Introduction to Head-driven Phrase Structure Grammar

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1 Signs

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phon} & \textit{list(phonstring)} \\ \textsc{synsem} & \textit{synsem} \end{bmatrix}$$

$$\begin{bmatrix} \textit{synsem} & \\ \textsc{loc} & \textit{local} \\ \textsc{nonloc} & \textit{non-local} \end{bmatrix}$$

$$\begin{bmatrix} \textit{local} & \\ \textsc{cat} & \textit{cat} \\ \textsc{content} & \textit{content} \end{bmatrix}$$

Valence information (also commonly known as **subcategorisation**).

$$\begin{bmatrix} \textit{cat} & \\ \textsc{head} & \textit{head} \\ \textsc{lex} & \textit{boolean} \\ \textsc{subj} & \textit{list(synsem)} \\ \textsc{comps} & \textit{list(synsem)} \\ \textsc{arg-str} & \textit{list(synsem)} \end{bmatrix}$$

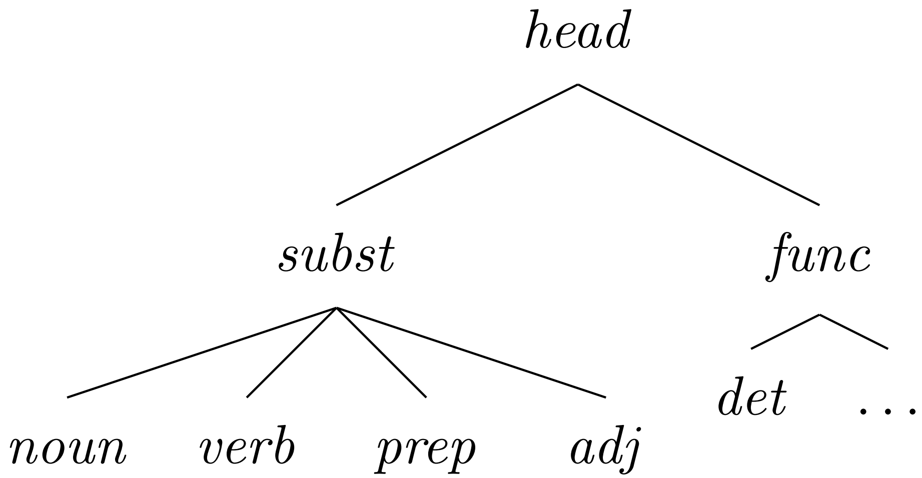


Figure 1: The *head* sortal hierarchy.

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phon} & \langle \textit{likes} \rangle \\ \textsc{synsem} & \begin{bmatrix} \textit{synsem} & \\ \textsc{loc} & \begin{bmatrix} \textit{local} & \\ \textsc{cat} & \begin{bmatrix} \textit{cat} & \\ \textsc{head} & \textit{verb} \\ \textsc{lex} & + \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Figure 2: Partial description of the verb *"likes"*

2 Valence

$$
\begin{array}{ccc}
 & \textit{list} & \\
\textit{elist} & & \begin{bmatrix} \textit{nelist} & \\ \textsc{first} & \top \\ \textsc{rest} & \textit{list} \end{bmatrix}
\end{array}
$$

The SUBJ and COMPS values for *"likes"* look like this.

$$\begin{bmatrix} \textit{cat} & \\ \text{SUBJ} & \begin{bmatrix} \textit{nelist} & \\ \text{FIRST} & \text{NP} \\ \text{REST} & \textit{elist} \end{bmatrix} \\ \text{COMPS} & \begin{bmatrix} \textit{nelist} & \\ \text{FIRST} & \text{NP} \\ \text{REST} & \textit{elist} \end{bmatrix} \end{bmatrix}$$

For a verb such as *"gives"*, which takes two **NP** complements (in examples like *"Kim gives her friends a lot of attention"*), the COMPS value would look like this.

$$\begin{bmatrix} \textit{cat} & \\ \textsc{comps} & \begin{bmatrix} \textit{nelist} & \\ \textsc{first} & \mathrm{NP} \\ \textsc{rest} & \begin{bmatrix} \textit{nelist} & \\ \textsc{first} & \mathrm{NP} \\ \textsc{rest} & \textit{elist} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

List notation

$$\begin{bmatrix} \textit{cat} & \\ \textsc{subj} & \langle \text{NP} \rangle \\ \textsc{comps} & \langle \text{NP} \rangle \end{bmatrix}$$

$$\begin{bmatrix} \textit{cat} & \\ \textsc{subj} & \langle \text{NP} \rangle \\ \textsc{comps} & \langle \text{NP, NP} \rangle \end{bmatrix}$$

$$\begin{bmatrix} \textit{cat} & \\ \textsc{subj} & \boxed{1}\langle \text{NP} \rangle \\ \textsc{comps} & \boxed{2}\langle \text{NP} \rangle \\ \textsc{arg-str} & \boxed{1} \oplus \boxed{2} \end{bmatrix}$$

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phon} & \langle \textit{likes} \rangle \\ \textsc{synsem} & \begin{bmatrix} \textit{synsem} & \\ \textsc{loc} & \begin{bmatrix} \textit{local} & \\ \textsc{cat} & \begin{bmatrix} \textit{cat} & \\ \textsc{head} & \textit{verb} \\ \textsc{lex} & + \\ \textsc{subj} & \boxed{1}\langle \text{NP} \rangle \\ \textsc{comps} & \boxed{2}\langle \text{NP} \rangle \\ \textsc{arg-str} & \boxed{1} \oplus \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Figure 3: Partial description the verb *"likes"* with valence values added.

3 Words and phrases

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phon} & \textit{list(phonstring)} \\ \textsc{synsem} & \textit{synsem} \end{bmatrix}$$

$$\begin{bmatrix} \textit{word} & \\ \textsc{synsem} \mid \textsc{loc} \mid \textsc{cat} & \begin{bmatrix} \textit{cat} & \\ \textsc{lex} & + \\ \textsc{arg-str} & \textit{list(synsem)} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \textit{phrase} & \\ \textsc{synsem} \mid \textsc{loc} \mid \textsc{cat} & \begin{bmatrix} \textit{cat} & \\ \textsc{lex} & - \end{bmatrix} \\ \textsc{daughters} & \textit{daughters} \end{bmatrix}$$

Figure 4: The sortal hierarchy for *sign*

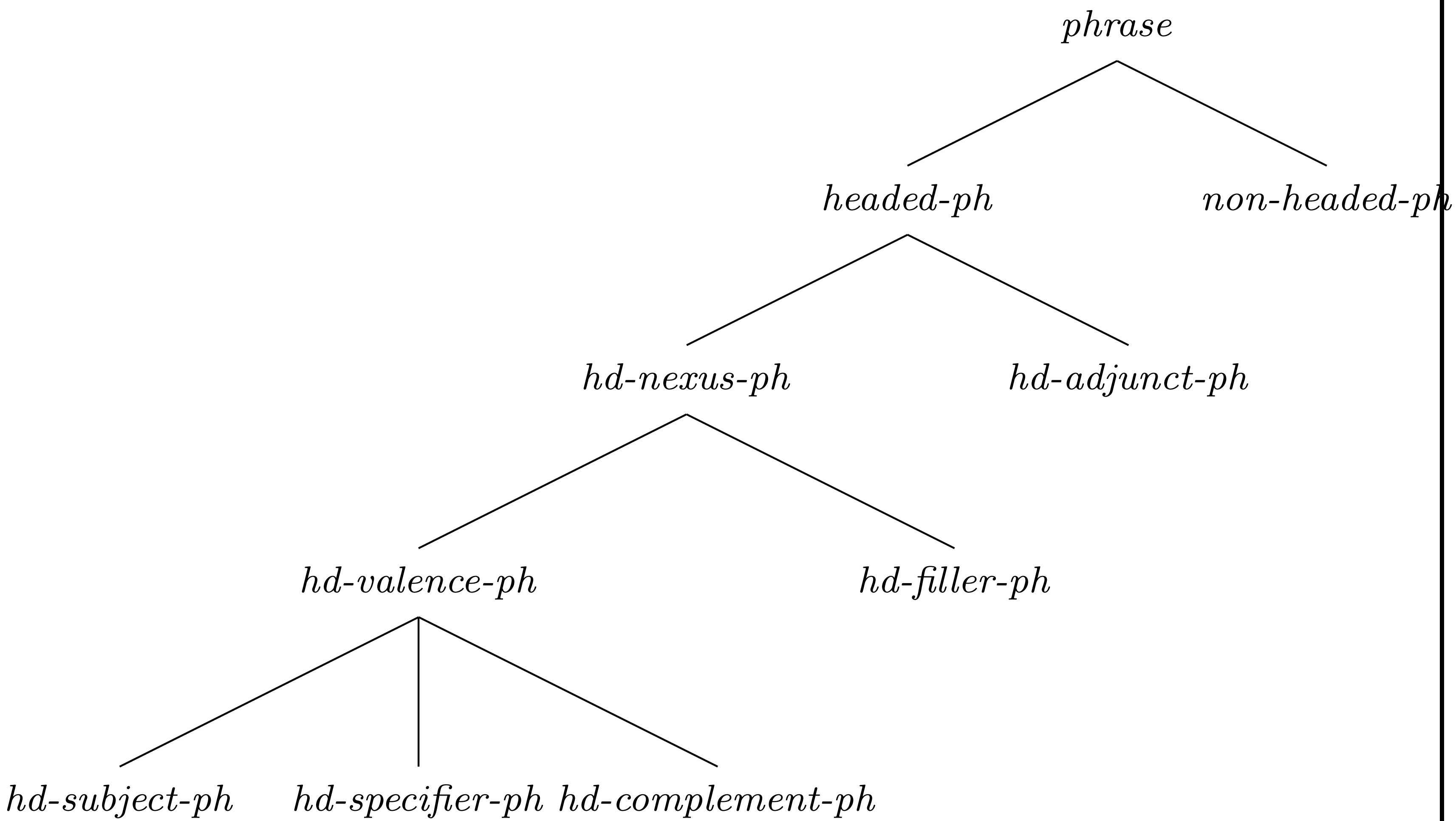
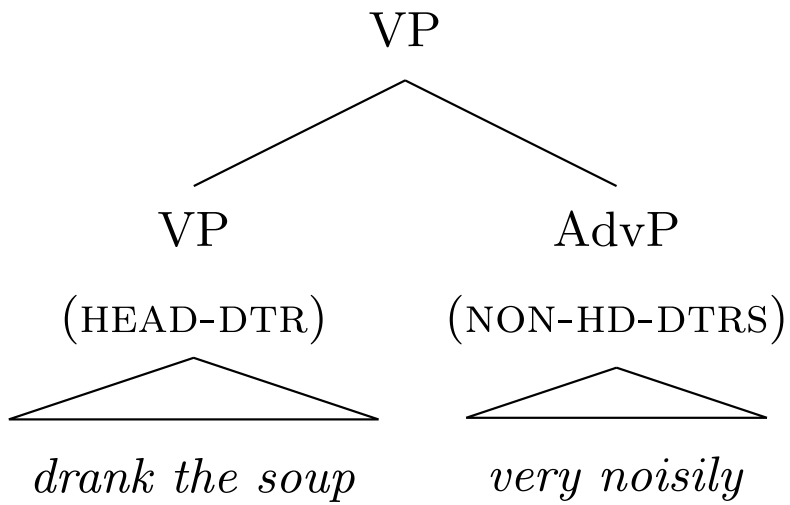
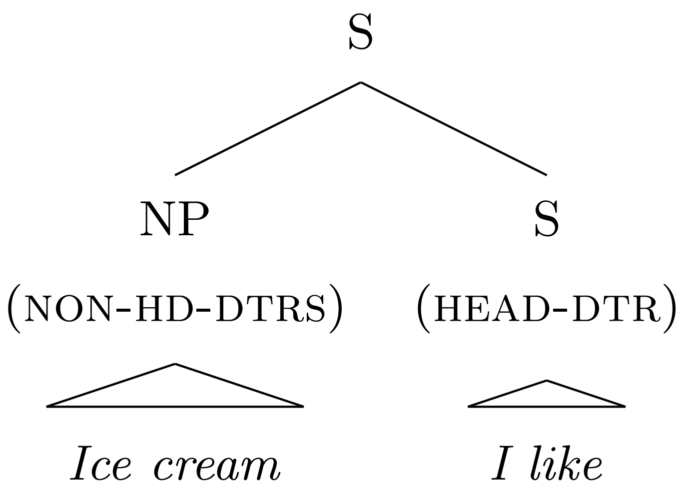
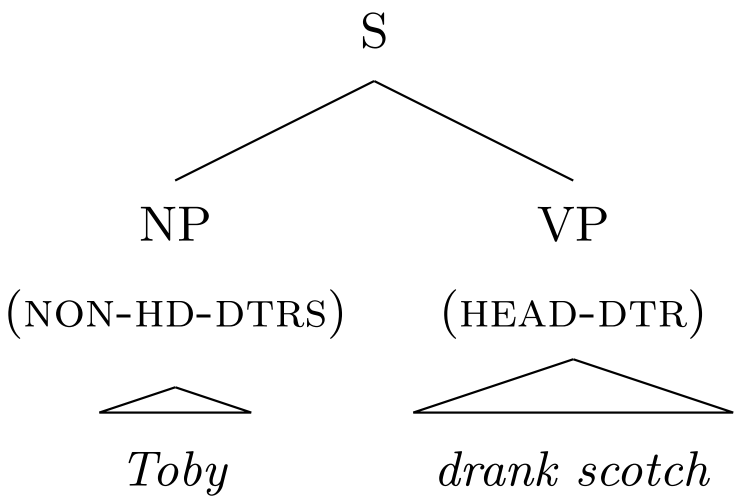
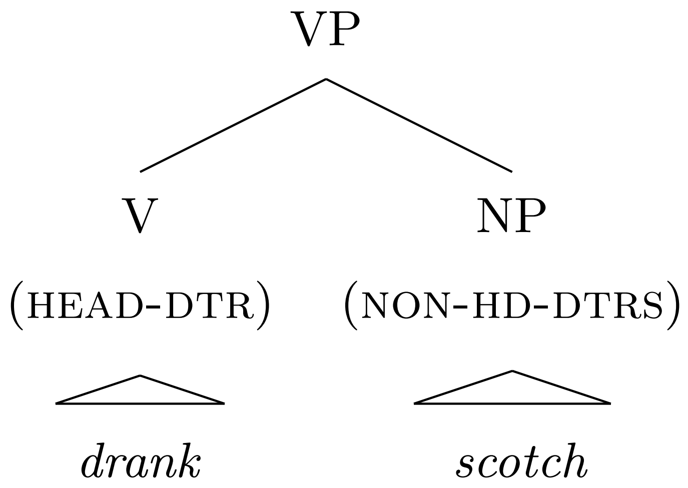
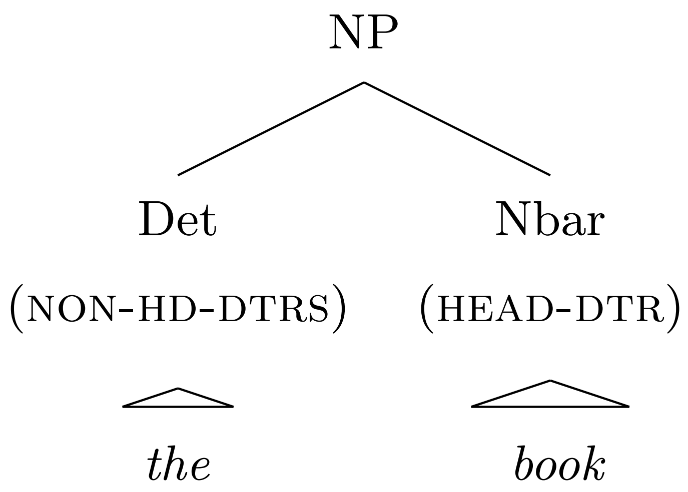


