*, volume II. Cambridge University Press.

Suresh Manandhar. 1994. Encoding information packaging information in HPSG. In Elisabet Engdahl, editor, *Integrating Information Structure into Constraint-based and Categorial*

Approaches, DYANA-2 Deliverable R1.3.B., pages 83–87. Institute for Logic, Language and Computation (ILLC), Amsterdam, The Netherlands.

William Mann and Sandra Thompson. 1987. Rhetorical structure theory: A framework for the analysis of texts. Technical Report RS-87-185, Information Science Institute, Marina del Rey, CA.

Pavel Materna and Petr Sgall. 1980. Functional sentence perspective, the question test, and intensional semantics. *SMIL-Journal of Linguistic Calculus*, (1-2):141–160.

Pavel Materna, Eva Hajičová, and Petr Sgall. 1987. Redundant answers and topic-focus articulation. *Linguistics and Philosophy*, 10:101–113.

Vilem Mathesius. 1929. Functional linguistics. In Josef Vachek, editor, *Praguiana: Some Basic and Less Well-known Aspects of the Prague Linguistics School*, pages 121–142. John Benjamins, Amsterdam. publ. 1983.

Vilém Mathesius. 1936. On some problems of the systematic analysis of grammar. In *Travaux du Cercle Linguistique de Prague*, volume VI, pages 95–107. Reprinted in (Vachek, 1964), pp.306-319.

Vilém Mathesius. 1975. On information bearing structure of the sentence. In S. Kuno, editor, *Harvard Studies in Syntax and Semantics*. Harvard University Press, Cambridge, Massachusetts.

Christian M.I.M. Matthiessen. 1995. Theme as an enabling resource in ideational 'knowledge' construction. In M. Ghadessy, editor, *Thematic development in English texts*, pages 20–54. Pinter Publishers, London.

Alex Monaghan. 1994. Intonation accent placement in a concept-to-dialogue system. In *Proceedings of the Second ESCA/IEEE Workshop on Speech Synthesis*, pages 171–174, New Paltz, NY, September.

Richard Montague. 1973. The proper treatment of quantification in ordinary english. In Jaakko Hintikka, J. M. E. Moravcsik, and Patrick Suppes, editors, *Approaches to Natural Language: Proceedings of the 1970 Stanford Workshop on Grammar and Semantics*, pages 221–242. Reidel, Dordrecht. Reprinted in Montague 1974, 247-279.

Michael Moortgat and Glyn Morrill. 1991. Heads and phrases: Type calculus for dependency and constituent structure. Unpublished manuscript. Available from http://www-lsi.upc.es/~morrill/.

Reinhard Muskens, Johan van Benthem, and Albert Visser. 1996. Dynamics. In Johan van Benthem and Alice ter Meulen, editors, *Handbook of Logic and Language*. Elsevier Science B.V., Amsterdam New York etc.

Christine H. Nakatani, Julia Hirschberg, and Barbara Grosz. 1995. Discourse structure in spoken language: Studies on speech corpora. In *Working notes of AAAI-95 Spring Symposium on Empirical Methods in Discourse Interpretation, Palo Alto, CA*.

Barbara H. Partee and Petr Sgall, editors. 1995. *Discourse and Meaning*. John Benjamins Publishing Company.

Barbara H. Partee, Eva Hajičová, and Petr Sgall. 1998. *Topic-Focus Articulation, Tripartite Structures, and Semantic Content*. Kluwer, Amsterdam.

Barbara H. Partee. 1991. Topic, focus and quantification. In S. Moore and A. Wyner, editors, *Proceedings from Semantics and Linguistic Theory I*, pages 257–280, Ithaca NY. Cornell University.

Barbara Partee. 1995. Allegation and local accommodation. In Partee and Sgall (Partee and Sgall, 1995), pages 65–86.

Catherine Pelachaud, Justine Cassel, Norman Badler, Mark Steedman, Scott Prevost, and Mathew Stone. 1998. Synthesizing cooperative conversation. In Harry Bunt and R. J. Beun, editors, *Multimodal Human-Computer Communication - Systems, Techniques and Experiments*, Springer Notes in Artificial Intelligence 1374, pages 68–88. Springer Verlag.

Jaroslav Peregrin. 1995. Topic and focus in a formal framework. In Partee and Sgall (Partee and Sgall, 1995), pages 235–254.

