Introduction to HPSG
Class 1: Clause Structure, Hierarchical Organization of Knowledge, Lexical Regularities

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Course Page and Material

- Web page with the slides and handouts of the three lectures: http://hpsg.stanford.edu/LSA07/

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  http://hpsg.stanford.edu/LSA07/
- The analyses are implemented.
  A CD rom image which contains the grammar development software and example grammars for German, Chinese, and Maltese can be downloaded from:
  http://www.cl.uni-bremen.de/Software/Grammix/

  If you have a writable CD, we can burn it here.

Outline of the Whole Course

Class 1 Feature structures, the linguistic sign,
basic clause structures, phrasal projection,
the hierarchical organization of lexical and phrasal information.

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Class 3 The feature-based analysis of long distance dependencies
(in cross-linguistic perspective), island constraints.

Outline

- Motivation & Psychological Reality
- General Overview of the Framework
- Valency
- Head Argument Structures
- Semantics
- Hierarchical Organization of Knowledge

Motivations for HPSG

- Increased Precision

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- Psycholinguistic Plausibility

Important Moments in the History of Linguistics – I

Chomsky (1968) speaking of early psycholinguistic findings in relation to the 'derivational theory of complexity' (DTC):

> *The results show a remarkable correlation of the amount of memory and number of transformations. (Chomsky, 1968)*

Important Moments in the History of Linguistics – II

Fodor, Bever and Garrett (1974):

> *Experimental investigations of the psychological reality of linguistic structural descriptions have [. . .] proved quite successful.*

Important Moments in the History of Linguistics – III

Fodor, Bever and Garrett (1974):

> *Investigations of DTC...have generally proved equivocal. This argues against the occurrence of grammatical derivations in the computations involved in sentence recognition.*

- HPSG as response to the Fodor, Bever, Garrett dilemma

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- HPSG recognizes the 'linguistic structural descriptions' whose psychological reality is established, e.g. phonological representations, semantic representations.
- HPSG defines these descriptions via structural definitions and 'interface constraints' (Jackendoff), thus eliminating grammatical derivations in FBG's sense.

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- phonology, syntax, and semantics are represented in one description:
  - Phonology
  - Syntax
  - Semantics

$$\begin{bmatrix} \textsc{phon} & \langle\ \textit{Grammatik}\ \rangle \\ \textsc{synsem|loc} & \begin{bmatrix} \textsc{cat} & \begin{bmatrix} \textsc{head} & \begin{bmatrix} \textsc{case}\ \boxed{1} \\ \textit{noun} \end{bmatrix} \\ \textsc{subcat} & \langle \textsc{det}[\textsc{case}\ \boxed{1}] \rangle \\ \textit{cat} \end{bmatrix} \\ \textsc{cont} & \ldots \begin{bmatrix} \textsc{inst}\ X \\ \textit{grammatik} \end{bmatrix} \\ \textit{loc} \end{bmatrix} \\ \textit{word} \end{bmatrix}$$

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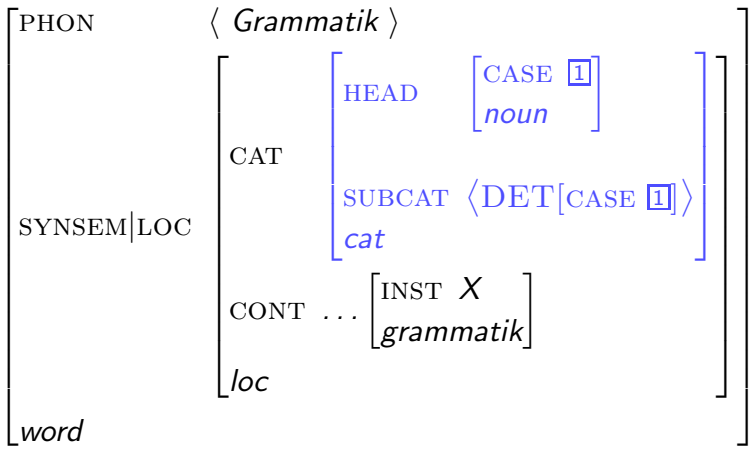

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Valency and Grammar Rules: PSG

- huge number of rules:

S → NP, V	*X schläft* ('sleeps')
S → NP, NP, V	*X Y liebt* ('loves')
S → NP, PP[*über*], V	*X über y spricht* ('talks about')
S → NP, NP, NP, V	*X Y Z gibt* ('gives')
S → NP, NP, PP[*mit*], V	*X Y mit Z dient* ('serves')

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- verbs have to be used with the right rule

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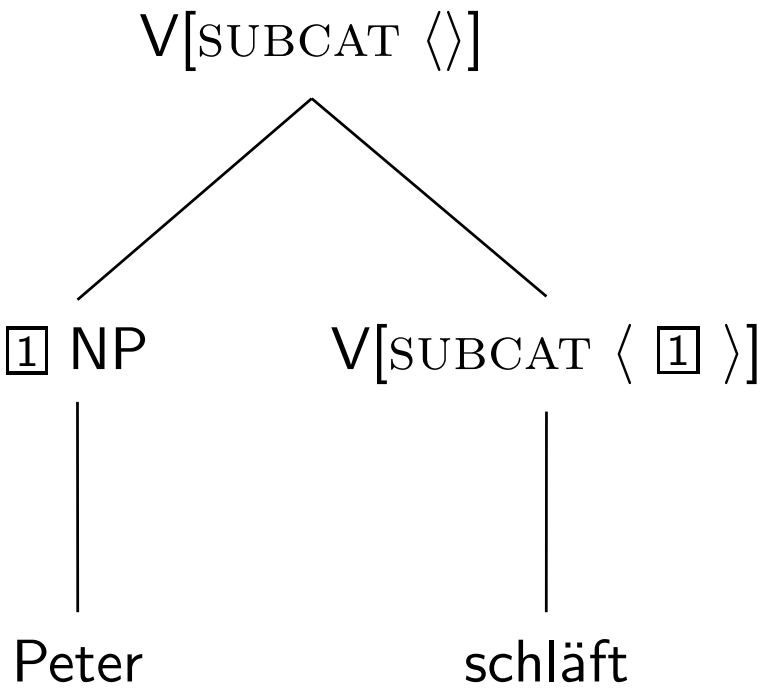
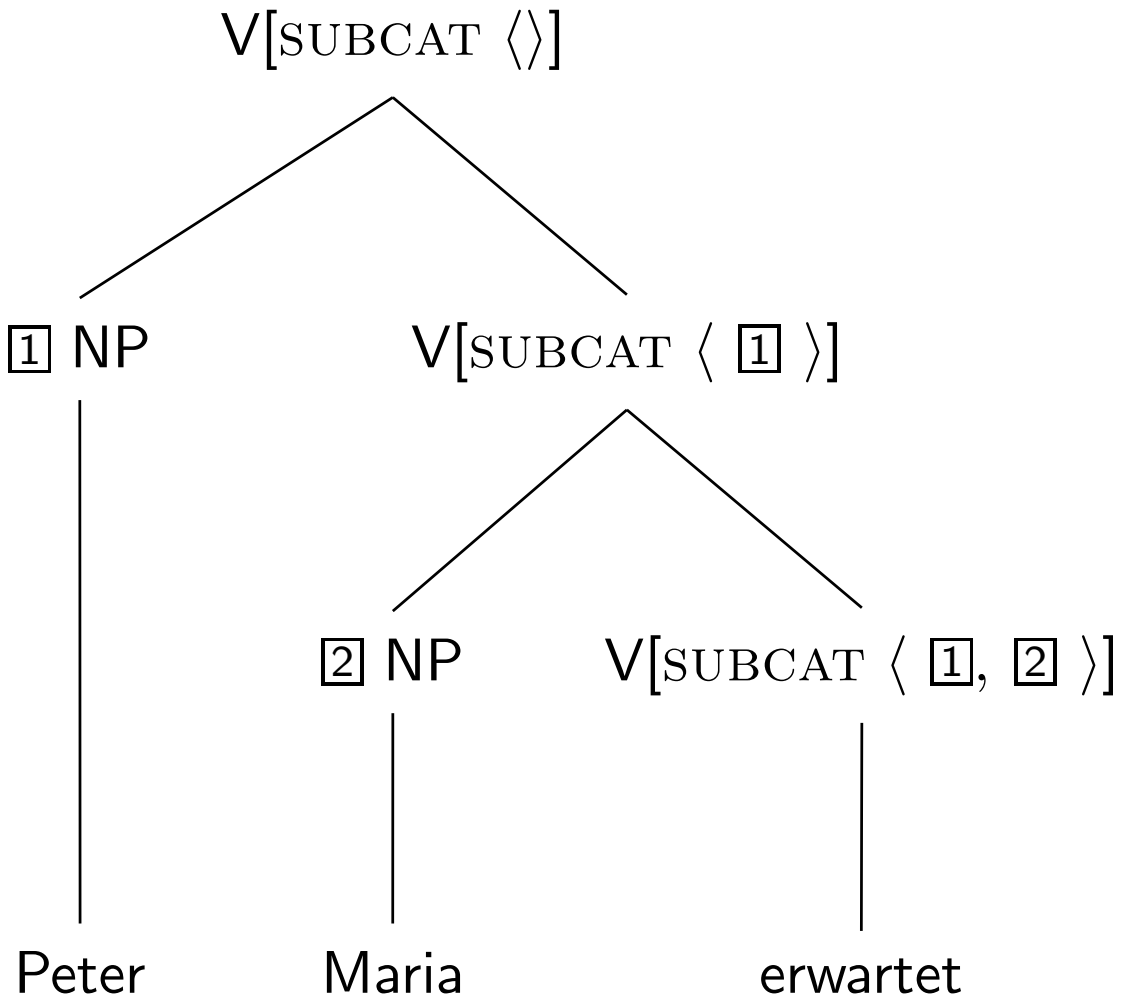
Verb	SUBCAT
schlafen	⟨ NP ⟩
lieben	⟨ NP, NP ⟩
sprechen	⟨ NP, PP[*über*] ⟩
geben	⟨ NP, NP, NP ⟩
dienen	⟨ NP, NP, PP[*mit*] ⟩

Example Tree with Valency Information (I)



V[SUBCAT ⟨ ⟩] corresponds to a fully saturated phrase (VP or S)

Example Tree with Valency Information (II)



Valency and Grammar Rules: HPSG

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  V[SUBCAT $\boxed{A}$] $\rightarrow$ $\boxed{1}$ V[SUBCAT $\boxed{A} \oplus \langle \boxed{1} \rangle$]

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- $\oplus$ is a relation that concatenates two lists:
  $\langle\, a,\, b \,\rangle = \langle\, a \,\rangle \oplus \langle\, b \,\rangle$ or
  $\langle\rangle \oplus \langle\, a,\, b \,\rangle$ or
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- In the rule above a list is split in a list that contains exactly one element ($\boxed{1}$) and a rest ($\boxed{A}$).
- Depending on the valency of the head the rest may contain zero or more elements.