Figure 5: The sortal hierarchy for *phrase*

Table 1: Examples of phrases

SORT	EXAMPLE
hd-adjunct-ph	

SORT	EXAMPLE
hd-filler-ph	
hd-subject-ph	

SORT	EXAMPLE
hd-complement-ph	
hd-specifier-ph	

3.1 Complements

$$
\textit{headed-phrase} \quad \Longrightarrow \quad \begin{bmatrix} \textsc{dtrs} & \begin{bmatrix} \textit{dtrs} & \\ \textsc{head-dtr} & \textit{sign} \\ \textsc{non-hd-dtrs} & \textit{list(sign)} \end{bmatrix} \end{bmatrix}
$$

Head-Complement Phrase

$$
\textit{hd-comp-ph} \implies \begin{bmatrix} \text{SYNSEM} \mid \ldots \begin{bmatrix} \text{SUBJ} & \boxed{1} \\ \text{SPR} & \boxed{2} \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \\ \text{DTRS} \begin{bmatrix} \text{HD-DTR} & \begin{bmatrix} \textit{word} \\ \text{SYNSEM} \mid \ldots \begin{bmatrix} \text{SUBJ} & \boxed{1} \\ \text{SPR} & \boxed{2} \\ \text{COMPS} & \langle \boxed{3}, \ \ldots, \ \boxed{n} \rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-HD-DTRS} & \langle [\text{SYNSEM}\ \boxed{3}], \ \ldots, \ [\text{SYNSEM}\ \boxed{n}] \rangle \end{bmatrix} \end{bmatrix}
$$

This states that a well-formed *head-complement-phrase*

- must have a *lexical* head daughter (of sort *word*),
- must have an empty COMPS value
- the values of its head daughter's COMPS attribute must be token identical to the SYNSEM values of its non-head daughters, and
- its SUBJ and SPR values are identical to those of its head daughter

$$\begin{bmatrix} \textit{hd-comp-ph} & \\ \text{SYNSEM}\,|\,\text{LOC}\,|\,\text{CAT} & \begin{bmatrix}\text{SUBJ} & \boxed{1} \\ \text{COMPS} & \langle\ \rangle\end{bmatrix} \\ \text{DTRS} & \begin{bmatrix} \text{HD-DTR} & \begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{likes}\rangle \\ \text{SYNSEM} & \begin{bmatrix} \textit{synsem} & \\ \text{LOC} & \begin{bmatrix}\textit{local} & \\ \text{CAT} & \begin{bmatrix} \textit{cat} & \\ \text{HEAD} & \textit{verb} \\ \text{LEX} & + \\ \text{SUBJ} & \boxed{1}\langle\text{NP}\rangle \\ \text{COMPS} & \boxed{2}\langle\boxed{3}\,\text{NP}\rangle \\ \text{ARG-STR} & \boxed{1}\oplus\boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix} \\ \text{NON-HD-DTRS} & \left\langle\begin{bmatrix}\text{SYNSEM} & \boxed{3}\end{bmatrix}\right\rangle \end{bmatrix}\end{bmatrix}$$

Figure 6: A head complement phrase.

Abbreviations:

For

$$\begin{bmatrix} \textit{headed-ph} & \\ \textsc{synsem} \mid \textsc{loc} \mid \textsc{cat} \mid \textsc{head} & \textit{verb} \end{bmatrix}$$

we will simply write

$$\begin{bmatrix} \textit{headed-ph} & \\ \textsc{head} & \textit{verb} \end{bmatrix}$$

The Head Feature Principle

$$
\textit{headed-ph} \implies \begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{HD-DTR} & \begin{bmatrix} \text{HEAD} & \boxed{1} \end{bmatrix} \end{bmatrix}
$$

The Head Feature Principle requires that the sign's HEAD value be token identical to that of its head daughter.

$$
\begin{bmatrix}
\textit{hd-comp-ph} & \\
\text{SYNSEM} \mid \text{LOC} \mid \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{SUBJ} & \boxed{2} \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \\
\text{DTRS} & \begin{bmatrix}
\text{HD-DTR} & \begin{bmatrix}
\textit{word} & \\
\text{PHON} & \langle \textit{likes} \rangle \\
\text{SYNSEM} & \begin{bmatrix}
\textit{synsem} & \\
\text{LOC} & \begin{bmatrix}
\textit{local} & \\
\text{CAT} & \begin{bmatrix}
\textit{cat} & \\
\text{HEAD} & \boxed{1}\ \textit{verb} \\
\text{LEX} & + \\
\text{SUBJ} & \boxed{2}\ \langle \text{NP} \rangle \\
\text{COMPS} & \boxed{3}\ \langle \boxed{4}\ \text{NP} \rangle \\
\text{ARG-STR} & \boxed{2} \oplus \boxed{3}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix} \\
\text{NON-HD-DTRS} & \left\langle \begin{bmatrix} \text{SYNSEM} & \boxed{4} \end{bmatrix} \right\rangle
\end{bmatrix}
\end{bmatrix}
$$

Figure 7: A verb phrase.

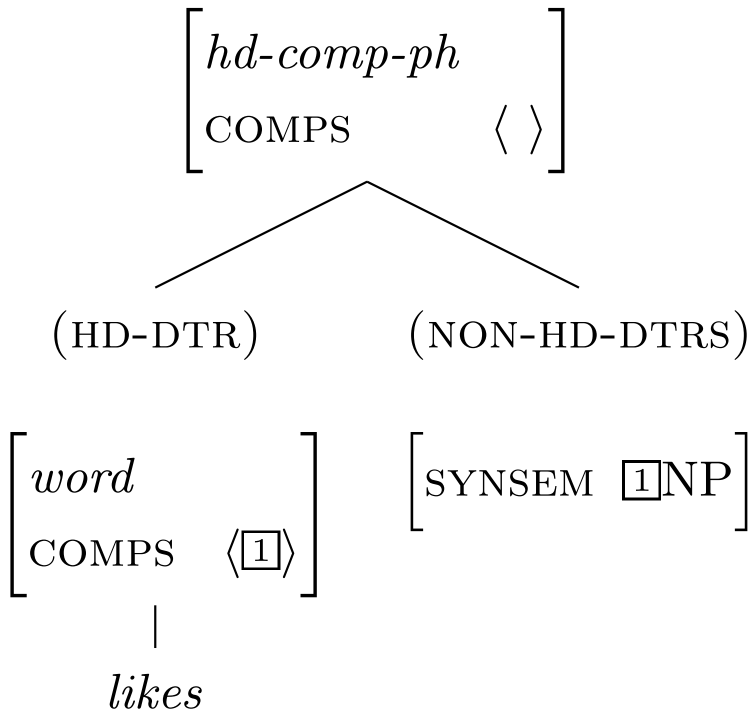


Figure 8: Tree illustrating a head complement phrase.

$$
\left[\begin{array}{ll}
\textit{hd-comp-ph} & \\
\text{PHON} & \boxed{1} \oplus \boxed{2} \\
\text{HEAD} & \boxed{3} \\
\text{SUBJ} & \boxed{4} \\
\text{COMPS} & \langle\ \rangle \\
\text{HD-DTR} & \left[\begin{array}{ll}
\textit{word} & \\
\text{PHON} & \boxed{1}\ \langle \textit{likes} \rangle \\
\text{SYNSEM} & \left[\begin{array}{ll}
\textit{synsem} & \\
\text{LOC} & \left[\begin{array}{ll}
\textit{local} & \\
\text{CAT} & \left[\begin{array}{ll}
\textit{cat} & \\
\text{HEAD} & \boxed{3}\ \textit{verb} \\
\text{LEX} & + \\
\text{SUBJ} & \boxed{4}\ \langle \text{NP} \rangle \\
\text{COMPS} & \boxed{5}\ \langle \boxed{6}\ \text{NP} \rangle \\
\text{ARG-STR} & \boxed{4} \oplus \boxed{5}
\end{array}\right]
\end{array}\right]
\end{array}\right]
\end{array}\right] \\
\text{NON-HD-DTRS} & \left\langle \left[\begin{array}{ll}
\textit{sign} & \\
\text{PHON} & \boxed{2}\ \langle \textit{scotch} \rangle \\
\text{SYNSEM} & \boxed{6}
\end{array}\right] \right\rangle
\end{array}\right]
$$

Figure 9: Partial description of the VP *"likes scotch"*.