Vladimír Petkevič. 1987. A new dependency based specification of underlying representations of sentences. *Theoretical linguistics*, 14:143–172. Walter de Gruyter, Berlin, Germany.

Vladimír Petkevič. 1995. A new formal specification of underlying structures. *Theoretical linguistics*, 21(1):7–61. Walter de Gruyter, Berlin, Germany.

Vladimír Petkevič. in prep. *Underlying Structure of Sentence Based on Dependency*. Charles University, Prague.

Janet Pierrehumbert and Julia Hirschberg. 1990. The meaning of intonational contours in the interpretation of discourse. In Philip Cohen, Jerry Morgan, and Martha Pollack, editors, *Intentions in Communication*, pages 271–312. MIT Press, Cambridge, MA.

Janet Pierrehumbert. 1980. *The Phonology and Phonetics of English Intonation*. Ph.D. thesis, MIT. Distributed by Indiana University Linguistics Club, Bloomington.

Livia Polanyi and Remko Scha. 1983. The syntax of discourse. *Text*, 3:261–270.

Scott Prevost and Mark Steedman. 1993. Generating contextually appropriate intonation. In *Proceedings of the Sixth Conference of the European Chapter of the Association for Computational Linguistics, Utrecht*, pages 332–340, San Francisco, CA. Morgan Kaufmann.

Scott Prevost and Mark Steedman. 1994. Specifying intonation from context for speech synthesis. *Speech Communication*, 15:139–153.

Scott Prevost. 1995a. *A Semantics of Contrast and Information Structure for Specifying Intonation in Spoken Language Generation*. Ph.D. thesis, University of Pennsylvania.

Scott Prevost. 1995b. *A Semantics of Contrast and Information Structure for Specifying Intonation in Spoken Language Generation*. Ph.D. dissertation, IRCS TR 96-01, University of Pennsylvania, Philadelphia.

Ellen Prince. 1981. Toward a taxonomy of given-new information. In Peter Cole, editor, *Radical Pragmatics*, pages 223–256. Academic Press.

Ellen Prince. 1992. The ZPG letter: subjects, definiteness, and information status. In Sandra Thompson and William Mann, editors, *Discourse Description: diverse analyses of a fund raising text*, pages 295–325. John Benjamins.

Owen Rambow. 1993. Pragmatic aspects of scrambling and topicalization in German: A centering approach.

Craige Roberts. 1998. Focus, information flow, and universal grammar. In Peter Culicover and Louise McNally, editors, *Syntax and Semantics, Vol. 29: The Limits of Syntax*, pages 109–160. Academic Press, San Diego, CA.

Mats Rooth. 1985a. *Association with Focus*. Ph.D. thesis, University of Massachusetts, Amherst.

Mats Rooth. 1985b. *A Theory of Focus Interpretation*. Ph.D. thesis, Graduate School of the University of Massachusetts, Amherst, Massachusetts.

Mats Rooth. 1992. A theory of focus interpretation. *Natural Language Semantics*, 1:75–116.

Bertrand Russell. 1905. On denoting. *Mind*, 14:479–493.

Harvey Sacks, Emanuel Schegloff, and Gail Jefferson. 1974. A simplest semantics for the organization of turn–taking for conversation. *Language*, 50:696–735.

Elisabeth Selkirk. 1984. *Phonology and Syntax*. MIT Press, Cambridge, MA.

Petr Sgall, Ladislav Nebeský, Alla Goralčíková, and Eva Hajičová. 1969. *A Functional Approach to Syntax In Generative Description of Language*. Elsevier Science B.V., Amsterdam New York etc.

Petr Sgall, Eva Hajičová, and Eva Benešová. 1973. *Topic, Focus, and Generative Semantics*. Kronberg/Taunus.

Petr Sgall, Eva Hajičová, and Eva Buráňová. 1980. *Aktuální členění věty v češtině [Topic/Focus Articulation of the Czech Sentence]*. Academia, Prague, Czechoslovakia.

Petr Sgall, Eva Hajičová, and Jarmila Panevová. 1986. *The meaning of the sentence in its semantic and pragmatic aspects*. Reidel, Dordrecht, The Netherlands.