Generalization over Rules

- specific rules for head argument combinations:

  V[SUBCAT $\boxed{A}$] → $\boxed{1}$ V[SUBCAT $\boxed{A} \oplus \langle \boxed{1} \rangle$]

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  N[SUBCAT $\boxed{A}$] → $\boxed{1}$ N[SUBCAT $\boxed{A} \oplus \langle \boxed{1} \rangle$]

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- abstraction with respect to the order:

  $V[\text{SUBCAT } \boxed{A}] \rightarrow V[\text{SUBCAT } \boxed{A} \oplus \langle \boxed{1} \rangle] \quad \boxed{1}$

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- generalized, abstract schema (H = head):

  $H[\text{SUBCAT } \boxed{A}] \rightarrow H[\text{SUBCAT } \boxed{A} \oplus \langle \boxed{1} \rangle] \quad \boxed{1}$

Application of the Rules

- generalized, abstract shema (H = head):
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Application of the Rules

- generalized, abstract shema (H = head):
  H[SUBCAT $\boxed{A}$] → H[SUBCAT $\boxed{A} \oplus \langle \boxed{1} \rangle$] $\boxed{1}$
- possible instantiations of the schema:

V[SUBCAT $\boxed{A}$]	→	V[SUBCAT $\boxed{A} \langle\rangle \oplus \langle \boxed{1}\ \mathrm{NP} \rangle$]	$\boxed{1}$ NP
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  erwartet (wait for) Maria

  N[SUBCAT $\boxed{A}$] → N[SUBCAT $\boxed{A} \langle\rangle \oplus \langle \boxed{1}\ \textsc{Det} \rangle$] $\boxed{1}$ Det
  Mann (man) der (the)

Representation of Valency in Feature Descriptions

gibt ('gives', finite form):

$$\begin{bmatrix} \textsc{phon} & \langle\ \textit{gibt}\ \rangle \\ \textsc{part-of-speech} & \textit{verb} \\ \textsc{subcat} & \left\langle \mathrm{NP}[\textit{nom}],\ \mathrm{NP}[\textit{acc}],\ \mathrm{NP}[\textit{dat}] \right\rangle \end{bmatrix}$$

NP[*nom*], NP[*acc*] and NP[*dat*] are abbreviations of complex feature descriptions.

Demo: Grammar 3

(1) a. der Mann schläft
the man sleeps
'The man sleeps'

b. der Mann die Frau kennt
the man the woman knows
'The man knows the woman.'

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  - morphological rules
  - lexical entries
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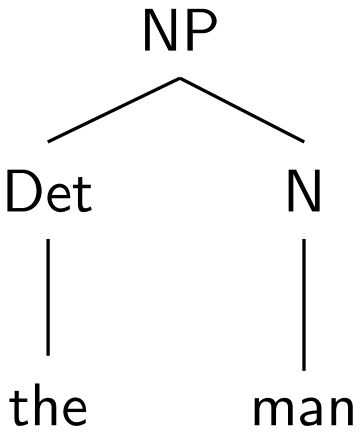
- separation of immediate dominance (ID) and linearer precedence (LP)
- dominance in DTR features (head daughters and non-head daughters)
- precedence is implicit in PHON

Part of the Structure in AVM Representation – PHON values (I)



$$\begin{bmatrix} \textsc{phon} & \langle\ \textit{the man}\ \rangle \\ \textsc{head-dtr} & \left[\textsc{phon}\ \langle\ \textit{man}\ \rangle\right] \\ \textsc{non-head-dtrs} & \left\langle \left[\textsc{phon}\ \langle\ \textit{the}\ \rangle\right] \right\rangle \end{bmatrix}$$

- There is exactly one head daughter (HEAD-DTR).
  The head daughter contains the head.
  a structure with the daughters *the* and *picture of Mary* →
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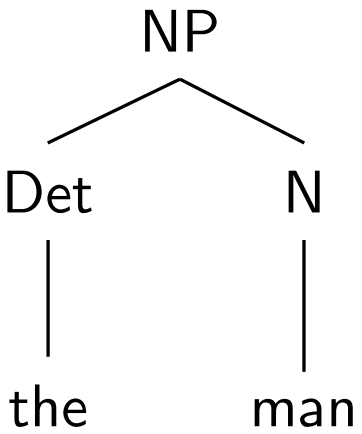

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- There may be several non-head daughters
  (if we assume flat structures or in headless binary branching structures).

Representation of Grammar Rules

- Dominance Rule:

  head-argument-phrase ⇒

  $$\begin{bmatrix} \textsc{subcat}\ \boxed{A} \\ \textsc{head-dtr}|\textsc{subcat}\ \boxed{A} \oplus \langle\ \boxed{1}\ \rangle \\ \textsc{non-head-dtrs}\ \langle\ \boxed{1}\ \rangle \end{bmatrix}$$

  The arrow stands for implication

- alternative spelling, inspired by the $\overline{\text{X}}$ Schema:
  H[SUBCAT $\boxed{A}$]→H[SUBCAT $\boxed{A} \oplus \langle\ \boxed{1}\ \rangle$] $\boxed{1}$

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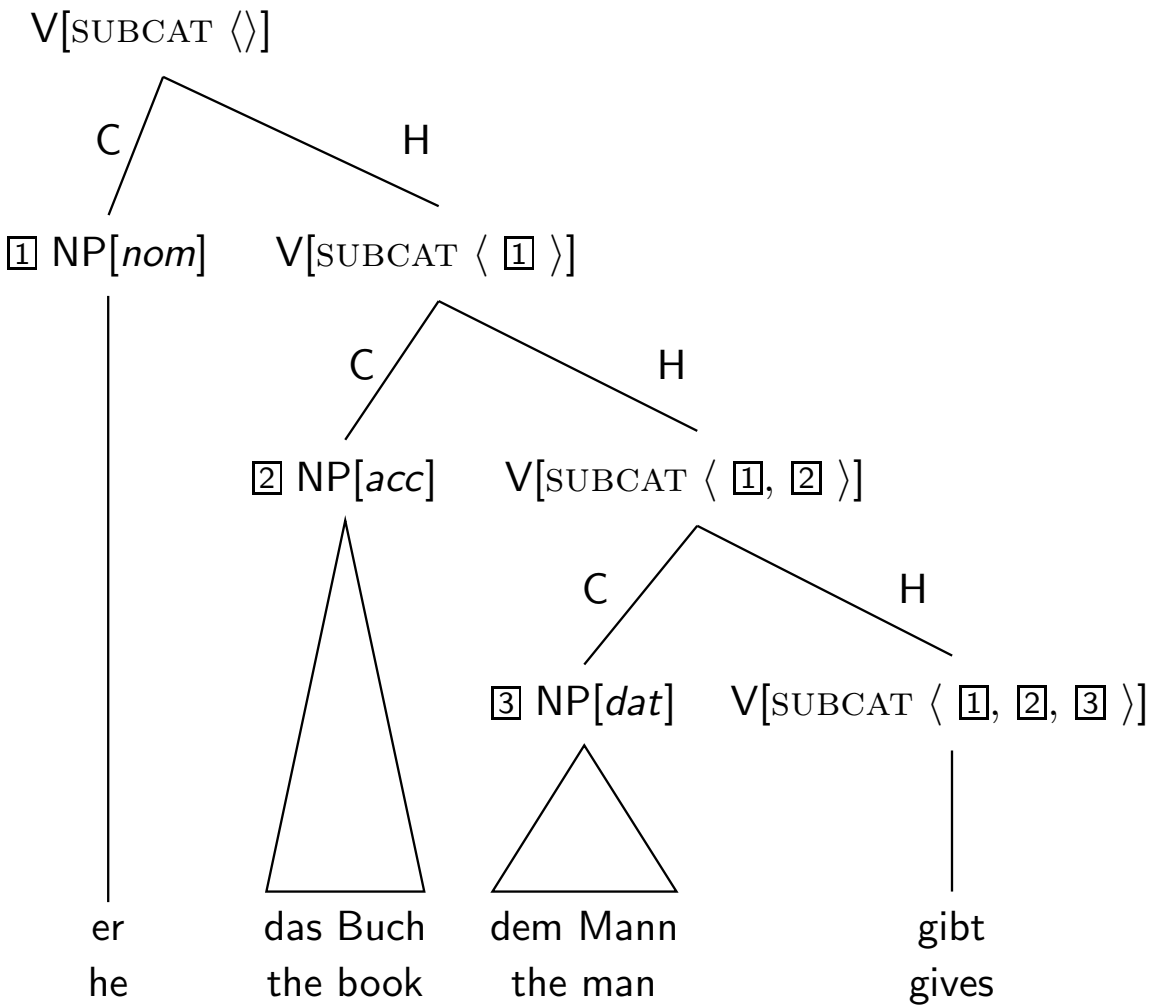
- possible instantiations:
  N[SUBCAT $\boxed{A}$]→N[SUBCAT $\boxed{A}\ \langle\rangle \oplus \langle\ \textsc{Det}\ \rangle$] Det
  V[SUBCAT $\boxed{A}$]→V[SUBCAT $\boxed{A}\ \langle\rangle \oplus \langle\ \textsc{np}\ \rangle$] NP
  V[SUBCAT $\boxed{A}$]→V[SUBCAT $\boxed{A}\ \langle\ \textsc{np}\ \rangle \oplus \langle\ \textsc{np}\ \rangle$] NP

An Example


V[SUBCAT ⟨⟩]
C
H
1 NP[nom]
V[SUBCAT ⟨ 1 ⟩]
C
H
2 NP[acc]
V[SUBCAT ⟨ 1, 2 ⟩]
C
H
3 NP[dat]
V[SUBCAT ⟨ 1, 2, 3 ⟩]
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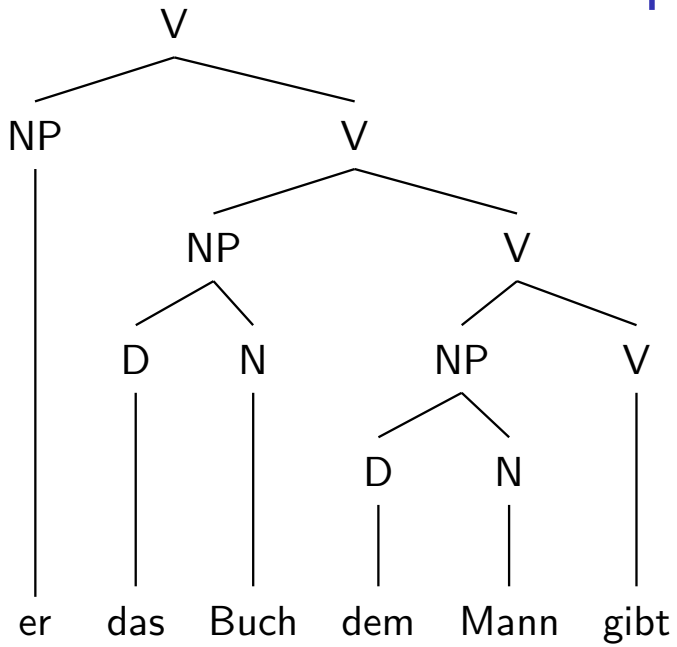