For ditransitives such as *"gives"*, which can take two **NP** complements, the only modification that we need to make is the addition of a lexical entry for *"gives"*. This requires a COMPS value which is a list of two **NP**s:

$$\begin{bmatrix} \textsc{comps} & \langle \text{NP}, \text{NP} \rangle \end{bmatrix}$$

3.2 Subjects

Head-Subject Phrase

$$
\textit{hd-subj-ph} \Longrightarrow \begin{bmatrix} \text{PHON} & \boxed{1} \oplus \boxed{2} \\ \text{SUBJ} & \langle\ \rangle \\ \text{SPR} & \boxed{3} \\ \text{COMPS} & \boxed{4} \\ \text{HEAD-DTR} & \begin{bmatrix} \textit{phrase} & \\ \text{PHON} & \boxed{2} \\ \text{SUBJ} & \langle \boxed{5} \rangle \\ \text{SPR} & \boxed{3}\langle\ \rangle \\ \text{COMPS} & \boxed{4}\langle\ \rangle \end{bmatrix} \\ \text{NON-HD-DTRS} & \left\langle \begin{bmatrix} \textit{sign} & \\ \text{PHON} & \boxed{1} \\ \text{SYNSEM} & \boxed{5} \end{bmatrix} \right\rangle \end{bmatrix}
$$

$$
\begin{bmatrix}
\textit{hd-subj-ph} & \\
\text{PHON} & \boxed{1} \oplus \boxed{2} \\
\text{HEAD} & \boxed{3} \\
\text{SUBJ} & \langle\ \rangle \\
\text{COMPS} & \langle\ \rangle \\
\text{LEX} & - \\
\text{HD-DTR} & \begin{bmatrix}
\textit{phrase} & \\
\text{PHON} & \boxed{2}\,\langle \textit{likes},\ \textit{scotch} \rangle \\
\text{HEAD} & \boxed{3}\ \textit{verb} \\
\text{SUBJ} & \langle \boxed{4} \rangle \\
\text{COMPS} & \langle\ \rangle \\
\text{LEX} & -
\end{bmatrix} \\
\text{NON-HD-DTRS} & \left\langle \begin{bmatrix}
\textit{phrase} & \\
\text{PHON} & \boxed{1}\,\langle \textit{Toby} \rangle \\
\text{SYNSEM} & \boxed{4}\ \text{NP}
\end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 10: Partial AVM for the sentence *“Toby likes scotch”*.

Table 2: Verbal projections.

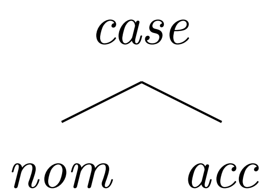
Verb	$\begin{bmatrix} \textit{word} & \\ \text{HEAD} & \textit{verb} \\ \text{SUBJ} & \boxed{1}\langle \textit{synsem} \rangle \\ \text{COMPS} & \boxed{2}\textit{list(synsem)} \\ \text{ARG-STR} & \boxed{1} \oplus \boxed{2} \\ \text{LEX} & + \end{bmatrix}$

Verb Phrase	$\begin{bmatrix} \textit{hd-comp-ph} & \\ \text{HEAD} & \textit{verb} \\ \text{SUBJ} & \langle \textit{synsem} \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \\ \text{HD-DTR} & \textit{word} \\ \text{NON-HD-DTRS} & \textit{list(sign)} \end{bmatrix}$
Sentence	$\begin{bmatrix} \textit{hd-subj-ph} & \\ \text{HEAD} & \textit{verb} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \\ \text{HD-DTR} & \textit{phrase} \\ \text{NON-HD-DTRS} & \langle \textit{sign} \rangle \end{bmatrix}$

3.3 Nouns and Noun Phrases

The sort *head* has *noun* as one of its subsorts. The sort *noun* is in its turn defined for the feature CASE, with value *case*.

$$\begin{bmatrix} \textit{noun} & \\ \textsc{case} & \textit{case} \end{bmatrix}$$



A proper noun such as *"Toby"* will a have feature structure very similar to that for the verb *"likes"* in figure 3. The only differences will be

- PHONOLOGY, which has the value $\langle Toby \rangle$, rather than $\langle likes \rangle$,
- HEAD, which will have the value $\begin{bmatrix} noun & \\ \text{CASE} & case \end{bmatrix}$, rather than *verb*, and
- the valence values SUBJ and COMPS, which will both have the empty list as value, since proper nouns take neither complements nor subjects

The result is shown in the AVM in figure 11.

$$
\begin{bmatrix}
\textit{word} & \\
\text{PHON} & \langle \textit{Toby} \rangle \\
\text{SYNSEM} & \begin{bmatrix}
\textit{synsem} & \\
\text{LOC} & \begin{bmatrix}
\textit{local} & \\
\text{CAT} & \begin{bmatrix}
\textit{cat} & \\
\text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{CASE} & \textit{case} \end{bmatrix} \\
\text{LEX} & + \\
\text{SUBJ} & \boxed{1} \ \langle \ \rangle \\
\text{COMPS} & \boxed{2} \ \langle \ \rangle \\
\text{ARG-STR} & \boxed{1} \oplus \boxed{2}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Figure 11: Partial AVM for the proper noun *"Toby"*.

This lexical entry satisfies the definition of the head daughter in a head-complement phrase, which, together with the Head Feature, licenses the head-complement phrase shown in figure 12. This is the nominal counterpart of the verb phrase shown in figure 9.

$$\left[\begin{array}{ll} \textit{hd-comp-ph} & \\ \text{PHON} & \boxed{1} \\ \text{HEAD} & \boxed{3} \\ \text{SUBJ} & \boxed{5} \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \\ \text{HD-DTR} & \left[\begin{array}{ll} \textit{word} & \\ \text{PHON} & \boxed{1}\,\langle \textit{Toby}\rangle \\ \text{HEAD} & \boxed{3}\left[\begin{array}{ll}\textit{noun} & \\ \text{CASE} & \textit{case}\end{array}\right] \\ \text{SUBJ} & \boxed{5}\,\langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & + \end{array}\right] \\ \text{NON-HD-DTRS} & \langle\ \rangle \end{array}\right]$$

Figure 12: Partial AVM for the **Nbar** *“Toby”*.

It is tempting to think that determiners are the nominal counterpart to subjects – where verbs require subjects, nouns may require determiners. However, things turn out to be more complex, since common nouns can have both a subject and a determiner, as does the common noun *"clown"* in the following examples.

(1) *"Toby is a clown."*

(2) *"Everybody considered Toby a clown."*

Note that the semantics of both of these sentences require the sub-translation *clown1(t)* as a component, exactly parallel to *drink1(t)* for the semantics of *"Toby drinks"*, in which the argument t is indisputably the translation of the subject **NP**.

The HPSG solution to this is to posit an additional valence feature called SPECIFIER (abbreviated to SPR) which specifies what determiner if any the head requires. This requires the following modification of the features appropriate to the sort *category*.

$$\begin{bmatrix} \textit{cat} & \\ \text{HEAD} & \textit{head} \\ \text{LEX} & \textit{boolean} \\ \text{SUBJ} & \boxed{6}\ \textit{list(synsem)} \\ \text{SPR} & \boxed{7}\ \textit{list(synsem)} \\ \text{COMPS} & \boxed{8}\ \textit{list(synsem)} \\ \text{ARG-STR} & \boxed{6} \oplus \boxed{7} \oplus \boxed{8} \end{bmatrix}$$

"Dagger" will therefore have the following *category* specification.

$$\begin{bmatrix} \textit{cat} & \\ \textsc{head} & \begin{bmatrix} \textit{noun} & \\ \textsc{case} & \textit{case} \end{bmatrix} \\ \textsc{lex} & + \\ \textsc{subj} & \boxed{1}\ \langle\ \rangle \\ \textsc{spr} & \boxed{2}\langle \text{DetP} \rangle \\ \textsc{comps} & \boxed{3}\ \langle\ \rangle \\ \textsc{arg-str} & \boxed{1} \oplus \boxed{2} \oplus \boxed{3} \end{bmatrix}$$

Specifiers comprise a broader class than determiners and include the underlined items in the following examples.

(3) *"Macbeth was <u>very/too/six feet</u> tall."*

(4) *"Glamis is <u>just/right/four miles</u> over the border."*

(5) *"Toby drank <u>too/very/very much too</u> fast."*

Heads select their specifiers, just as they select their subject and complements, so common nouns like *"dagger"* will contain the valence specification [SPR ⟨DetP⟩] while proper nouns like *"Toby"* will have [SPR ⟨ ⟩].

However, in contrast to subjects and complements, specifiers also select the head with which they co-occur; determiners require a nominal sister, degree specifiers like *"very"* and *"too"* require an adjectival sister and so on.

Restricting attention to determiners, recall that the sort *det* is a subsort of *head* (cf. the sortal hierarchy on page 3). The sort *det* is appropriate for a new feature SPECIFIED (abbreviated SPEC) which determines the kind of category with which the determiner combines. So the head value for determiners looks like this

$$\begin{bmatrix} \textit{cat} & \\ \text{HEAD} & \begin{bmatrix} \textit{det} & \\ \text{SPEC} & \text{Nbar} \end{bmatrix} \\ \text{LEX} & + \\ \text{SUBJ} & \langle\ \rangle \\ \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix}$$

in which **Nbar** abbreviates the following feature description.

$$
\begin{bmatrix}
\textit{synsem} & \\
\textsc{loc}\,|\,\textsc{cat} & \begin{bmatrix}
\textsc{head} & \textit{noun} \\
\textsc{spr} & \langle \text{DetP} \rangle \\
\textsc{comps} & \langle\ \rangle \\
\textsc{lex} & -
\end{bmatrix}
\end{bmatrix}
$$

$$
\begin{bmatrix}
\textit{word} & \\
\textsc{phon} & \langle \textit{the} \rangle \\
\textsc{ss} & \boxed{1}\begin{bmatrix}
\textit{synsem} & \\
\textsc{l}\,|\,\textsc{c} & \begin{bmatrix}
\textsc{head} & \begin{bmatrix}
\textit{det} & \\
\textsc{spec} & \begin{bmatrix}
\textit{synsem} & \\
\textsc{l}\,|\,\textsc{c} & \begin{bmatrix}
\textsc{head} & \textit{noun} \\
\textsc{spr} & \left\langle \begin{bmatrix} \textit{synsem} & \\ \textsc{loc}\,|\,\ldots\,|\,\textsc{spec} & \boxed{1} \end{bmatrix} \right\rangle \\
\textsc{comps} & \langle\ \rangle \\
\textsc{lex} & -
\end{bmatrix}
\end{bmatrix}
\end{bmatrix} \\
\textsc{subj} & \langle\ \rangle \\
\textsc{spr} & \langle\ \rangle \\
\textsc{comps} & \langle\ \rangle \\
\textsc{lex} & +
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Figure 13: Partial feature structure of the determiner *"the"*.

$$
\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{dagger} \rangle \\ \text{SYNSEM} & \boxed{1} \begin{bmatrix} \textit{synsem} & \\ \text{LOC} \mid \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{SUBJ} & \langle\ \rangle \\ \text{SPR} & \left\langle \begin{bmatrix} \textit{synsem} & \\ \text{LOC} \mid \text{CAT} \mid \text{HEAD} & \begin{bmatrix} \textit{det} & \\ \text{SPEC} & \boxed{1} \end{bmatrix} \\ \text{LEX} & - \end{bmatrix} \right\rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & + \end{bmatrix} \end{bmatrix} \end{bmatrix}
$$

Figure 14: Partial feature structure of the common noun *“dagger”*.

Head-Specifier Phrase

$$
\textit{hd-spr-ph} \implies \begin{bmatrix} \text{PHON} & \boxed{1} \oplus \boxed{2} \\ \text{SPR} & \langle\ \rangle \\ \text{HD-DTR} & \begin{bmatrix} \textit{phrase} & \\ \text{PHON} & \boxed{2} \\ \text{SPR} & \langle \boxed{3} \rangle \end{bmatrix} \\ \text{NON-HD-DTRS} & \left\langle \begin{bmatrix} \textit{phrase} & \\ \text{PHON} & \boxed{1} \\ \text{SYNSEM} & \langle \boxed{3} \rangle \end{bmatrix} \right\rangle \end{bmatrix}
$$

$$\begin{bmatrix}
\textit{hd-spr-phr} & \\
\text{PHON} & \boxed{1} \oplus \boxed{2} \\
\text{SS} \mid \text{LOC} \mid \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{3} \\ \text{SPR} & \langle\ \rangle \end{bmatrix} \\
\text{HD-DTR} & \begin{bmatrix} \textit{hd-comp-phr} & \\ \text{PHON} & \boxed{2} \\ \text{SS} \mid \boxed{4}\ \text{LOC} \mid \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{3} \\ \text{SPR} & \langle \boxed{5} \rangle \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \textit{word} & \\ \text{PHON} & \boxed{2}\ \langle \textit{dagger} \rangle \\ \text{LOC} & \begin{bmatrix} \text{HEAD} & \boxed{3}\ \textit{noun} \\ \text{SPR} & \langle \boxed{5} \rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-HD-DTRS} & \langle\ \rangle \end{bmatrix} \\
\text{NON-HD-DTRS} & \left\langle \begin{bmatrix} \textit{hd-comp-phr} & \\ \text{PHON} & \boxed{1} \\ \text{SS} \mid \boxed{5}\ \text{LOC} \mid \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{6} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \textit{word} & \\ \text{PHON} & \boxed{1}\ \langle \textit{the} \rangle \\ \text{LOC} & \begin{bmatrix} \text{HEAD} & \boxed{6} \begin{bmatrix} \textit{det} & \\ \text{SPEC} & \boxed{4} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{NON-HD-DTRS} & \langle\ \rangle \end{bmatrix} \right\rangle
\end{bmatrix}$$

Figure 15: Partial description of the noun phrase *"the dagger"*.