Petr Sgall, Oskar E. Pfeiffer, Wolfgang U. Dressler, and M. Půček. 1995. Experimental research on systemic ordering. *Theoretical Linguistics*, 21:197–239.

Petr Sgall. 1967. Functional sentence perspective in a generative description. *Prague studies in mathematical linguistics*, 2:203–225. Prague, Czechoslovakia.

Petr Sgall. 1980. A dependency based specification of topic and focus II. *SMIL-Journal of Linguistic Calculus*, (1-2):110–140.

Mark Steedman. 1991. Structure and intonation. *Language*, 67:262–296.

Mark Steedman. 1996. *Surface Structure and Interpretation*. The MIT Press, Cambridge Massachusetts.

Mark Steedman. 2000a. Information structure and the syntax-phonology interface. *Linguistic Inquiry*, 31(4):649–689.

Mark Steedman. 2000b. *The Syntactic Process*. M.I.T. Press, Cambridge, MA.

Peter Strawson. 1950. On referring. *Mind*, 59:320–344.

Peter Strawson. 1954. A reply to mr. sellars. *Philosophical Review*, 63:216–231.

Michael Strube and Udo Hahn. 1999. Functional centering: Grounding referential coherence in information structure. *Computational Linguistics*. url.

David R. Traum and Staffan Larsson. 2003. The information state approach to dialog management. In *Current and New Directions in Discourse and Dialog*. Kluwer.

Carla Umbach. 2001. Contrast and contrastive topic. In Ivana Kruijff-Korbayová and Mark Steedman, editors, *Information Structure, Discourse Structure and Discourse Semantics, ESSLLI2001 Workshop Proceedings*, Helsinki, Finland, August 20-24. European Summer School in Logic, Language and Information (ESSLLI), The University of Helsinki. url.

Josef Vachek. 1964. *A Prague School Reader in Linguistics*. Indiana University Press, Bloomington, IN.

Enric Vallduví and Elisabet Engdahl. 1996. The linguistic realization of information packaging. *Linguistics*, 34:459–519.

Enric Vallduví and Maria Vilkuna. 1998. On rheme and kontrast. In Peter Culicover and Louise McNally, editors, *Syntax and Semantics, Vol. 29: The Limits of Syntax*, pages 79–108. Academic Press, San Diego, CA.

Enric Vallduví and Ron Zacharski. 1994. Accenting phenomena, association with focus, and the recursiveness of focus-ground. In Paul Dekker and Martin Stokhof, editors, *Proceedings of the Ninth Amsterdam Colloquium*, pages 683–702, Amsterdam, The Netherlands. Universiteit van Amsterdam.

Enric Vallduví. 1990. *The Information Component*. Ph.D. thesis, University of Pennsylvania.

Enric Vallduví. 1994. The dynamics of information packaging. In Elisabet Engdahl, editor, *Integrating Information Structure into Constraint-based and Categorial Approaches*,

DYANA-2 Deliverable R1.3.B. Institute for Logic, Language and Computation (ILLC), Amsterdam, The Netherlands.

Eija Ventola. 1995. Thematic development and translation. In M. Ghadessy, editor, *Thematic development in English texts*, pages 85–104. Pinter Publishers, London.

Tomáš Vlk. 1988. Towards a transduction of underlying structures into intensional logic. *Prague Bulletin of Mathematical Linguistics*, (50):35–70.

Arnim von Stechow. 1990. Categorial grammar and linguistic theory. *Studies in Language*, 14:433–478.

Arnim von Stechow. 1991. Focusing and backgrounding operators. In Werner Abraham, editor, *Discourse Particles: Descriptive and Theoretical Investigations on the Logical, Syntactic and Pragmatic Properties of Discourse Particles in German*, pages 37–84. John Benjamins, Amsterdam.

Marilyn Walker, Aravind K. Joshi, and Ellen F. Prince, editors. 1998. *Centering Theory in Discourse*. Oxford University Press.

Bonnie Webber. 1988. Tense as discourse anaphor. *Computational Linguistics*, 14:61–73.

Henri Weil. 1844. *The Order of Words in the Ancient Languages comparsed with that of the Modern Languages*. John Benjamins, Amsterdam, The Netherlands. Second edition 1884; French original 1844, English translation by Charles W. Super.

Terry Winograd. 1972. *Understanding Natural Language*. Edinburgh University Press, Edinburgh.