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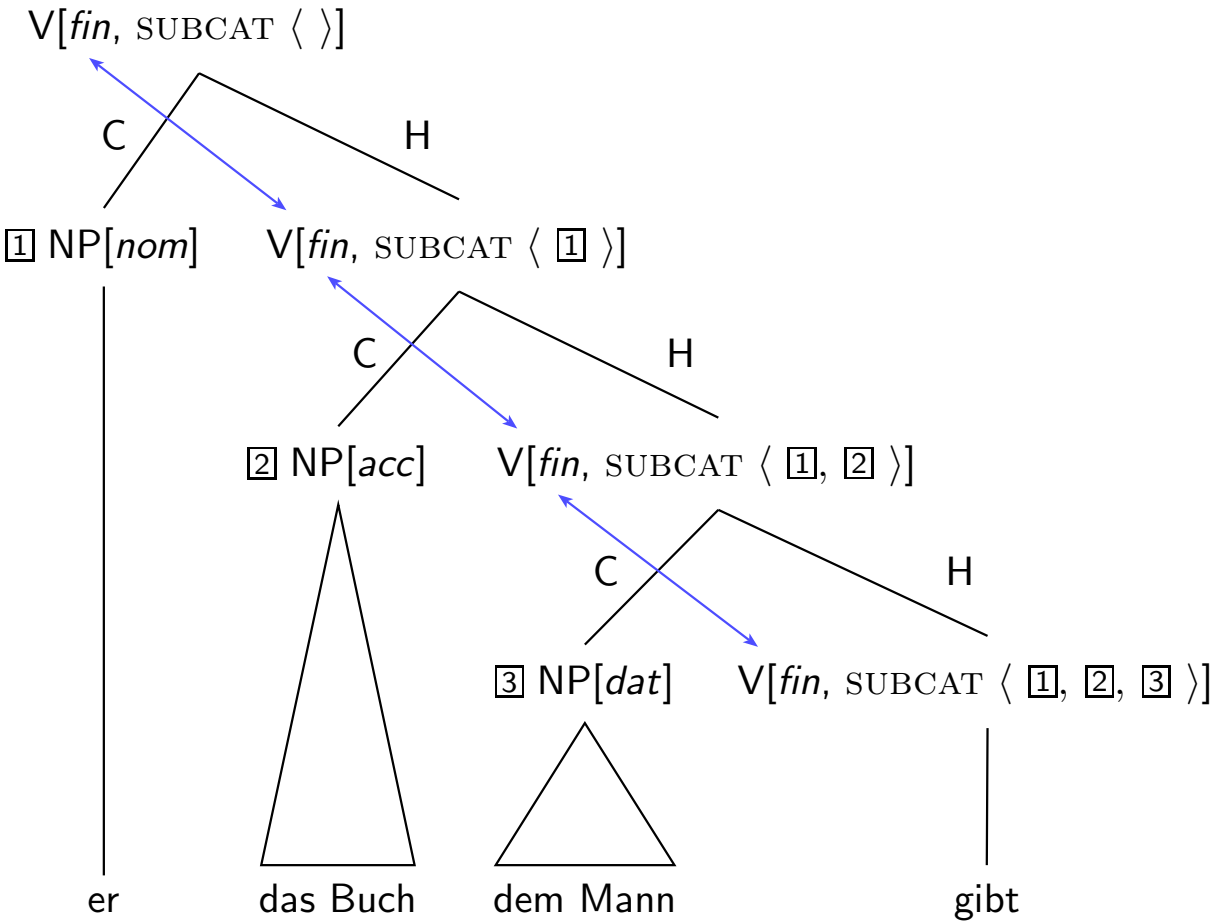
Partial Structure in Feature Structure Representation

$$\begin{bmatrix}
\textsc{phon} \langle \textit{dem Mann gibt} \rangle \\
\textsc{subcat} \boxed{A} \langle \mathrm{NP}[\textit{nom}], \mathrm{NP}[\textit{acc}] \rangle \\
\textsc{head-dtr} \begin{bmatrix} \textsc{phon} \langle \textit{gibt} \rangle \\ \textsc{subcat} \boxed{A} \oplus \langle \boxed{1} \rangle \end{bmatrix} \\
\textsc{non-head-dtrs} \left\langle \boxed{1} \begin{bmatrix} \textsc{phon} \langle \textit{dem Mann} \rangle \\ \textsc{p-o-s} \textit{ noun} \\ \textsc{subcat} \langle\rangle \\ \textsc{head-dtr} \ldots \\ \textsc{non-head-dtrs} \ldots \\ \textit{head-argument-phrase} \end{bmatrix} \right\rangle \\
\textit{head-argument-phrase}
\end{bmatrix}$$

Projection of Head Properties



The finite verb is the head.

Feature Structure Representation: the HEAD Value

- possible feature geometry:

$$\begin{bmatrix} \text{PHON} & \textit{list of phoneme strings} \\ \text{P-O-S} & \textit{p-o-s} \\ \text{VFORM} & \textit{vform} \\ \text{SUBCAT} & \textit{list} \end{bmatrix}$$

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- more structure, bundling of information that has to be projected:

$$\begin{bmatrix} \text{PHON} & \textit{list of phoneme strings} \\ \text{HEAD} & \begin{bmatrix} \text{P-O-S} & \textit{p-o-s} \\ \text{VFORM} & \textit{vform} \end{bmatrix} \\ \text{SUBCAT} & \textit{list} \end{bmatrix}$$

Different Heads Project Different Features

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- Better solution: different types of feature structures
  - for verbs:

$$\begin{bmatrix} \text{VFORM} & \textit{vform} \\ \textit{verb} & \end{bmatrix}$$

  - for nouns:

$$\begin{bmatrix} \text{CASE} & \textit{case} \\ \textit{noun} & \end{bmatrix}$$

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  - phonological information
  - head information (part of speech, verb form, ...)
  - valency information: a list of descriptions of arguments

The Head Feature Principle

- In a headed structure the head features of the mother are identical to the head features of the head daughter.

$$\textit{headed-phrase} \Rightarrow \begin{bmatrix} \textsc{head}\ \boxed{1} \\ \textsc{head-dtr}\,|\,\textsc{head}\ \boxed{1} \end{bmatrix}$$

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- *head-argument-phrase* is a subtype of *headed-phrase*
  $\rightarrow$ All constraints apply to structures of this type as well.
- *head-argument-phrase* inherits properties of/constraints on *headed-phrase*.

Demo: Grammar 4

(2) a. der Mann schläft
the man sleeps
'The man sleeps'

b. der Mann die Frau kennt
the man the woman knows
'The man knows the woman.'

Outline

- Motivation & Psychological Reality
- General Overview of the Framework
- Valency
- Head Argument Structures
- Semantics
- Hierarchical Organization of Knowledge

Semantics

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- More recent work (in particular work in relation to computational implementations) uses *Minimal Recursion Semantics* (Copestake, Flickinger, Pollard and Sag, 2005).

Minimal Recursion Semantics

- MRS allows for underspecified representation of quantifier scope. Lets consider the example in (3):

  (3) Every dog chased some cat.

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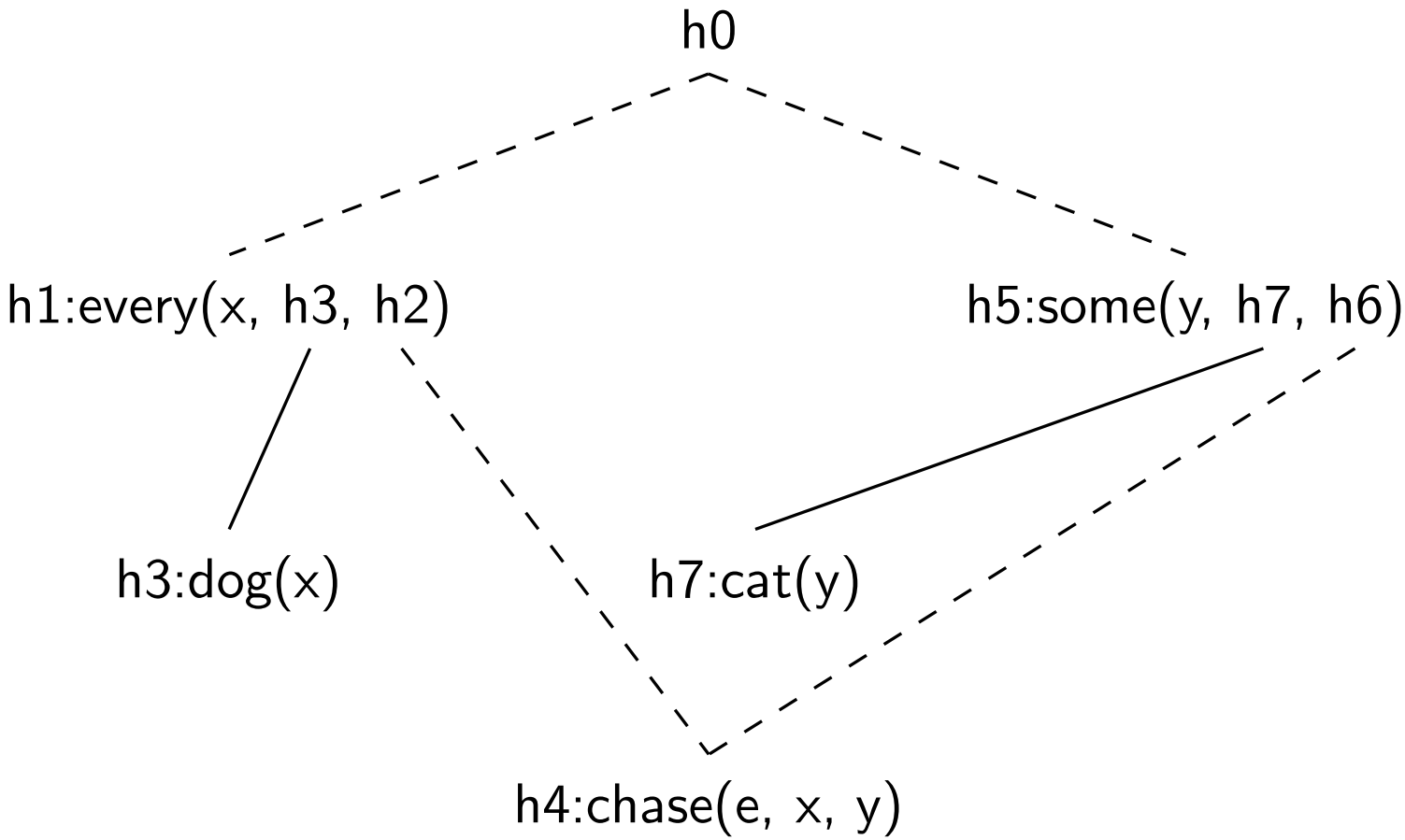
- MRS representation:
  top h0
  h1: every(x, h3, h2),
  h3: dog(x),
  h4: chase(e, x, y),
  h5: some(y, h7, h6),
  h7: cat(y)