- We will use the symbol **X** to stand for categories of sort *word*, i.e. lexical categories which contain the feature specification $[\textsc{lex}\ +]$)

- We will use the symbol **XP** to stand for an object of sort *phrase*

- We will use X'[a] to stand for an object of sort $\begin{bmatrix} \textit{phrase} \\ \textsc{spr}\ \langle [\ ] \rangle \end{bmatrix}$, i.e. a phrase with a non-empty SPR value

- We will use X''[b] to stand for an object of sort $\begin{bmatrix} \textit{phrase} \\ \textsc{spr}\ \langle\ \rangle \end{bmatrix}$

- We will use the symbol **VP** as an alias for XP $\begin{bmatrix} \textit{verb} \\ \textsc{subj}\ \langle [\ ] \rangle \end{bmatrix}$

[a] Pronounced “X-bar”.
[b] Pronounced “X-double-bar”.

- We will use the symbol **S** as an alias for XP $\begin{bmatrix} \textit{verb} \\ \textsc{subj}\ \langle\ \rangle \end{bmatrix}$

- We will also replace **X** in the above by **N**, **A**, **P**, **Det** and so on, to abbreviate X $\begin{bmatrix} \textsc{head}\ \textsc{noun} \end{bmatrix}$etc.

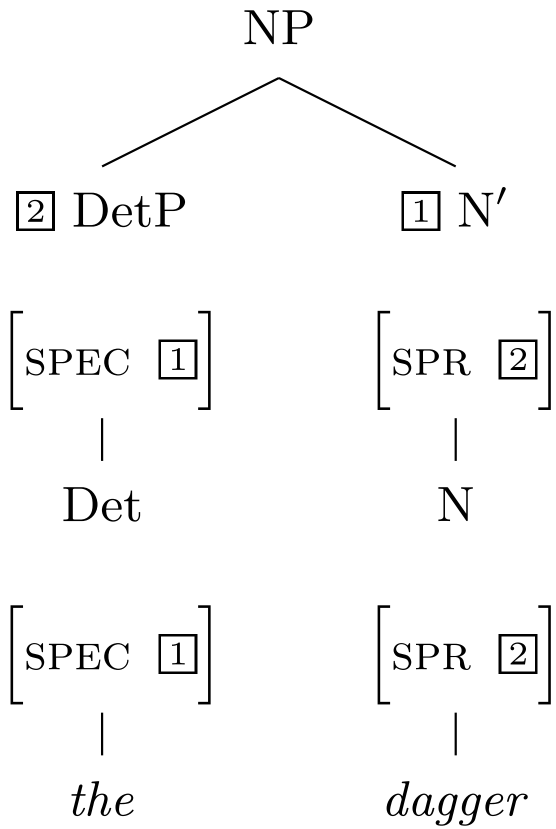


Figure 16: The NP *"the dagger"* in tree notation.

Nouns with complements

(6) *"Your disapproval <u>of our plans</u>."*

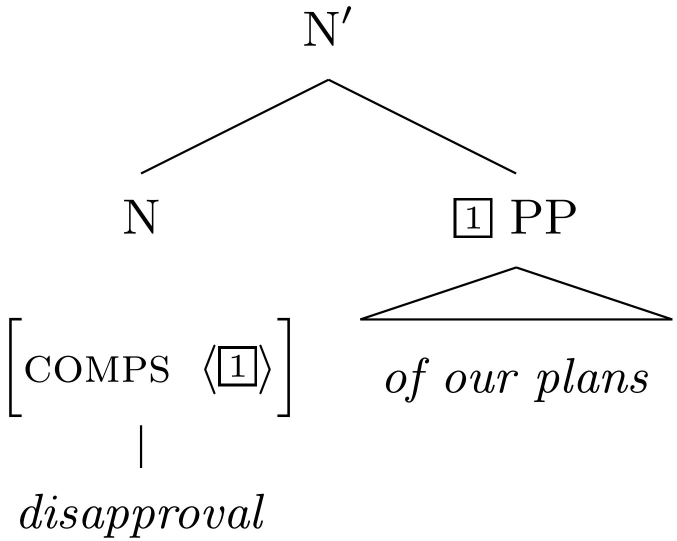
(7) *"A book <u>about linguistics</u>."*

(8) *"Her delight <u>at winning</u>."*

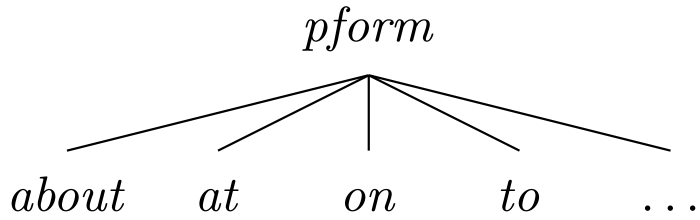
(9) *"That photograph <u>of your brother</u>."*

All that is necessary to accommodate such cases is the inclusion in the grammar of the relevant lexical entries along the following lines (details omitted).

$$\begin{bmatrix} \textsc{phon} & \textit{disapproval} \\ \textsc{subj} & \langle\ \rangle \\ \textsc{comps} & \langle \text{PP} \rangle \end{bmatrix}$$


N′
N
1 PP
COMPS ⟨1⟩
of our plans
disapproval

3.4 Prepositions and PPs



$$
\begin{bmatrix}
\textsc{phon} & \langle \textit{about} \rangle \\
\textsc{head} & \begin{bmatrix} \textit{prep} & \\ \textsc{pform} & \textit{about} \end{bmatrix} \\
\textsc{subj} & \langle\ \rangle \\
\textsc{comps} & \langle \mathrm{NP}[\textit{acc}] \rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\textsc{phon} & \langle \textit{disapproval} \rangle \\
\textsc{subj} & \langle\ \rangle \\
\textsc{comps} & \langle \mathrm{PP}[\textit{of}] \rangle
\end{bmatrix}
$$

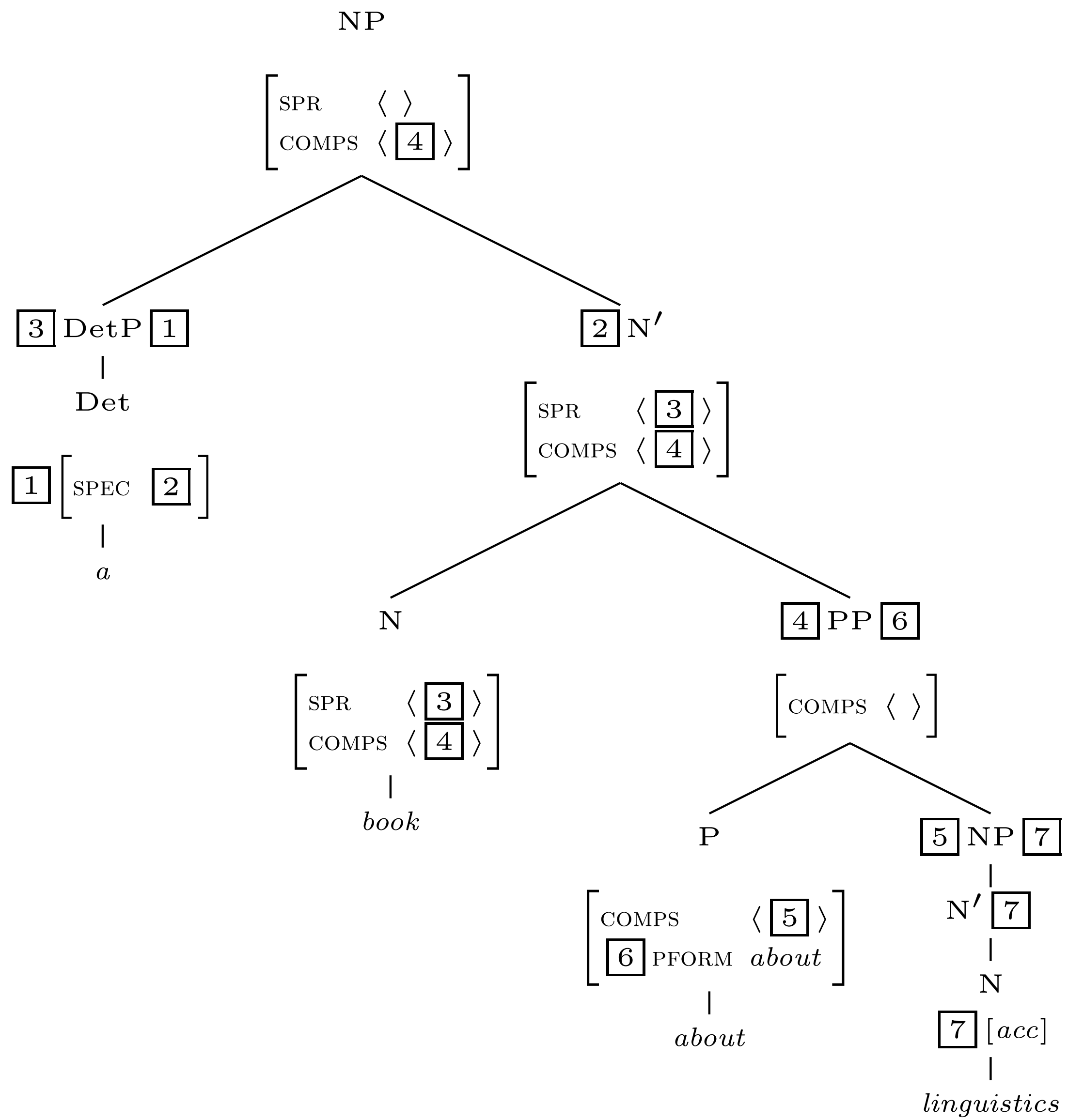


Figure 17: Tree representation for *"a book about linguistics"*.

3.5 Verbs and auxiliaries

Verbs selecting **VPs** as their complements.

(10) *"Toby may drink scotch."*

(11) *"Toby is drinking scotch."*

(12) *"Toby has drunk scotch."*

We assume without discussion that sentences like these have the structure shown in figure 18.

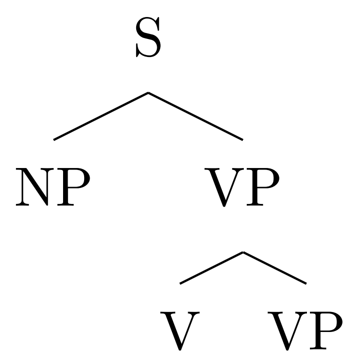


Figure 18: Constituent structure for auxiliary verbs.

There are a number of interesting things to note about examples like these.

- Firstly, the verb DRINK appears in a range of different forms (*"drink"*, *"drinking"*, *"drunk"*),
- secondly, the appropriate form of DRINK in each example is determined by the preceding verb. For example, *"is"* (or any other form of the lexeme BE) requires *"drinking"*, any other choice is ungrammatical (* *"Toby is drink scotch"*, * *"Toby is drunk scotch"*), and,
- thirdly, *"Toby"* is the subject of the second verb as well as the first one. (Who is doing the drinking?)

English verbs can appear in a range of different forms, as illustrated in table 3 with the lexeme DRINK, each with a distinctive distribution.

Finite	present tense	*"Toby drinks"*
	past tense	*"Toby drank"*
Present participle		*"Toby is drinking"*
Past participle		*"Toby has drunk"*
Base		*"Toby can drink"*
Gerund		*"Toby likes drinking"*

Table 3: Table of English verb forms

To distinguish between these different forms of the verb, we will introduce the attribute VFORM, with the value *vform*. The sort *vform* has the subsorts shown in figure 19, whose names are drawn from the labels in table 3.

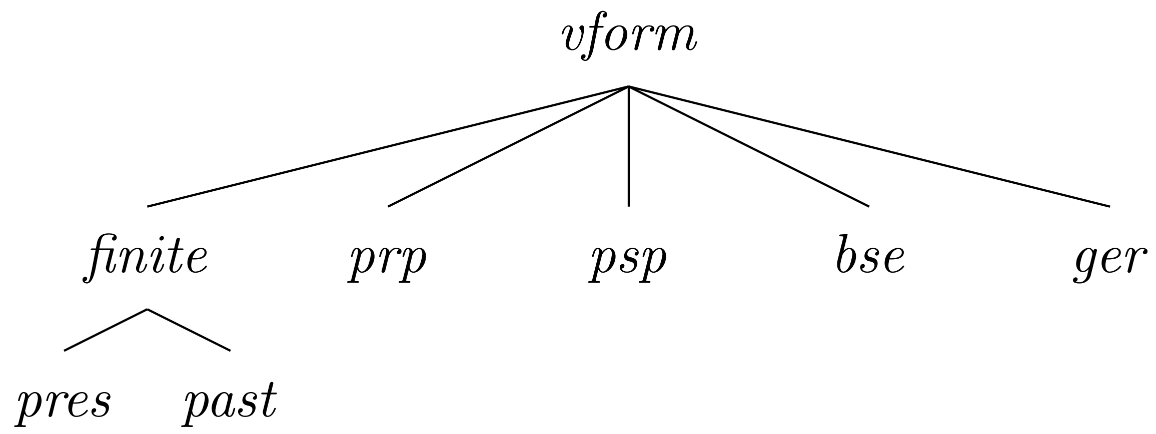


Figure 19: Sortal hierarchy for *vform*.

The attribute VFORM is appropriate for the *head* subsort *verb*, so every verbal category will contain the following feature structure.

$$\begin{bmatrix} \textit{cat} & \\ \textsc{head} & \begin{bmatrix} \textit{verb} & \\ \textsc{vform} & \textit{vform} \end{bmatrix} \end{bmatrix}$$

Verbs may possess the complete range of verbal forms (as DRINK does), or may be restricted to some subset of them. Among the first verbs in the sequences in (10)-(12), BE has all the forms shown for DRINK, whereas MAY lacks all except the finite forms. (There are no forms * *"maying"* or * *"mayed"*).

However, BE, MAY and HAVE also possess grammatical characteristics that are not shared by other verbs such as DRINK. These are neatly summed up by the acronym NICE.

Negation: *"Toby isn't tall."*

Inversion: *"Is Toby tall?"*

Contraction: *"Toby's tall."*

Ellipsis: *"People say Toby is tall, and he is."*

- **Negation**: the verb has a distinct negative form, usually represented orthographically with *n't*.
- **Inversion**: the capacity of the verb to precede the subject in interrogatives and some other sentence-types.
- **Contraction**: the verb has an alternative pronunciation which is shorter than its citation form – sometimes this is given orthographic recognition as with *'s* for *"is"* and *"has"*, sometimes not, as with the contracted version of *"can"* (rather like *"c'n"*).
- **Ellipsis**: a constituent which normally follows the verb may be omitted and its interpretation recovered from the context.
- Verbs that exhibit some or all of these properties are known as **auxiliary verbs**, or simply **auxiliaries**.

In contrast to main verbs, auxiliaries may precede or follow the subject - a phenomenon known as **subject-auxiliary inversion** (SAI).

One further detail of SAI is that the form of the verb which occurs in pre-subject position may be different to the one that occurs in post-subject position.

(13) *"I am not happy."*/ *"I'm not happy."*/* *"I aren't happy."*

(14) *"Aren't I happy."*

"Aren't" can only co-occur with a first person singular subject if it precedes it, not if it follows it.

These distinctions motivate the postulation of two additional HEAD features for verbs: AUX and INV.

AUX is *boolean* valued and partitions the class of verbs into auxiliaries ([AUX +]) and non-auxiliaries ([AUX –]).

[INV +] identifies those forms of auxiliaries that precede the subject, [INV –] those that follow it.

If we put these developments together, the value of HEAD for verbal projections looks like this.

$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{vform} \\ \text{AUX} & \textit{bool} \\ \text{INV} & \textit{bool} \end{bmatrix} \end{bmatrix}$$

What appears on the COMPS list of an auxiliary is a description of the following kind.

$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{INV} & - \end{bmatrix} \\ \text{SUBJ} & \langle [\ ] \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix}$$

$$
\begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{AUX} & + \end{bmatrix} \\
\text{SUBJ} & \boxed{1} \\
\text{COMPS} & \left\langle \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{prp} \\ \text{INV} & - \end{bmatrix} \\
\text{SUBJ} & \boxed{1} \\
\text{COMPS} & \langle\ \rangle
\end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 20: Partial lexical entry for the auxiliary verb *"be"*.

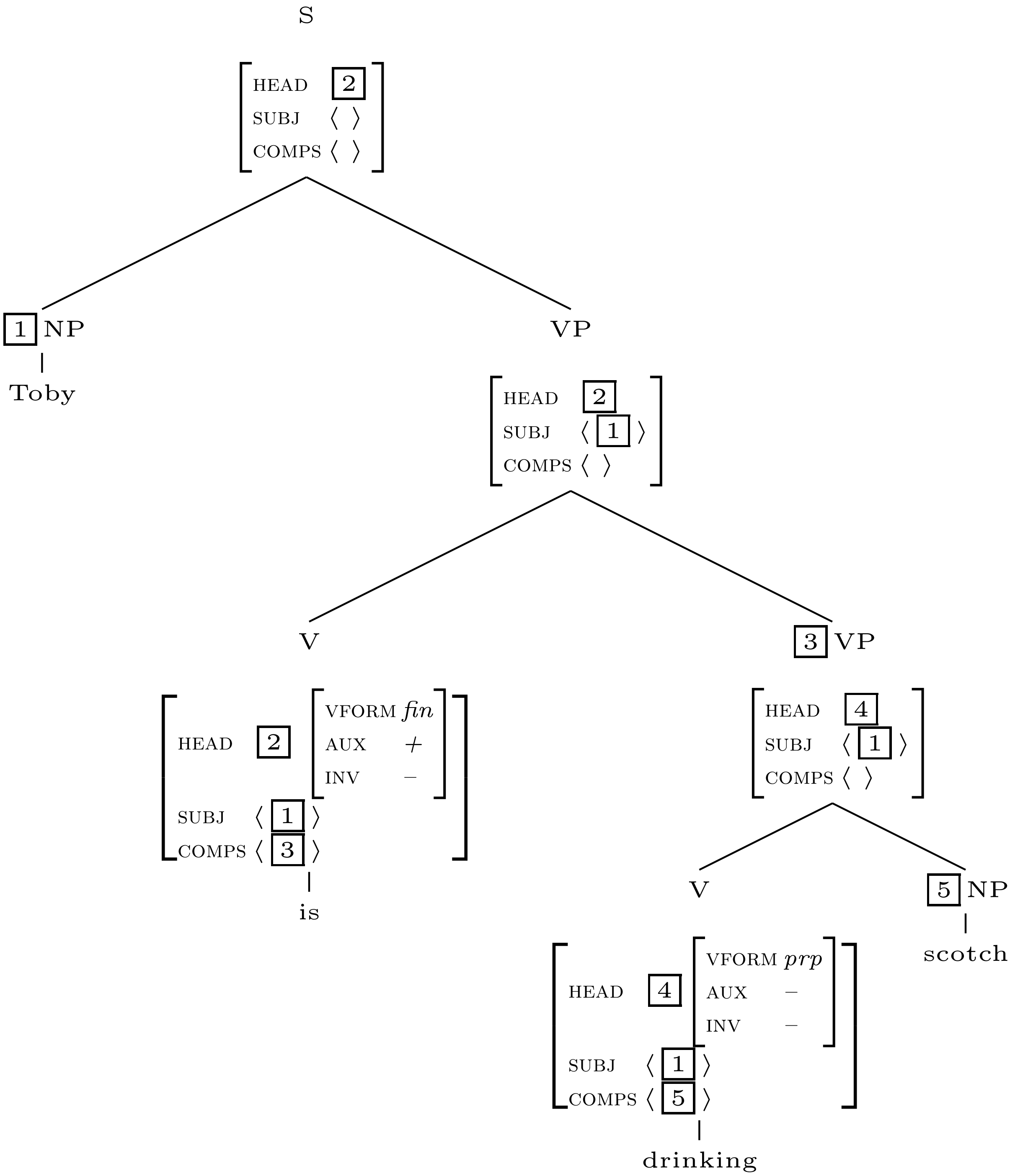


Figure 21: *"Toby is drinking scotch."*

MAY belongs to a large subclass of auxiliaries known as **modals**.

Other modals are *"can"*, *"could"*, *"will"*, *"would"*, *"shall"*, *"should"*, *"might"*, *"must"*.

These require that their complement contains the *base* form of the verb and

they exhibit the peculiarity (mentioned in respect of MAY above) that they are **defective** and possess only the *finite* form. (Which precludes them from following any other auxiliary, since no auxiliaries select a finite **VP**.)

Their lexical entries therefore look like figure 22.

$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{fin} \\ \text{AUX} & + \end{bmatrix} \\ \text{SUBJ} & \boxed{6} \\ \text{COMPS} & \left\langle \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{bse} \\ \text{INV} & - \end{bmatrix} \\ \text{SUBJ} & \boxed{6} \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Figure 22: Partial lexical entry for a modal auxiliary.

HAVE requires that its complement be in the past participle form, giving the lexical entry in figure 23.

$$
\begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{AUX} & + \end{bmatrix} \\
\text{SUBJ} & \boxed{6} \\
\text{COMPS} & \left\langle \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{psp} \\ \text{INV} & - \end{bmatrix} \\
\text{SUBJ} & \boxed{6} \\
\text{COMPS} & \langle\ \rangle
\end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 23: Partial lexical entry for the auxiliary verb HAVE.

A potentially confusing property of HAVE is that it represents the pronunciation of more than one lexical category: both an auxiliary and a main verb.

The version which subcategorises for a **VP** is an auxiliary and exhibits all the NICE properties.

- **Negation**: *"Toby hasn't drunk the scotch."*
- **Inversion**: *"Has Toby drunk the scotch?"*
- **Contraction**: *"Toby's drunk the scotch."*
- **Ellipsis**: *"People say Toby's drunk the scotch, and he has."*

The version that subcategorises for an **NP**, for many speakers, does not, and shares the distribution of main verbs like DRINK.

(15) (a) *"Toby has a book."*

(b) *"Toby drinks scotch."*

(16) (a) *"Toby doesn't have a book."*

(b) *"Toby doesn't drink scotch."*

(17) (a) *"Does Toby have a book."*

(b) *"Does Toby drink scotch."*

(18) (a) *"I don't have a book, but Toby does."*

(b) *"I don't drink scotch, but Toby does."*

For some speakers (mainly British), this version of *"have"* can also behave as an auxiliary, giving

(i) *"Toby hasn't a book."*

(ii) *"Has Toby a book?"*

(iii) *"I haven't a book, but Toby has."*

For such speakers, *"have"* has three lexical entries:

1. an auxiliary selecting a **VP** complement
2. an auxiliary selecting a **NP** complement
3. a main verb selecting a **NP** complement.

With main verbs, in the NICE contexts, a ‘dummy’ auxiliary verb *“do”* is required.

Auxiliary DO, like the modals, requires its complement to contain the *base* form of a verb.

Like HAVE, DO leads a double life, as both auxiliary and main verb, giving rise to sentences in which both auxiliary and main verb DO co-occur, such as *“What did you do?”*

The auxiliaries HAVE and DO are both defective. Auxiliary HAVE lacks present and past participle forms, thus disallowing sentences like the following.

* *"Toby is having drunk scotch."*

* *"Toby has had drunk scotch."*

Auxiliary DO, like the modals, lacks all but the *finite* form and, in addition, requires **VP** complements which are [AUX –] (thus precluding sentences like * *"Toby doesn't have drunk the scotch"*).

The final auxiliary that we will discuss is TO in sentences such as *"Toby wants to leave"*.

This is a highly defective auxiliary (it lacks finite, contracted and negated forms), but it does allow ellipsis: *"Toby says he isn't leaving, but I'm sure he really wants to"*.

TO requires us to posit an additional subsort of *vform*, *inf*, giving it the lexical entry shown in figure 24.