Dominance Graph for *Every dog chased some cat.* – Reading I



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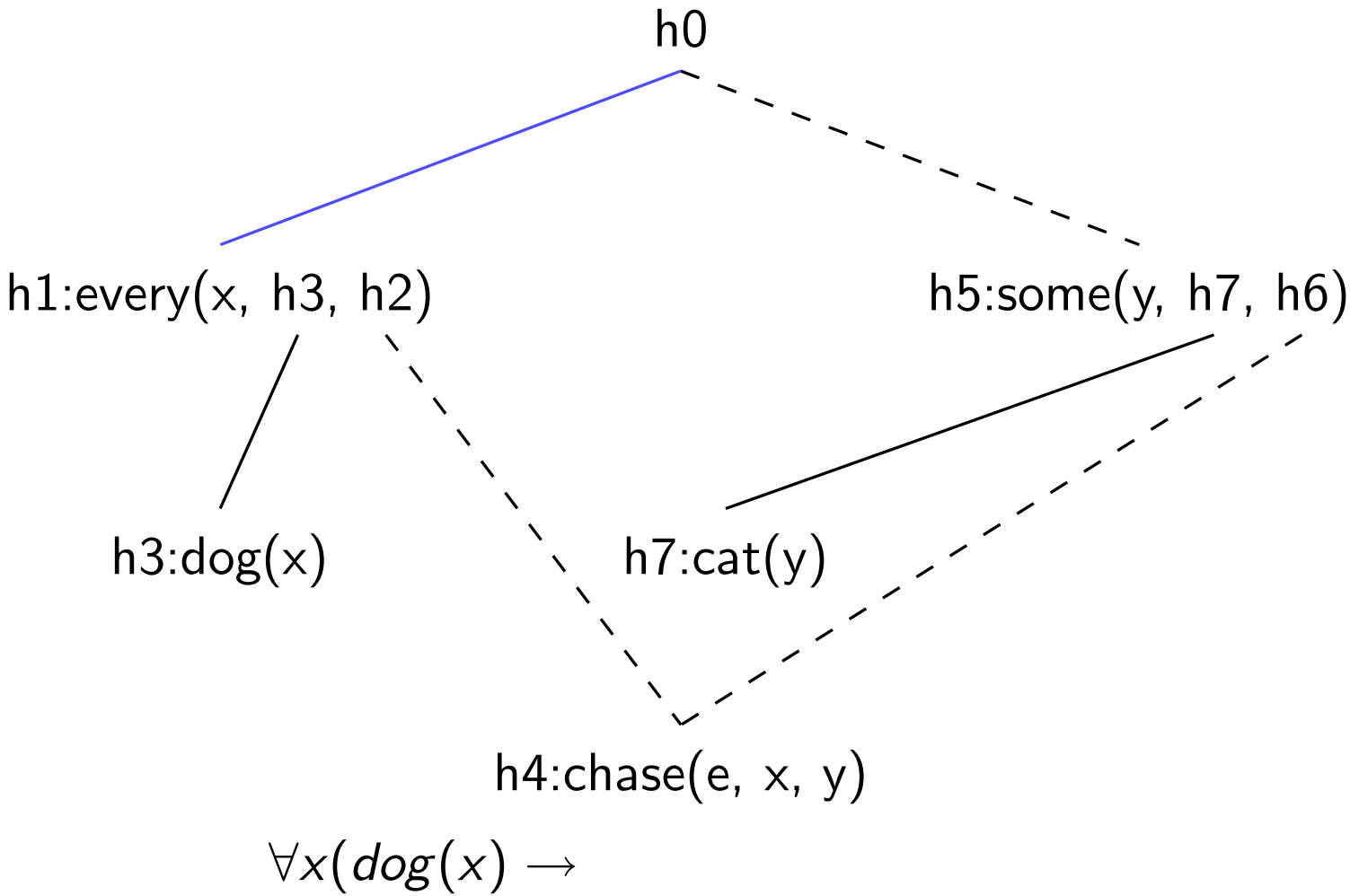

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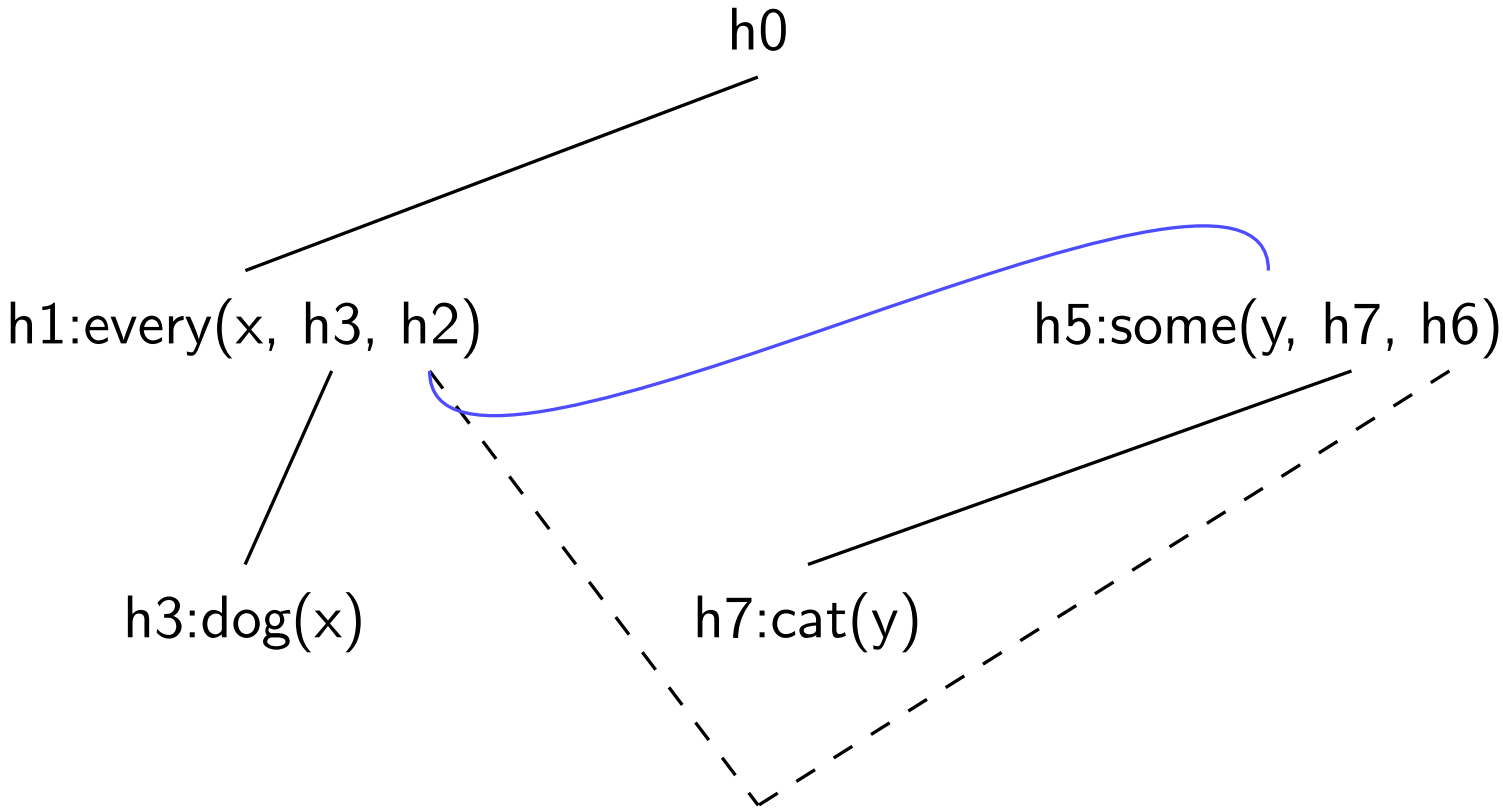