The phrase *"wants to drink"* will have the analysis shown in figure 25, in which *"wants"* selects a VP[VFORM *inf*].

$$
\begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{inf} \\ \text{AUX} & + \\ \text{INV} & - \end{bmatrix} \\
\text{SUBJ} & \boxed{6} \\
\text{COMPS} & \left\langle \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{bse} \\ \text{INV} & - \end{bmatrix} \\ \text{SUBJ} & \boxed{6} \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 24: Partial lexical entry for the auxiliary verb TO.

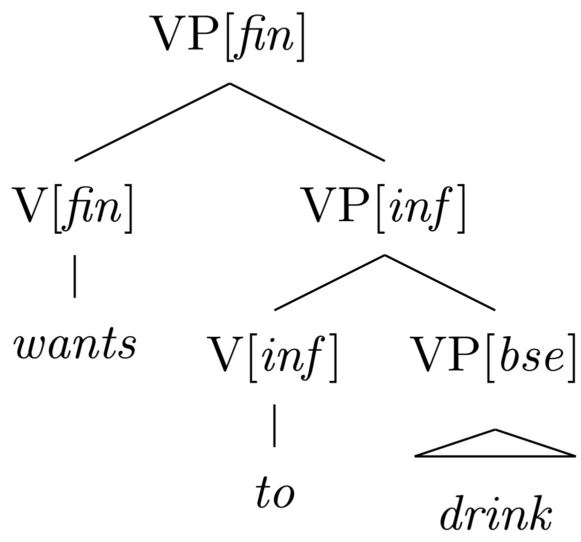


Figure 25: Tree for the phrase *"wants to drink"* showing VFORM values.

As a conclusion to this section, we observe that the lexical entries for auxiliaries that we have discussed here, together with the Head Feature Principle and the definition of *head-complement-phrase*, allow for sentences containing sequences of auxiliary verbs.

(19) *"Toby may be drinking scotch."*

(20) *"Toby may have been drinking scotch."*

(21) *"Toby has been drinking scotch."*

The flow of VFORM and valence information for (20) can be seen in the tree in figure 26.

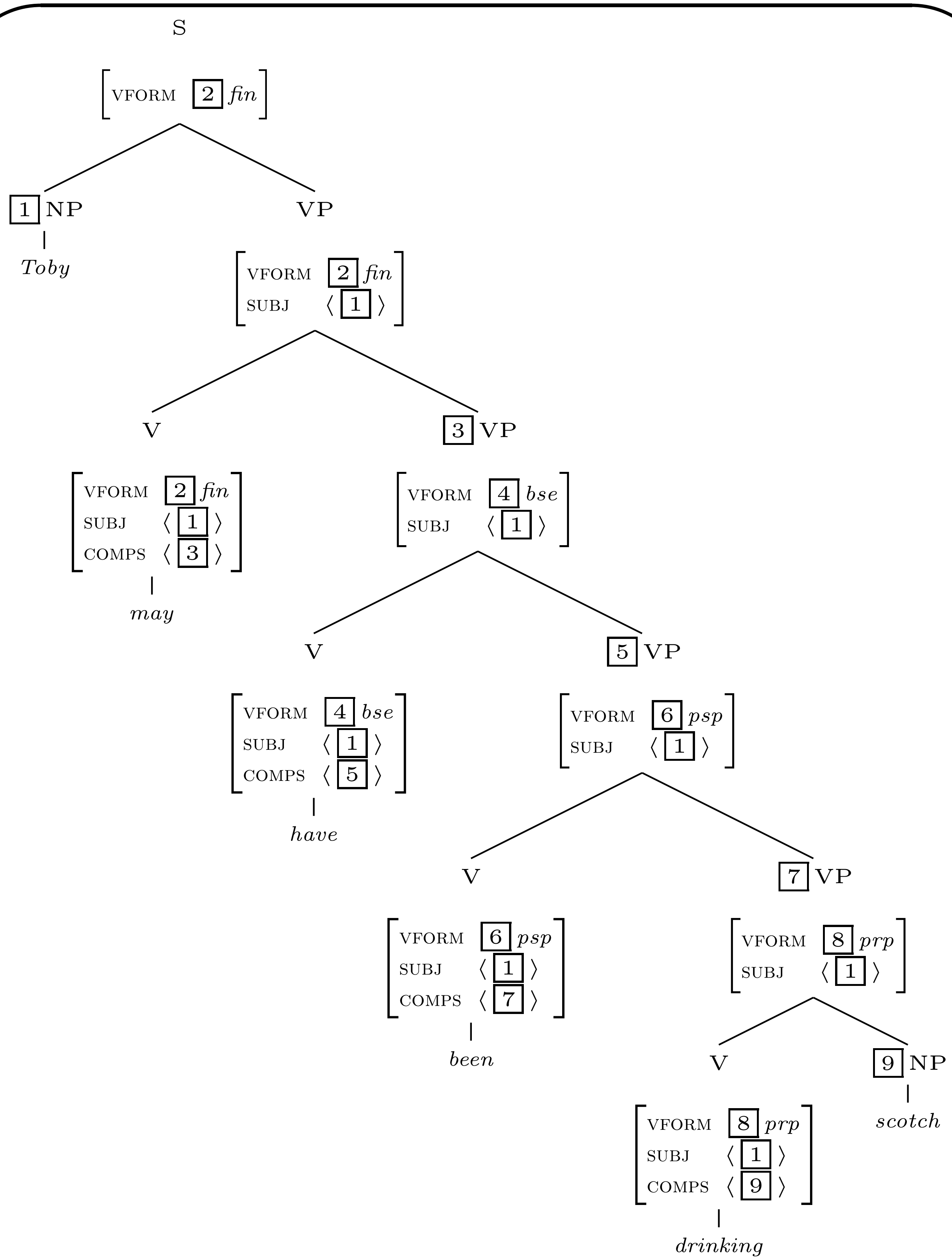


Figure 26: *"Toby may have been drinking scotch."*

3.6 Clauses

Clauses (i.e. sentences) are projections of verbs.

As a consequence of this and the way the Head Feature Principle operates, the VFORM value of the clause will be shared with that of the the 'highest' verb in the clause.

This means that it is straightforward to account for the following patterns of distribution.

(22) *"Andrew said Toby was drinking."*

(23) *"Andrew said that Toby was drinking."*

(24) *"That Toby was drinking surprised Andrew."*

(25) *"For Toby to be drinking is most unusual."*

(26) *"Andrew demanded that Toby stop drinking."*

(27) * *"Andrew said Toby be drinking."*

(28) * *"Andrew said (for) Toby to be drinking."*

(22)-(28) are all examples of sentences which contain a subordinate clause.

In (22) the subordinate clause *"Toby was drinking"* is headed by a finite verb (*"was"*).

Examples (27) and (28) show that the verb *"say"* cannot be followed by a subordinate clause headed by a *bse* (BE) or an *inf* verb (TO).

All that is required is that the COMPS value of SAY is specified as being $\langle$S[*fin*]$\rangle$.

$$
\begin{bmatrix}
\text{COMPS} & \left\langle \begin{bmatrix} \textit{synsem} & \\ \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{fin} \end{bmatrix} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \end{bmatrix} \right\rangle
\end{bmatrix}
$$

Example (23) is very similar, but the subordinate clause is introduced by the **complementiser** *"that"*.

Complementisers are lexical items which select a clausal complement, forming a constituent called a **complementiser phrase** (CP).

Many verbs which subcategorise for a clausal complement are, like *"say"*, indifferent as to whether it is **S** or **CP**.

Define a new sort for complementisers, *comp*, and introduce a new sort *verbal* of which *comp* and *verb* are subsorts.

The features VFORM, AUX and INV are appropriate for the new supersort and consequently are inherited by both subsorts.

$$\begin{array}{c} \begin{bmatrix} \mathit{verbal} & \\ \textsc{vform} & \mathit{vform} \\ \textsc{aux} & \mathit{bool} \\ \textsc{inv} & \mathit{bool} \end{bmatrix} \\ \mathit{comp} \qquad \mathit{verb} \end{array}$$

Since *"that"* introduces finite clauses, it is defined in feature structure terms as follows.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{that} \rangle \\ \text{HEAD} & \begin{bmatrix} \textit{comp} & \\ \text{VFORM} & \boxed{10}\,\textit{fin} \end{bmatrix} \\ \text{SUBJ} & \langle\ \rangle \\ \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle \text{S}[\text{VFORM}\ \boxed{10}] \rangle \end{bmatrix}$$

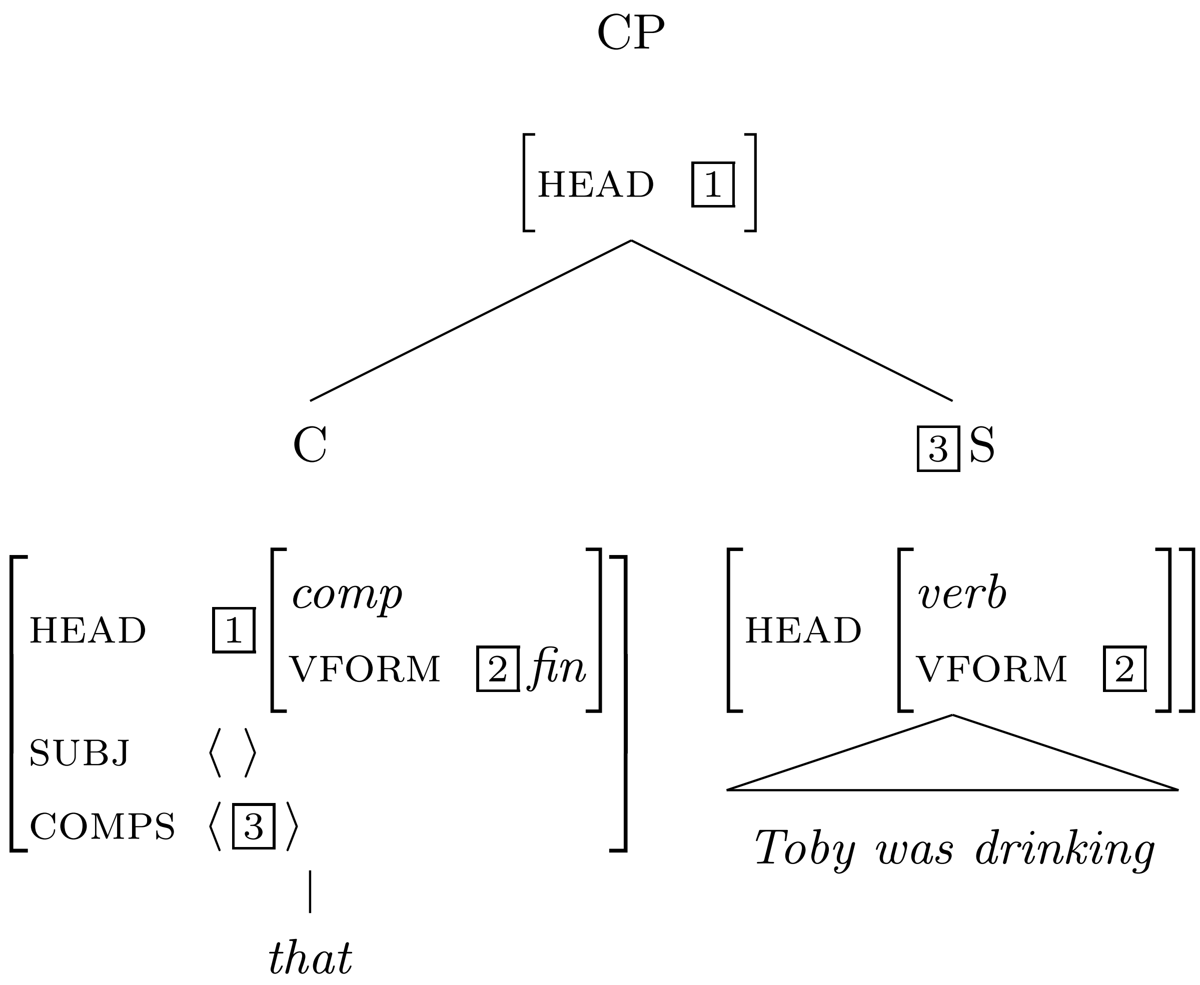


Figure 27: Tree for *"that Toby was drinking"*

Verbs like *"say"* are defined as taking a complement specified as

$$
\begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verbal} & \\ \text{VFORM} & \textit{fin} \end{bmatrix} \\
\text{SUBJ} & \langle\ \rangle \\
\text{COMPS} & \langle\ \rangle
\end{bmatrix}
$$

which subsumes both **S** and **CP**.