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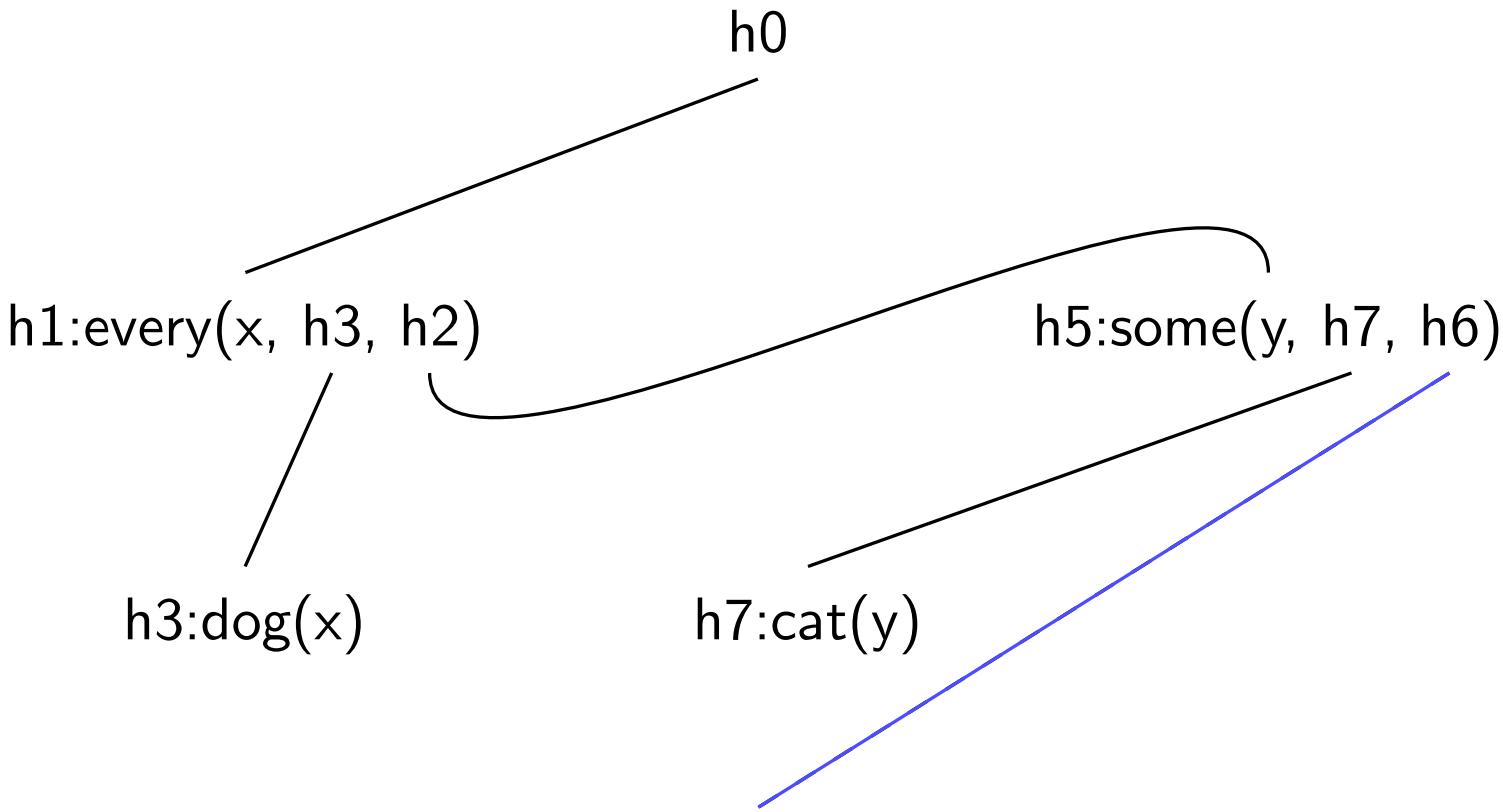
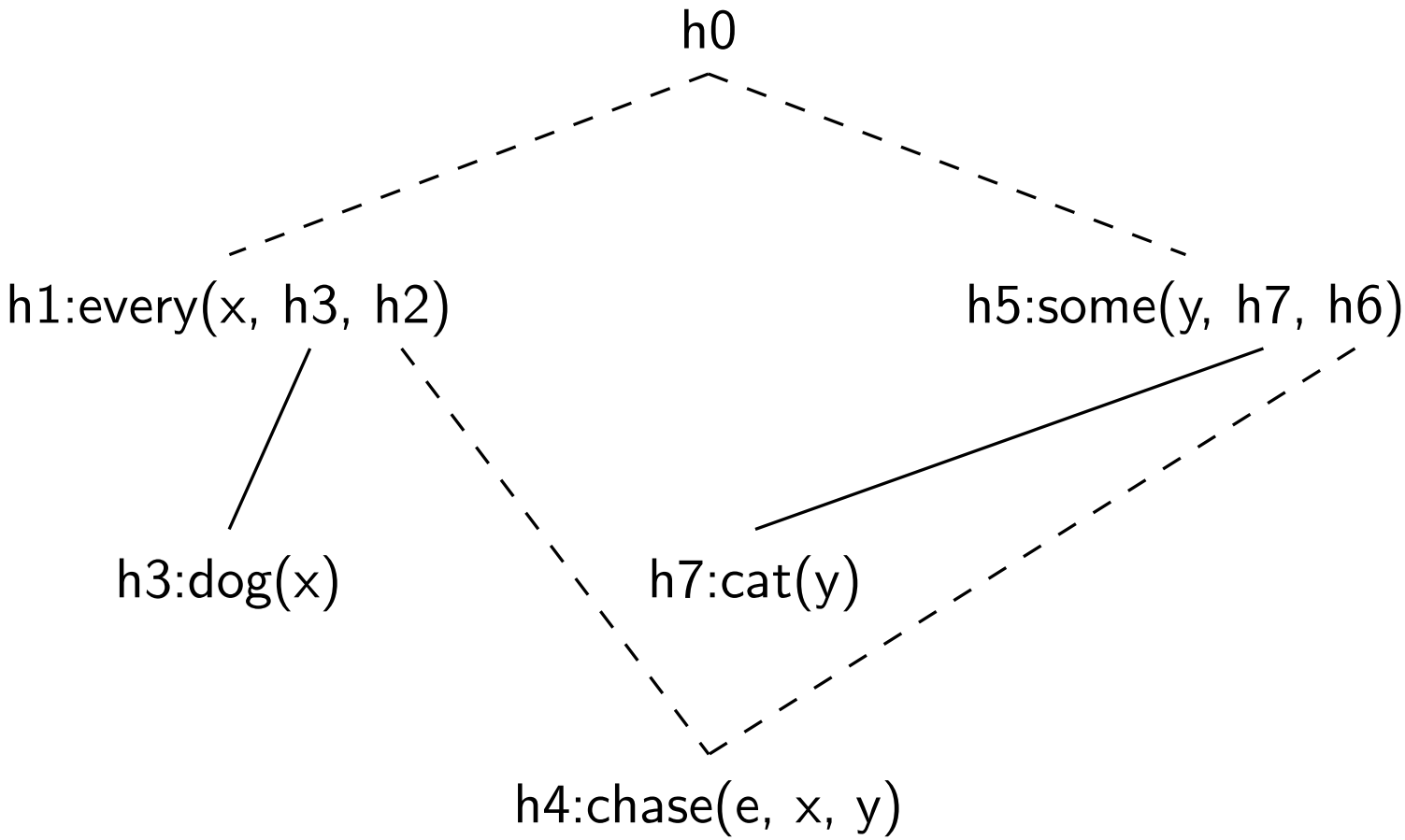
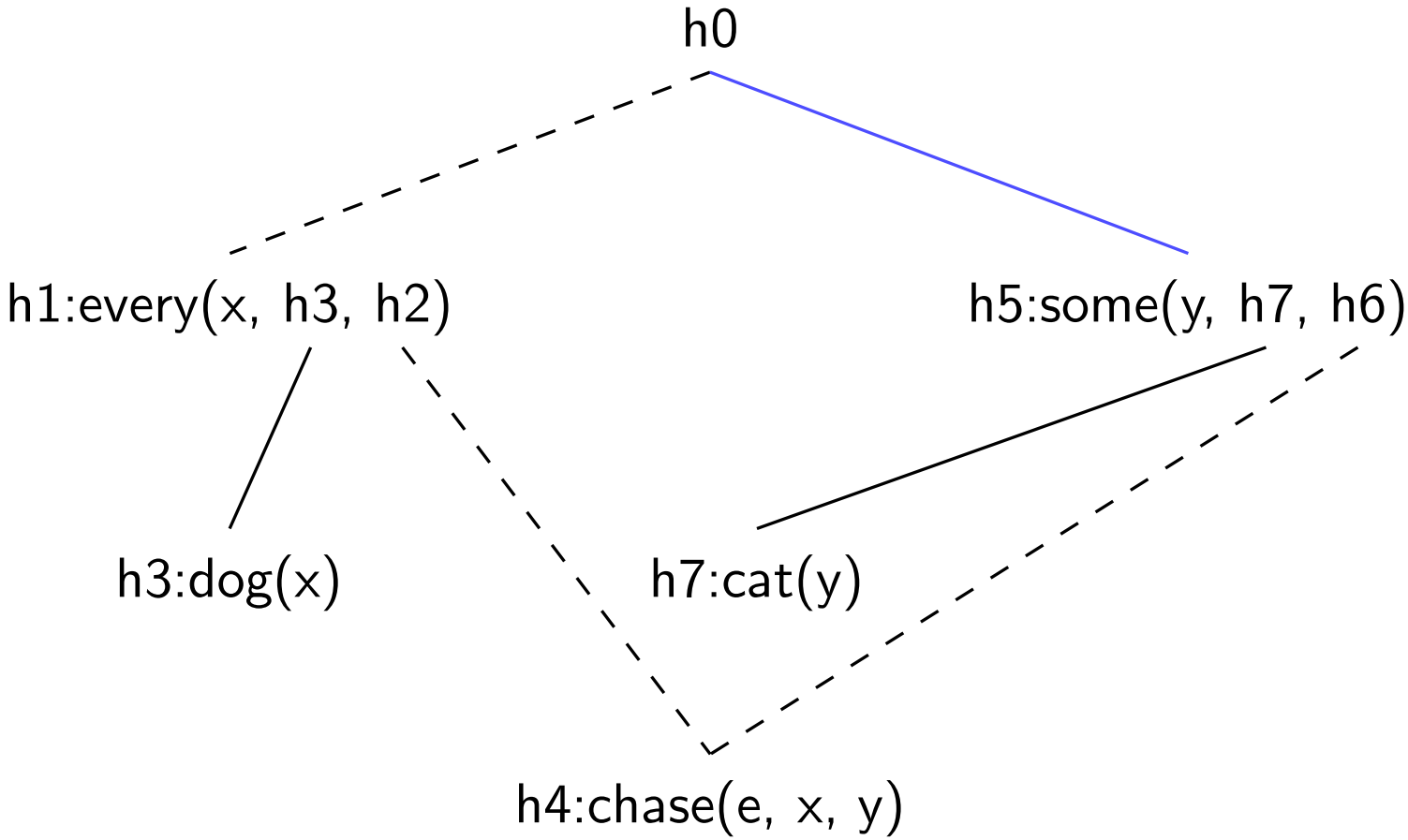


$$\forall x(dog(x) \rightarrow \exists y(cat(y) \wedge chase(x, y)))$$

Dominance Graph for *Every dog chased some cat.* – Reading II



Dominance Graph for *Every dog chased some cat.* – Reading II



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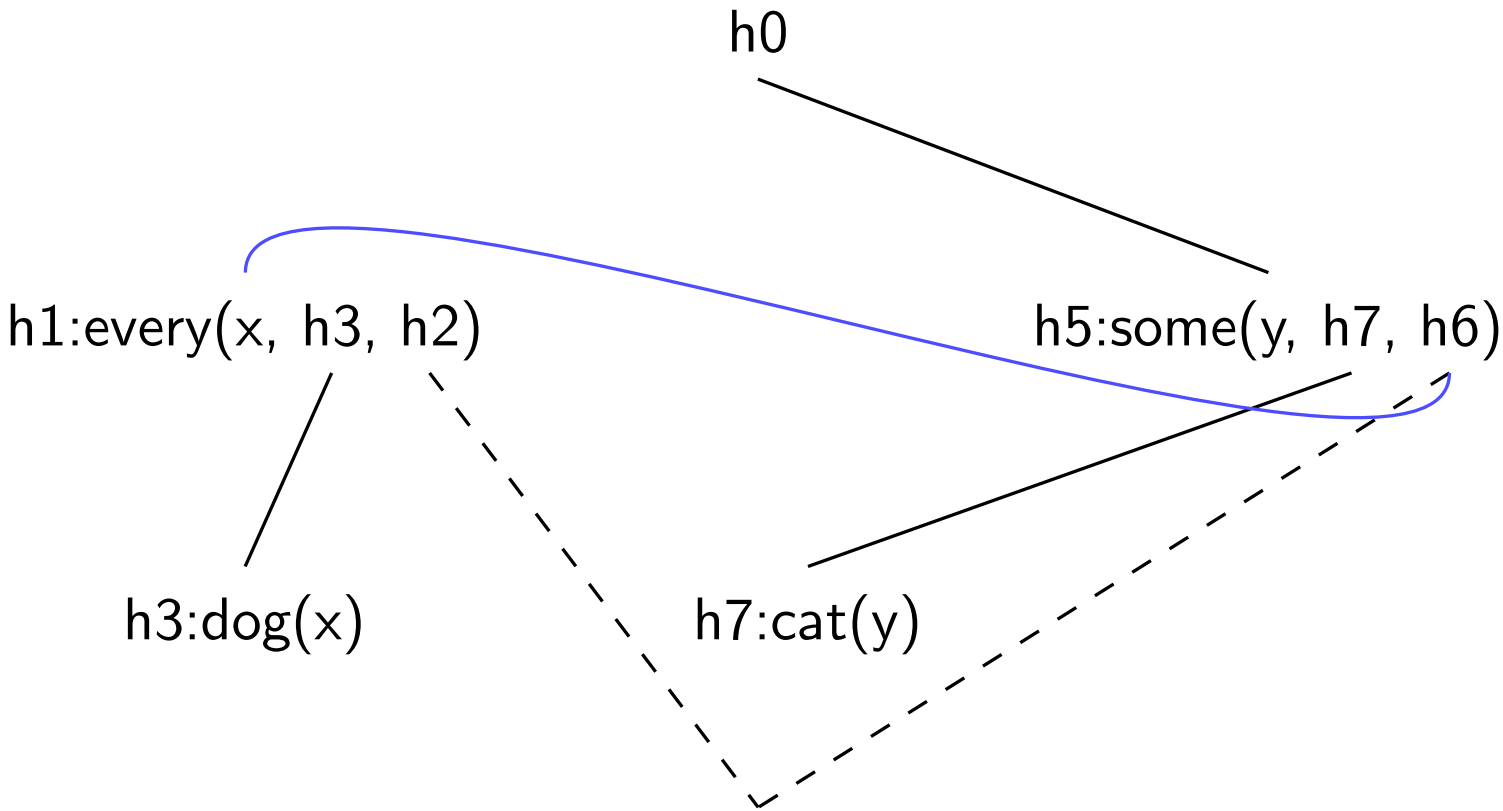

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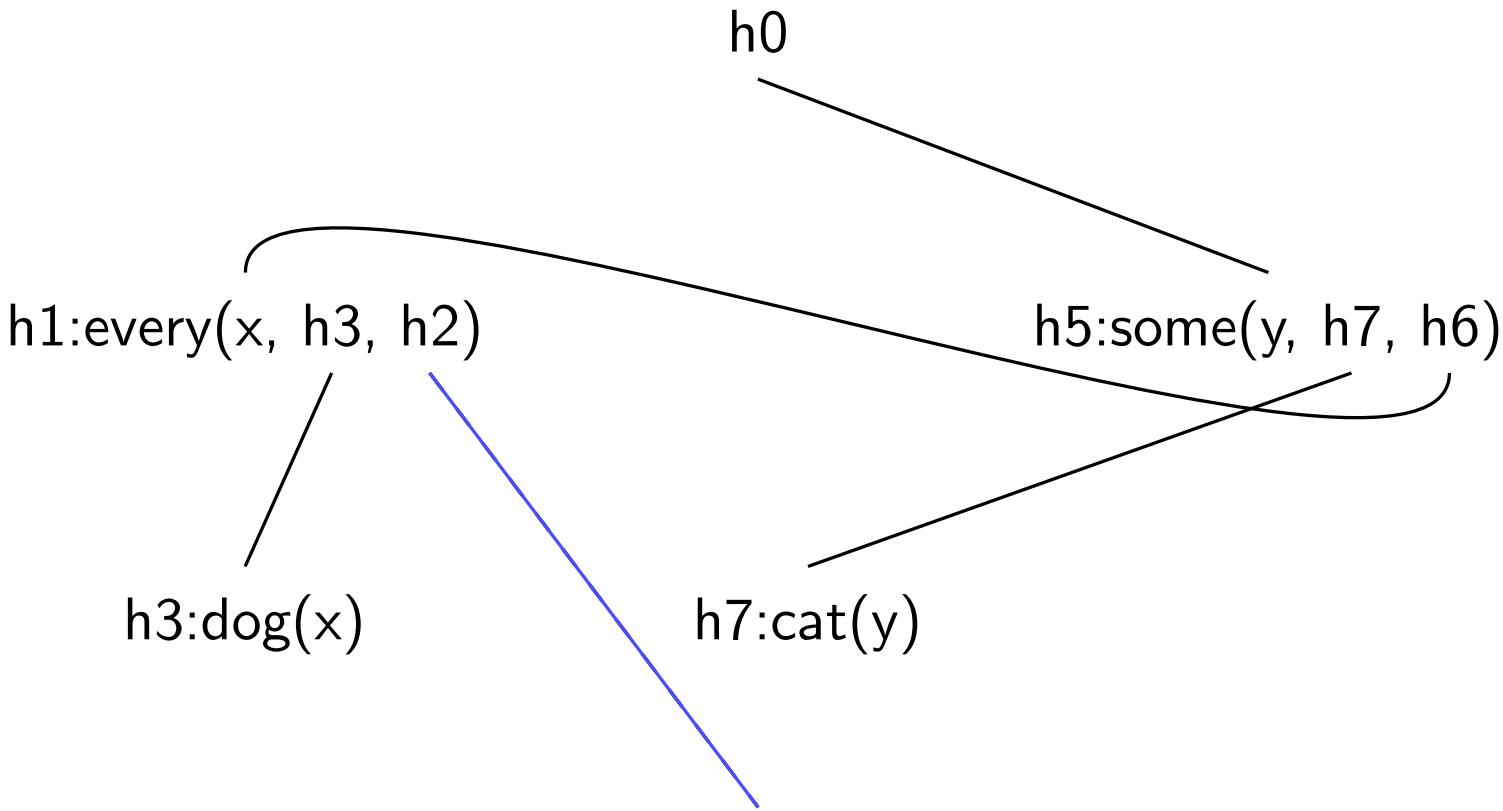

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Parts of an MRS Representation

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  These arguments have to be identified with a label.

More Complicated Cases

- The cat dog example is too simple,
  since quantifiers are identified with the label of the noun.
  This is not appropriate for (4a), since has the readings (4b–c).

  (4) a. Every nephew of some famous politician runs.

  b. every(x, some(y, famous(y) $\wedge$ politician(y), nephew(x, y)), run(x))

  c. some(y, famous(y) $\wedge$ politician(y), every(x, nephew(x, y), run(x)))

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- It is not correct to leave the plugging absolutely underspecified,
  since this would licence (5b–c).

  (5) a. h1, {h2:every(x, h3, h4), h5:nephew(x, y), h6:some(y, h7, h8),
  h7:politician(y), h7:famous(y), h10:run(x)}

  b. every(x, run(x), some(y, famous(y) ∧ politician(y), nephew(x, y)))

  c. some(y, famous(y) ∧ politician(y), every(x, run(x), nephew(x, y)))

Handle Constraints

- In addition so-called handle constraints are used (*qeq* oder $=_q$).
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  We recommend Blackburn and Bos, 2005 as a general introduction to underspecified semantic representations.
  After this the dense MRS paper can be understood.

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- This is pretty complicated.
  We recommend Blackburn and Bos, 2005 as a general introduction to underspecified semantic representations.
  After this the dense MRS paper can be understood.
- We now look at the representation of MRS with feature description.
  A demo will follow and make things clearer.

The Representation of Relations with Feature Descriptions

love(e,x,y)

$$\begin{bmatrix} \textsc{arg}0 & \textit{event} \\ \textsc{arg}1 & \textit{index} \\ \textsc{arg}2 & \textit{index} \\ \textit{love} & \end{bmatrix}$$

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book(x)

$$\begin{bmatrix} \textsc{arg}0 & \textit{index} \\ \textit{book} & \end{bmatrix}$$

Representation of the CONT Value

- possible data structure (CONT = CONTENT):

$$\begin{bmatrix} \text{PHON} & \textit{list of phoneme strings} \\ \text{HEAD} & \textit{head} \\ \text{SUBCAT} & \textit{list} \\ \text{CONT} & \textit{mrs} \end{bmatrix}$$

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- more structure:
  partition into syntactic and semantic information (CAT = CATEGORY)

$$\begin{bmatrix} \textsc{phon} & \textit{list of phoneme strings} \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{head} \\ \textsc{subcat} & \textit{list} \\ & \textit{cat} \end{bmatrix} \\ \textsc{cont} & \textit{mrs} \end{bmatrix}$$

- $\rightarrow$ it is now possible to share syntactic information only

Sharing of Syntactic Information in Coordinations

- symmetric coordination: the CAT value is identical

$$\begin{bmatrix} \textsc{phon} & \textit{list of phoneme strings} \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{head} \\ \textsc{subcat} & \textit{list} \\ & \textit{cat} \end{bmatrix} \\ \textsc{cont} & \textit{mrs} \end{bmatrix}$$

- Examples:

(6) a. [the man and the woman]
b. He [knows and likes] this record.
c. He is [stupid and arrogant].

The Semantic Contribution of Nominal Objects

- semantic index + restrictions

$$\begin{bmatrix}
\textsc{phon} & \langle\, \textit{Buch} \,\rangle & \\
\textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{noun} \\ \textsc{subcat} & \langle \textsc{det} \rangle \end{bmatrix} & \\
\textsc{cont} & \begin{bmatrix}
\textsc{ind} & \boxed{1} & \begin{bmatrix} \textsc{per} & \textit{3} \\ \textsc{num} & \textit{sg} \\ \textsc{gen} & \textit{neu} \\ \textit{index} & \end{bmatrix} \\
\textsc{rels} & \left\langle \begin{bmatrix} \textsc{arg0} & \boxed{1} \\ \textit{buch} & \end{bmatrix} \right\rangle & \\
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\end{bmatrix} &
\end{bmatrix}$$

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\textsc{cont} & \begin{bmatrix}
\textsc{ind} & \boxed{1} \begin{bmatrix} \textsc{per} & 3 \\ \textsc{num} & \textit{sg} \\ \textsc{gen} & \textit{neu} \\ \textit{index} & \end{bmatrix} \\
\textsc{rels} & \left\langle \begin{bmatrix} \textsc{arg0} & \boxed{1} \\ \textit{buch} & \end{bmatrix} \right\rangle \\
\textit{mrs} &
\end{bmatrix} &
\end{bmatrix}$$

- Person, number, and gender are relevant for reference/coreference:

(7) Die Frau$_i$ kauft ein Buch$_j$. Sie$_i$ liest es$_j$.
the woman buys a book she reads it

Abbreviations

$$\mathrm{NP}_{[3,sg,fem]} \quad \begin{bmatrix} \textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{noun} \\ \textsc{subcat} & \langle\rangle \end{bmatrix} \\ \textsc{cont}|\textsc{ind} & \begin{bmatrix} \textsc{per} & \textit{3} \\ \textsc{num} & \textit{sg} \\ \textsc{gen} & \textit{fem} \end{bmatrix} \end{bmatrix}$$