It requires only a slight modification to the lexical entry for the complementiser *"that"* to accommodate example (26) in which DEMAND selects a **CP** headed by a *bse* verb – changing the VFORM value from *fin* to *fin*∨*bse*, as shown below.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{that} \rangle \\ \text{HEAD} & \begin{bmatrix} \textit{comp} & \\ \text{VFORM} & \boxed{2}\, \textit{fin} \vee \textit{bse} \end{bmatrix} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle \text{S}[\text{VFORM}\ \boxed{2}] \rangle \end{bmatrix}$$

The contrast between the subcategorisation requirements of verbs like SAY and verbs like DEMAND is that the latter require a COMPS value which is $\langle$CP[VFORM bse]$\rangle$.

SURPRISE in sentence (24) differs from the previous examples in taking a finite **CP** as its subject. One of its subcategorisation requirements is therefore the following.

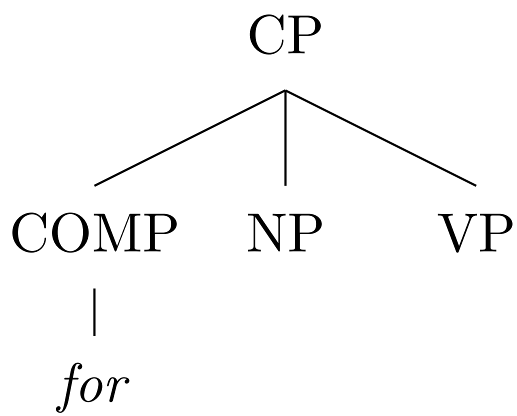
$$\begin{bmatrix} \textsc{subj} & \langle \text{CP}[\textit{fin}] \rangle \\ \textsc{comps} & \langle \text{NP} \rangle \end{bmatrix}$$

Example (25) is one in which the subject of *"is surprising"* is an infinitival clause (i.e. one whose head contains [VFORM *inf*]).

Infinitival clauses take a different complementiser, *"for"*, whose syntax is defined as follows.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{for} \rangle \\ \text{HEAD} & \begin{bmatrix} \textit{comp} & \\ \text{VFORM} & \boxed{2}\ \textit{inf} \end{bmatrix} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \left\langle \boxed{4}\text{NP},\ \text{VP}\begin{bmatrix} \text{VFORM} & \boxed{2} \\ \text{SUBJ} & \langle \boxed{4} \rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Note that the valence values of this complementiser are different to those of the complementiser *"that"*. *"That"* takes a single (sentential) complement, whereas *"for"* take a sequence of two complements, an **NP** and a **VP**. In tree terms, the constituent structure of non-finite clauses defined by this lexical entry for *"for"* is the following.



The SUBJ value of expressions like *"is most unusual"* is simply $\langle \mathrm{CP}[inf] \rangle$.

Before we conclude this section, there is a further comment to be made about the relationship between VFORM values and the case of **NP**s.

pronouns in English exhibit differences in case marking, depending upon the syntactic position in which they occur.

These differences are related to the kind of clause in which they occur:

the subjects of finite clauses are *nominative*, other **NP**s are *accusative*.

This can be handled by specifying that when a finite verb takes an **NP** subject, it specifies its SUBJ value as $\langle \mathrm{NP}[nom] \rangle$. Any **NP** on a COMPS list, on the other hand, is specified as NP[*acc*]. A description of the finite transitive verb *"drinks"* will therefore contain the following, where the case values are inherited from a supersort.

$$
\begin{bmatrix}
\textit{word} & \\
\textsc{phon} & \langle \textit{drinks} \rangle \\
\textsc{head} & \begin{bmatrix} \textit{verb} & \\ \textsc{vform} & \textit{fin} \\ \textsc{aux} & - \\ \textsc{inv} & - \end{bmatrix} \\
\textsc{subj} & \langle \mathrm{NP}[\textit{nom}] \rangle \\
\textsc{comps} & \langle \mathrm{NP}[\textit{acc}] \rangle
\end{bmatrix}
$$

3.7 Subject-auxiliary Inversion (SAI)

The clauses that we have looked at so far have all taken the form NP VP.

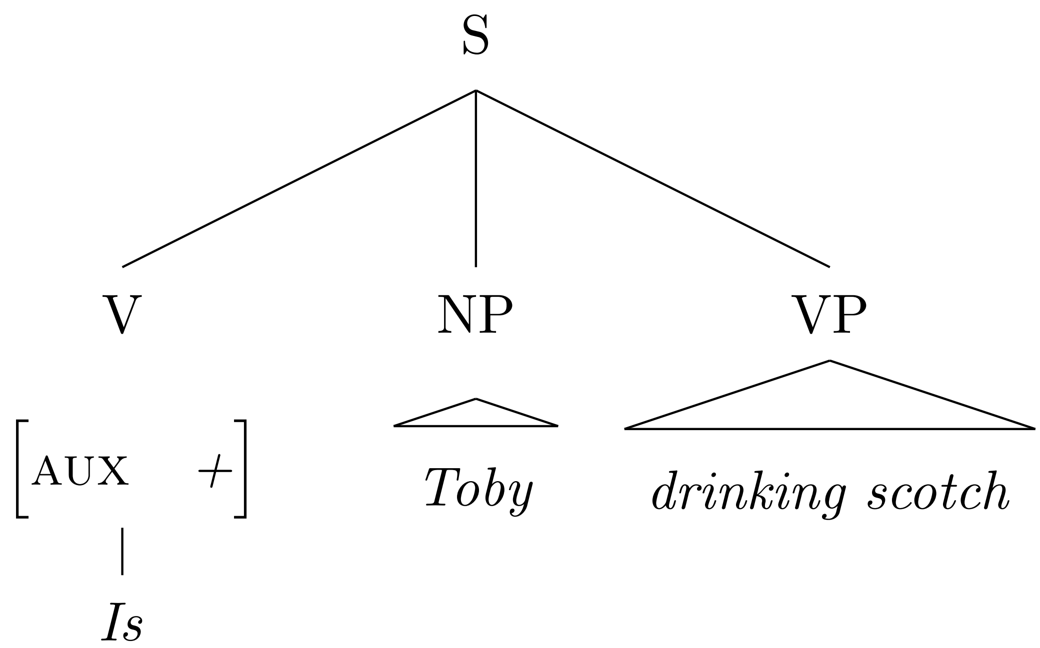
There are also English clauses in which an auxiliary verb precedes the subject:

(29) *"Is Toby drinking scotch."*

(30) *"What is Toby drinking."*

(31) *"Seldom did Toby drink scotch."*

We take the view that clauses like these simply have a flat structure in which the auxiliary, subject and post-subject constituent are sisters:



We need a way of providing for these constructions and do so by introducing a new type of clausal construction, *sai-ph*, a subsort of *hd-nexus-ph*, with the following constraint:

sai-phrase

$$
\textit{sai-ph} \Longrightarrow \begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{HD-DTR} & \begin{bmatrix} \textit{word} & \\ \text{INV} & + \\ \text{AUX} & + \\ \text{SUBJ} & \langle \boxed{1} \rangle \\ \text{COMPS} & \boxed{2} \end{bmatrix} \\ \text{NON-HD-DTRS} & \langle \boxed{1} \rangle \oplus \boxed{2} \end{bmatrix}
$$

This constraint ensures that only verbs marked as [AUX +, INV +]

will appear in such clauses and that the sister constituents will obey the constraints imposed by such verbs on their subject and complements.

4 The Lexicon

We have seen in the preceding sections of this chapter how HPSG represents linguistic information in terms of feature structure descriptions. Since HPSG is strongly lexical, the bulk of the information required by the grammar is encoded in lexical entries, as shown in a typical lexical entry (for the transitive verb LIKE) in figure 28.

$$
\begin{bmatrix}
\textit{word} & \\
\textsc{phon} & \langle \textit{like} \rangle \\
\textsc{cat} & \begin{bmatrix}
\textsc{head} & \begin{bmatrix}
\textit{verb} & \\
\textsc{vform} & \textit{fin} \\
\textsc{aux} & - \\
\textsc{inv} & -
\end{bmatrix} \\
\textsc{lex} & + \\
\textsc{subj} & \boxed{3}\,\langle \mathrm{NP} \rangle \\
\textsc{spr} & \boxed{4}\,\langle\ \rangle \\
\textsc{comps} & \boxed{5}\,\langle \mathrm{NP}[\textit{acc}] \rangle \\
\textsc{arg-str} & \boxed{3} \oplus \boxed{4} \oplus \boxed{5}
\end{bmatrix}
\end{bmatrix}
$$

Figure 28: Lexical entry for LIKE.

Now, this is the lexical entry for just a single English word.

Since every English other mono-transitive verb will require an almost identical lexical entry, it looks as if the lexicon will contain massive amounts of repetition.

However, looked at from a different perspective, the fact that much of this information is shared with other verbs provides the opportunity to avoid unnecessary redundancy by organising lexical entries as an inheritance hierarchy.

LIKE shares all the information in figure 28 except its pronunciation with every other mono-transitive verb; the value of HEAD is shared by every other verb, irrespective of valence; its value for SUBJ is shared by many other finite verbs, and so on.

These observations lead to the conclusion that the lexicon can be structured into an inheritance hierarchy in which it is necessary to specify in the lexicon only the most idiosyncratic information for any given word.

Let us pursue this idea by first of all looking at parts of speech (i.e. noun, verb, etc.), and set up a sortal hierarchy of lexical types, i.e. partitions of the sort *word*.

Table 4: Hierarchy of lexical parts of speech

SORT	CONSTRAINT	ISA
sign	$\begin{bmatrix} \text{PHON} & \textit{list(phonstring)} \\ \text{SYNSEM} & \begin{bmatrix} \textit{synsem} & \\ \text{LOCAL} & \begin{bmatrix} \textit{local} & \\ \text{CAT} & \begin{bmatrix} \textit{cat} & \\ \text{SUBJ} & \textit{list(ss)} \\ \text{SPR} & \textit{list(ss)} \\ \text{COMPS} & \textit{list(ss)} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$	$\top$
word	$\begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{LEX} & + \\ \text{SUBJ} & \boxed{1} \\ \text{SPR} & \boxed{2} \\ \text{COMPS} & \boxed{3} \\ \text{ARG-STR} & \boxed{1} \oplus \boxed{2} \oplus \boxed{3} \end{bmatrix} \end{bmatrix}$	*sign*
verb-wd	$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{vform} \\ \text{AUX} & \textit{bool} \\ \text{INV} & \textit{bool} \end{bmatrix} \\ \text{SUBJ} & \langle \textit{synsem} \rangle \\ \text{SPR} & \langle\ \rangle \end{bmatrix}$	*word*

SORT	CONSTRAINT	ISA
main-verb-wd	$\left[\text{HEAD} \left[\begin{array}{ll}\text{AUX} & - \\ \text{INV} & -\end{array}\right]\right]$	*verb-wd*
aux-verb-wd	$\left[\begin{array}{ll}\text{HEAD} & \left[\text{AUX} \quad +\right] \\ \text{ARG-STR} & \langle \textit{synsem}, \text{ VP}\rangle\end{array}\right]$	*verb-wd*
noun-wd	$\left[\text{HEAD} \left[\begin{array}{ll}\textit{noun} & \\ \text{CASE} & \textit{case}\end{array}\right]\right]$	*word*
prep-wd	$\left[\text{HEAD} \left[\begin{array}{ll}\textit{prep} & \\ \text{PFORM} & \textit{pform}\end{array}\right]\right]$	*word*