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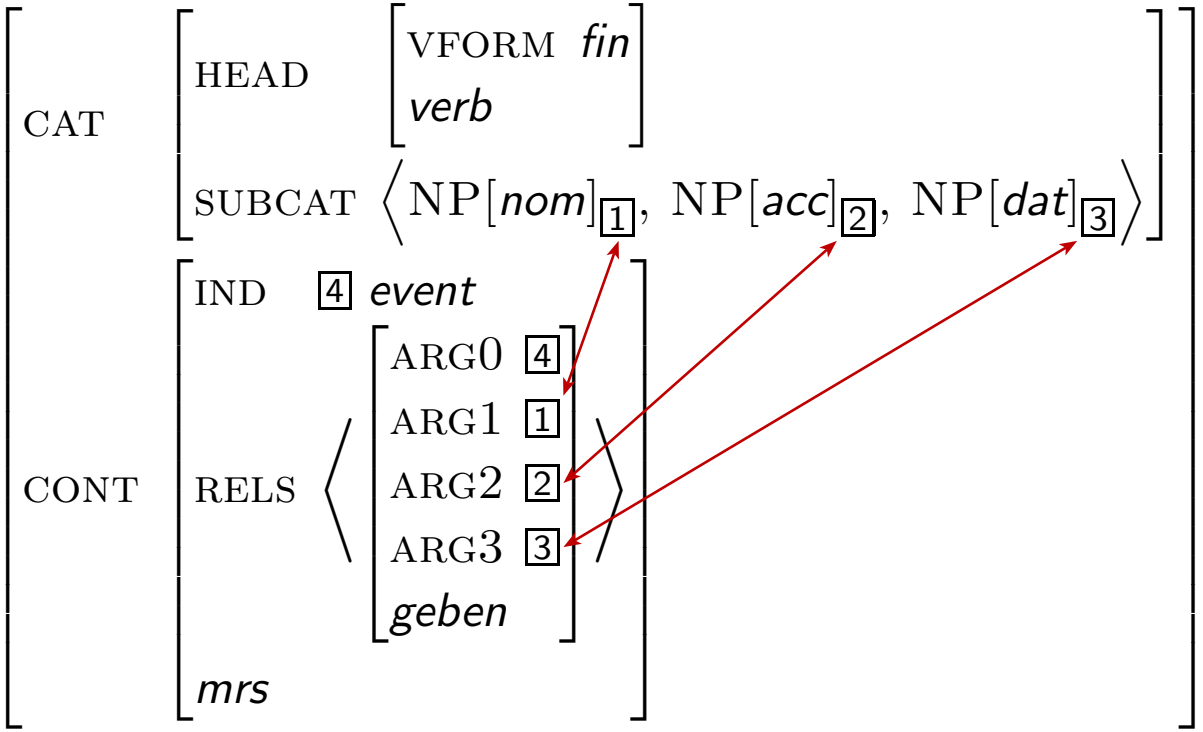
The Semantic Contribution of Verbs and Linking

- Linking of valency information and semantic contribution

  gibt (*gives*, finite Form):



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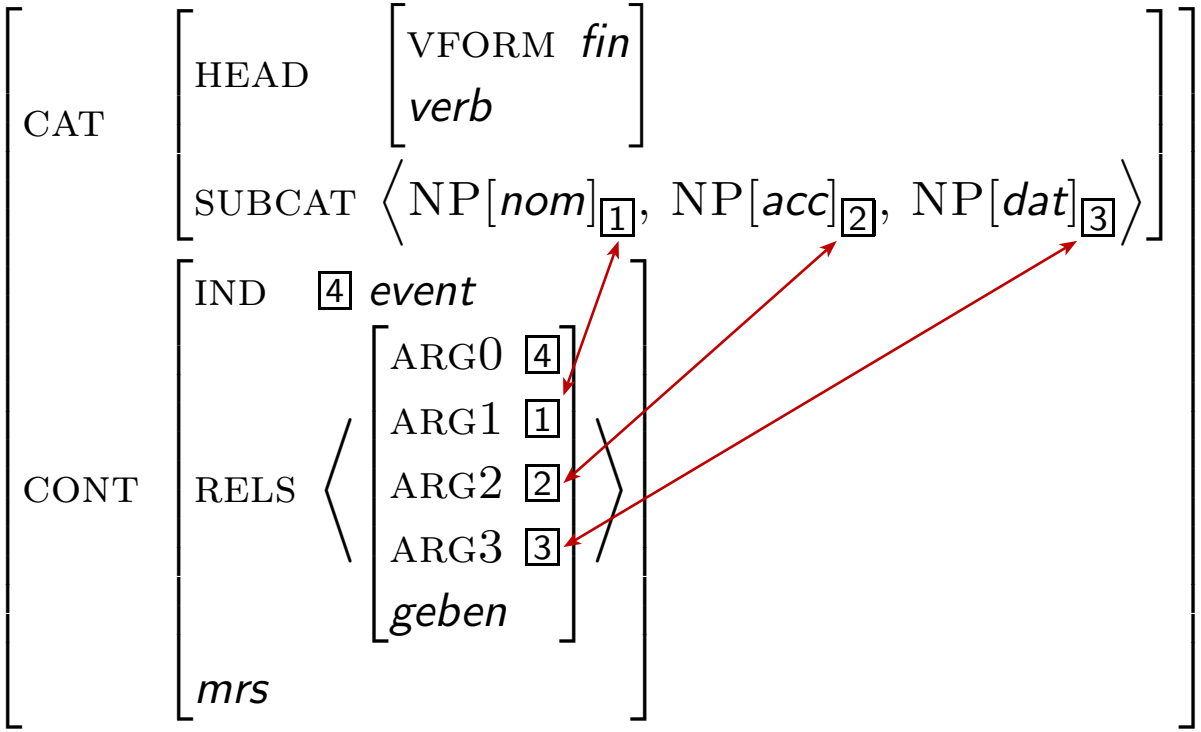
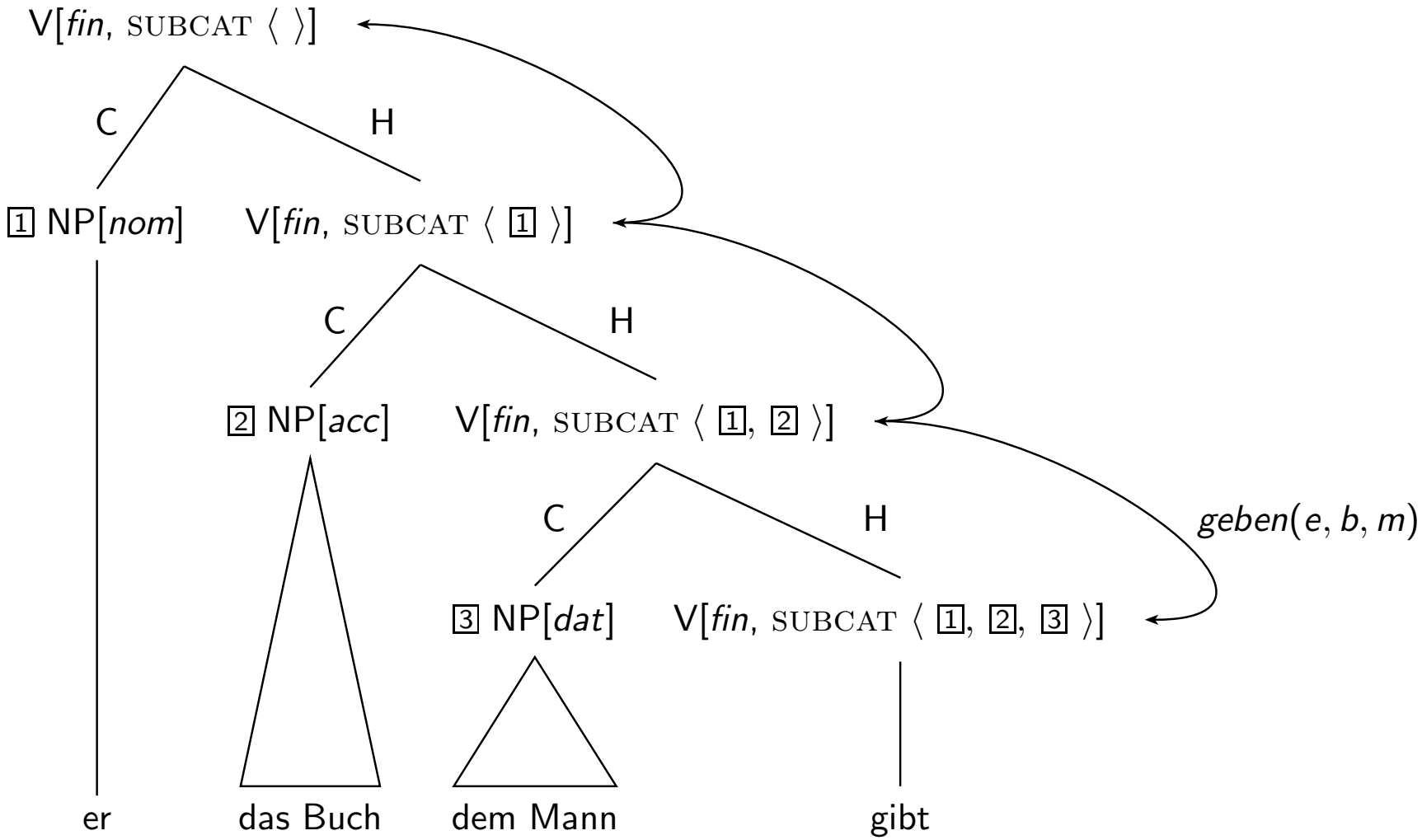


- The referential indices of the NPs are identified with the semantic roles.

The Projection of the Semantic Contribution of the Head



Semantics Principle (Part)

In headed strucutres the semantic index of the mother is identical to the semantic index of the head daughter.

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In headed strucutres the semantic index of the mother is identical to the semantic index of the head daughter.

The RELS list of the mother is the concatenation of the RELS lists of the daughters.

The H-CONS list of the mother is the concatenation of the H-CONS lists of the daughters.

Demo: Berligram

(8) Jeder Sohn eines Beamten rennt.
every son of.a state.employee runs

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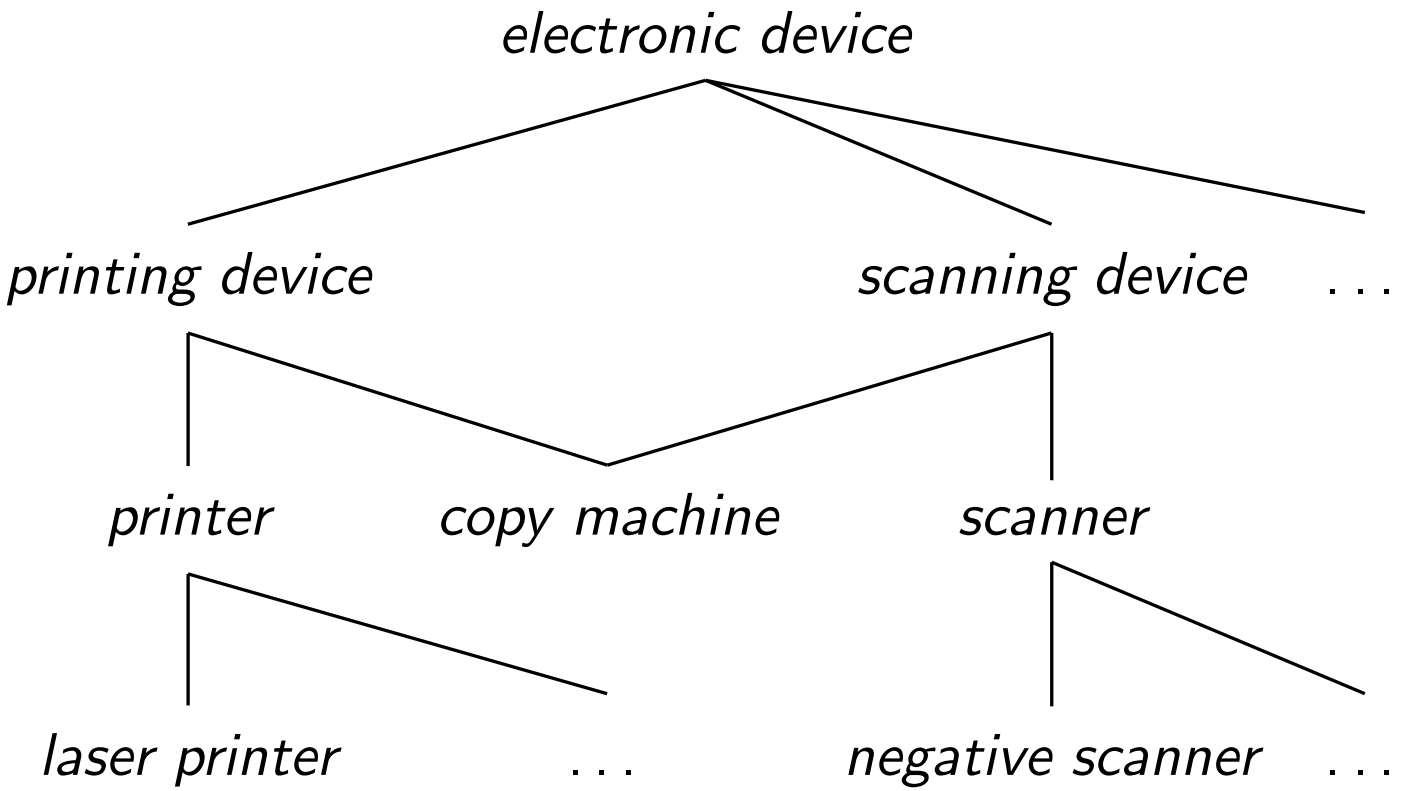
Types: A Non-Linguistic Example for Multiple Inheritance



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- We can represent information with no redundancy.

Linguistic Generalizations in the Type System

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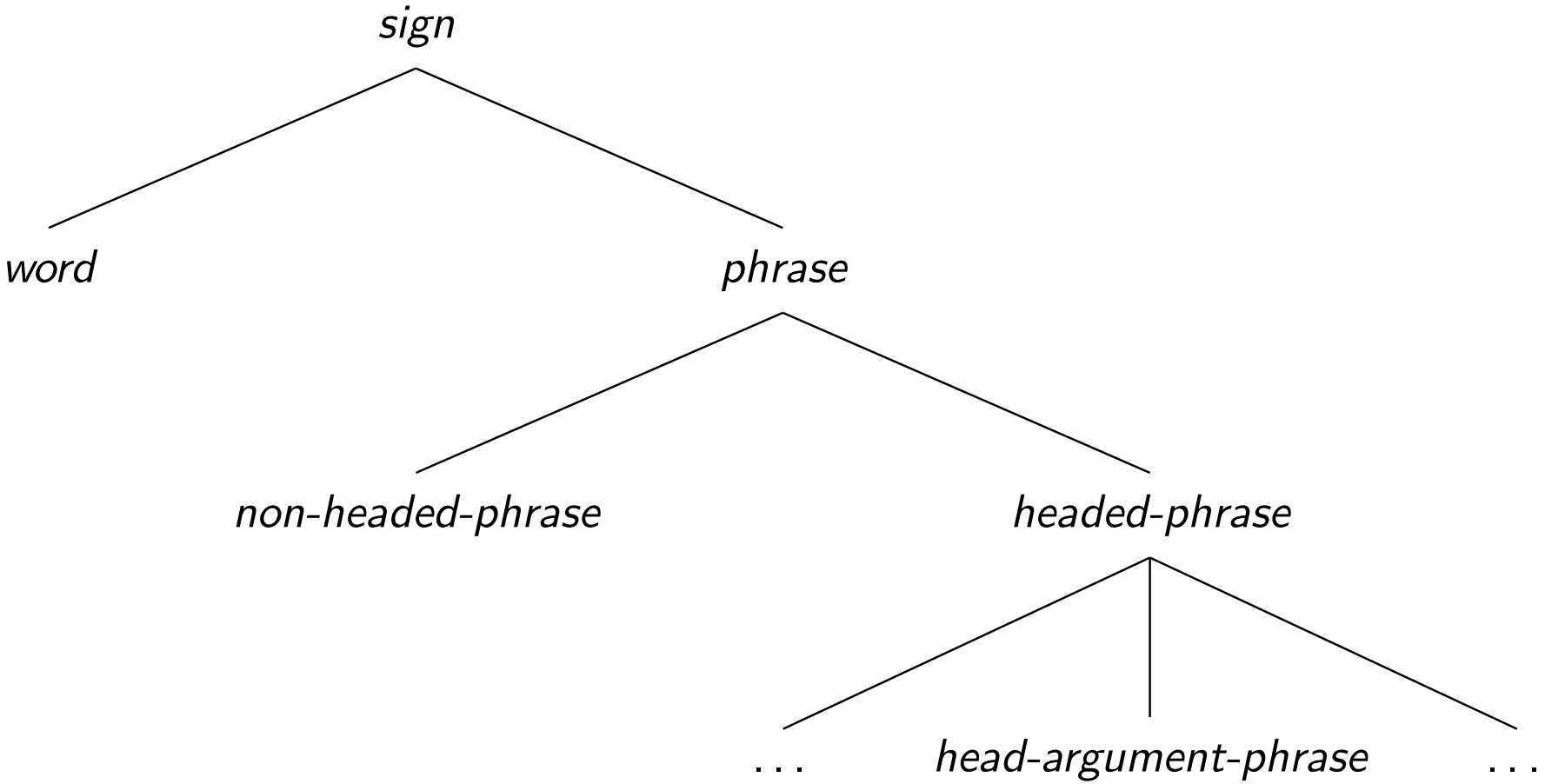
- The upper part of the hierarchy is relevant for all languages ("universal grammar").
- More specific type can be relevant for certain classes of languages or even single languages only.

Type Hierarchy for *sign*



all subtypes of *headed-phrase* inherit restrictions

All Constraints for a Local Tree (Head-Argument)

$$\begin{bmatrix} \textsc{head} & \boxed{1} \\ \textsc{subcat} & \boxed{A} \\ \textsc{head-dtr} & \begin{bmatrix} \textsc{head} & \boxed{1} \\ \textsc{subcat} & \boxed{A} \oplus \langle\, \boxed{2} \,\rangle \end{bmatrix} \\ \textsc{non-head-dtrs} & \langle\, \boxed{2} \,\rangle \\ \multicolumn{2}{l}{\textit{head-argument-phrase}} \end{bmatrix}$$

Partial Structure in Feature Structure Representation

$$\left[\begin{array}{l}
\textsc{phon} \langle\ \textit{dem Mann gibt}\ \rangle \\
\textsc{head}\ \boxed{1} \\
\textsc{subcat}\ \boxed{A}\ \langle\ \mathrm{NP}[\textit{nom}],\ \mathrm{NP}[\textit{acc}]\ \rangle \\
\textsc{head-dtr}\ \left[\begin{array}{l}
\textsc{phon} \langle\ \textit{gibt}\ \rangle \\
\textsc{head}\ \boxed{1}\ \left[\begin{array}{l}\textsc{vform}\ \textit{fin} \\ \textit{verb}\end{array}\right] \\
\textsc{subcat}\ \boxed{A} \oplus \langle\ \boxed{2}\ \rangle \\
\textit{word}
\end{array}\right] \\
\textsc{non-head-dtrs}\ \left\langle \boxed{2}\ \left[\begin{array}{l}
\textsc{phon} \langle\ \textit{dem Mann}\ \rangle \\
\textsc{head}\ \left[\begin{array}{l}\textsc{cas}\ \textit{dat} \\ \textit{noun}\end{array}\right] \\
\textsc{subcat} \langle\rangle \\
\textsc{head-dtr}\ \ldots \\
\textsc{non-head-dtrs}\ \ldots \\
\textit{head-argument-phrase}
\end{array}\right] \right\rangle \\
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Barwise, Jon and Perry, John. 1983. *Situations and Attitudes*. Cambridge: Massachusetts, London: England: The MIT Press.

Barwise, Jon and Perry, John. 1987. *Situationen und Einstellungen – Grundlagen der Situationssemantik*. Berlin, New York: de Gruyter.

Blackburn, Patrick and Bos, Johan. 2005. *Representation and Inference for Natural Language. A First Course in Computational Semantics*. Stanford: CSLI Publications.

Borsley, Robert D. 1999. *Syntactic Theory: A Unified Approach*. London: Edward Arnold, second edition.

Chomsky, Noam. 1968. *Language and Mind*. New York: Harcourt, Brace and World.

Cooper, Robin, Mukai, Kuniaki and Perry, John (eds.). 1990. *Situation Theory And Its Applications, Volume 1*. CSLI Lecture Notes, No. 22, Stanford: CSLI Publications.

Copestake, Ann, Flickinger, Daniel P., Pollard, Carl J. and Sag, Ivan A. 2005. Minimal Recursion Semantics: an Introduction. *Research on Language and Computation* 4(3), 281–332. http://lingo.stanford.edu/sag/papers/copestake.pdf, 11.10.2006.

Devlin, Keith. 1992. *Logic and Information*. Cambridge: Cambridge University Press.

Fodor, Jerry, Bever, T.G. and Garrett, M.F. 1974. *The Psychology of Language*. New York: McGraw-Hill.

Ginzburg, Jonathan and Sag, Ivan A. 2001. *Interrogative Investigations: the Form, Meaning, and Use of English Interrogatives*. CSLI Lecture Notes, No. 123, Stanford: CSLI Publications.

Müller, Stefan. 2007. *Head-Driven Phrase Structure Grammar: Eine Einführung*. Stauffenburg Einführungen, No. 17, Tübingen: Stauffenburg Verlag. http://www.cl.uni-bremen.de/~stefan/Pub/hpsg-lehrbuch.html, 02.07.2007.

Pollard, Carl J. and Sag, Ivan A. 1987. *Information-Based Syntax and Semantics*. CSLI Lecture Notes, No. 13, Stanford: CSLI Publications.

Pollard, Carl J. and Sag, Ivan A. 1994. *Head-Driven Phrase Structure Grammar*. Studies in Contemporary Linguistics, Chicago, London: University of Chicago Press.

Sag, Ivan A., Wasow, Thomas and Bender, Emily M. 2003. *Syntactic Theory: A Formal Introduction*. CSLI Lecture Notes, No. 152, Stanford: CSLI Publications, second edition. http://cslipublications.stanford.edu/site/1575864002.html, 05.06.2003.

Saussure, Ferdinand de. 1916. *Grundfragen der allgemeinen Sprachwissenschaft*. Berlin: Walter de Gruyter & Co.