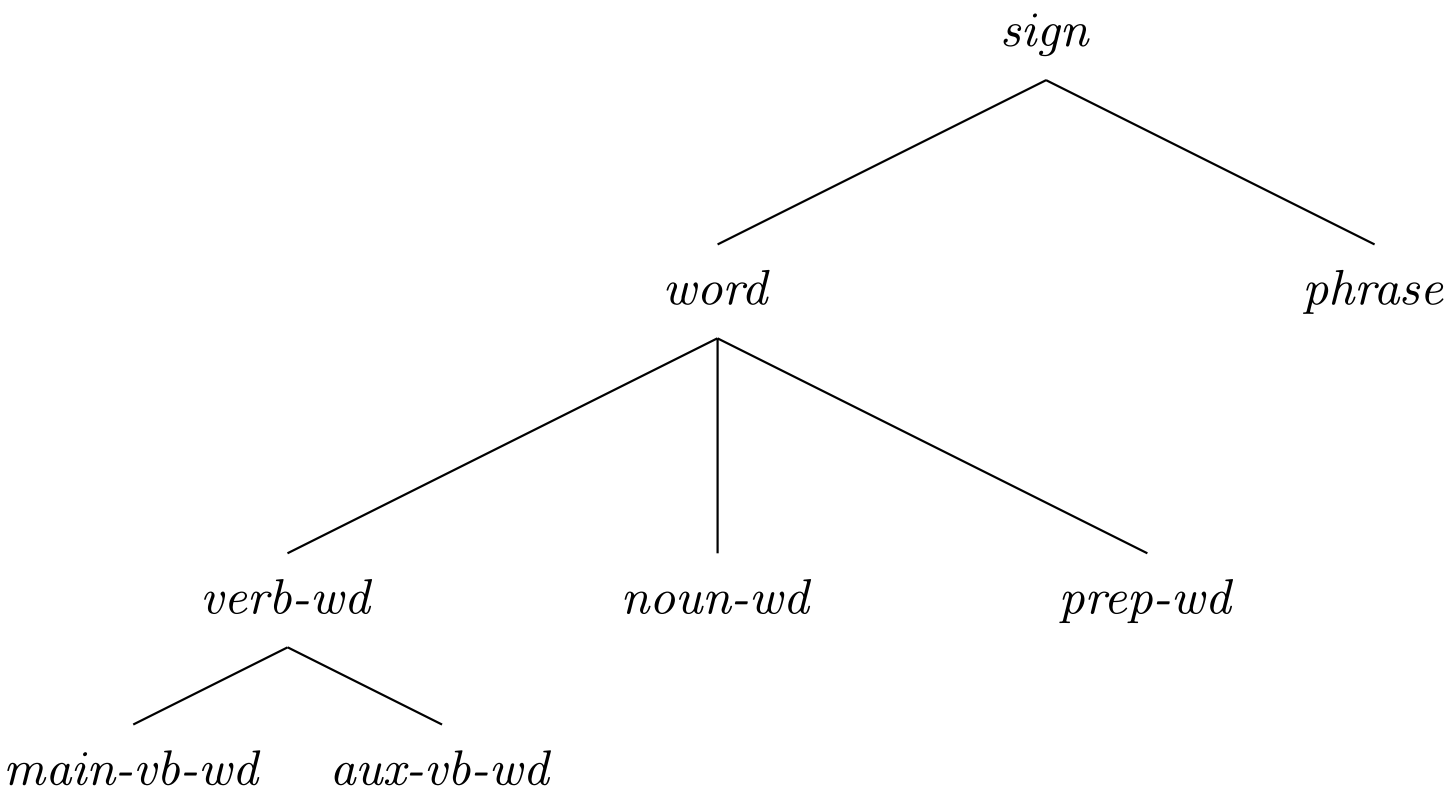


Figure 29: Part of speech hierarchy.

With the definitions in this sortal hierarchy, we can simplify the lexical entry for *"like"* to that below. All the other information specified in figure 28 is inherited from the sort *main-verb-wd*.

$$
\begin{bmatrix}
\textit{main-vb-wd} & \\
\textsc{phon} & \langle \textit{like} \rangle \\
\textsc{cat} & \begin{bmatrix}
\textsc{head} & \begin{bmatrix} \textsc{vform} & \textit{bse} \end{bmatrix} \\
\textsc{subj} & \langle \text{NP} \rangle \\
\textsc{comps} & \langle \text{NP} \rangle
\end{bmatrix}
\end{bmatrix}
$$

Let us now turn our attention to valence and show that a similar inheritance hierarchy is possible.

We will consider separately the set of possibilities in subject position and the set of possible complements.

We start by drawing a distinction between words which require a subject (such as verbs) and those which do not (such as prepositions), assigning the former to the sort *predicator-wd* and the latter to *non-predicator-wd*.

The sort *predicator-wd* can be subdivided into those words which require an **NP** subject (*np-predicator-wd*) and

those that require a **CP** subject (*cp-predicator-wd*).

The sort *cp-predicator-wd* can be further partitioned into words requiring a finite **CP** (*finite-cp-predicator-wd*) or an infinitival **CP** (*infinitival-cp-predicator-wd*).

This hierarchy and the constraints associated with the various subsorts are listed in table 5 and shown in diagrammatic form in figure 30.

SORT	CONSTRAINT	ISA
non-predicator-wd	$\left[\text{SUBJ} \quad \langle\ \rangle\right]$	*word*
predicator-wd	$\left[\text{SUBJ} \quad \langle \mathit{synsem} \rangle\right]$	*word*
np-predicator-wd	$\left[\text{SUBJ} \quad \langle \text{NP} \rangle\right]$	*prd-wd*
cp-predicator-wd	$\left[\text{SUBJ} \quad \langle \text{CP} \rangle\right]$	*prd-wd*
finite-cp-prd-wd	$\left[\text{SUBJ} \quad \langle \text{CP}[\mathit{fin}] \rangle\right]$	*cp-prd-wd*
infinitival-cp-prd-wd	$\left[\text{SUBJ} \quad \langle \text{CP}[\mathit{inf}] \rangle\right]$	*cp-prd-wd*

Table 5: Subject valence hierarchy.

Figure 30: Subject valence hierarchy diagram.

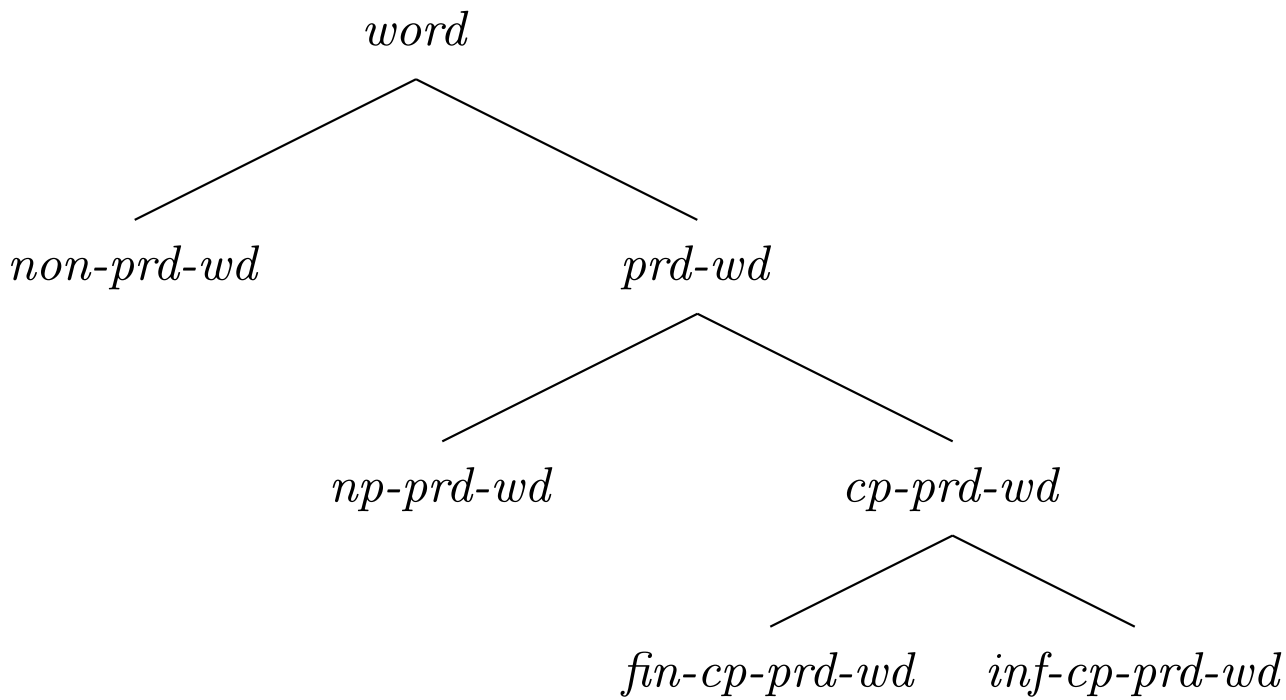
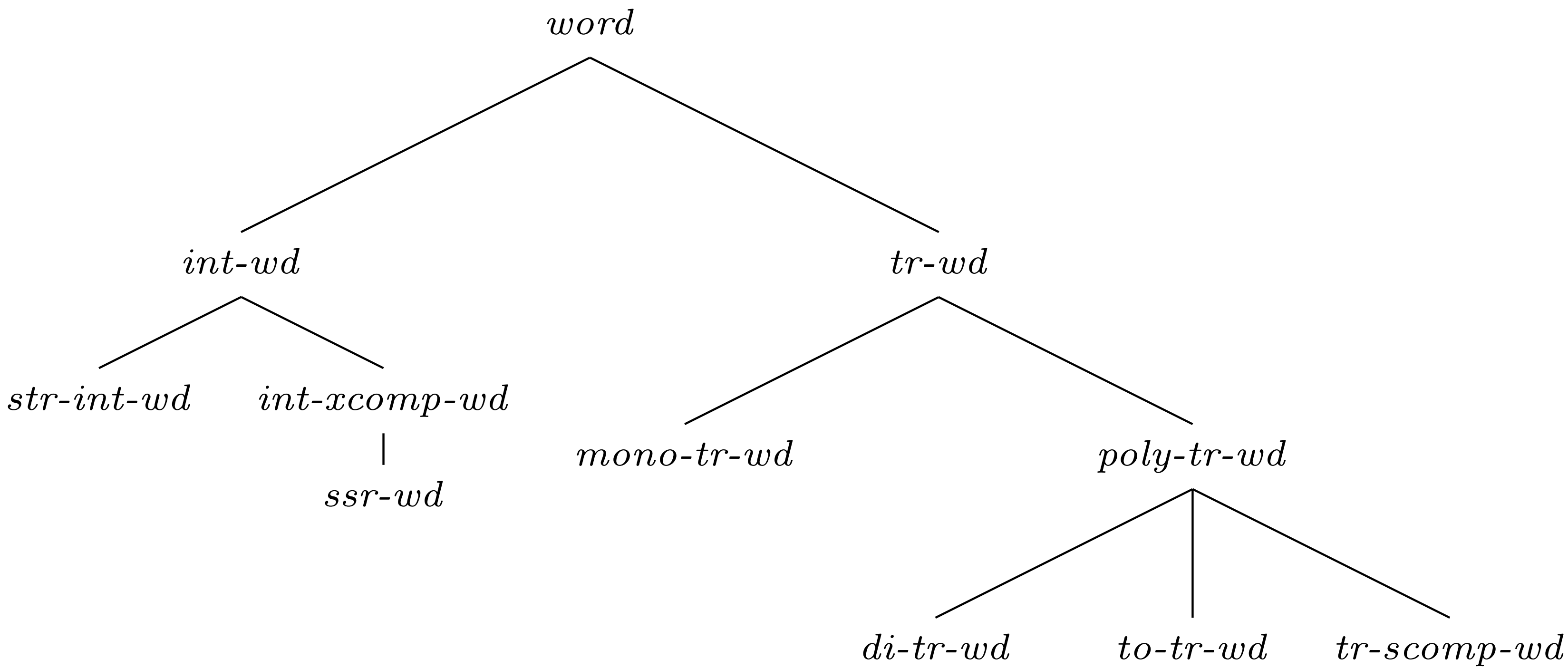


Table 6: Complement valence hierarchy

SORT	CONSTRAINT	ISA
intran-wd		*word*
strict-intran-wd	$\left[\text{ARG-STR} \quad \left[\text{FIRST} \quad \textit{synsem}\right]\right]$	*intran-wd*
intran-xcomp-wd	$\left[\text{ARG-STR} \quad \left[\text{REST} \quad \left[\text{FIRST} \quad \text{XP}[\text{SUBJ} \ \langle \textit{synsem} \rangle]\right]\right]\right]$	*intran-wd*
ssr-wd	$\left[\text{ARG-STR} \quad \left\langle \boxed{1}, \begin{bmatrix}\text{SUBJ} & \boxed{1} \\ \text{COMPS} & \langle\ \rangle\end{bmatrix} \right\rangle\right]$	*intran-xcomp-wd*
trans-wd	$\left[\text{ARG-STR} \quad \left[\text{REST} \quad \left[\text{FIRST} \ \text{NP}[\textit{acc}]\right]\right]\right]$	*word*

SORT	CONSTRAINT	ISA
mono-trans-wd	$\left[\text{ARG-STR} \left[\text{REST} \left[\text{REST}\ \langle\ \rangle\right]\right]\right]$	*trans-wd*
poly-trans-wd	$\left[\text{ARG-STR} \left[\text{REST} \left[\text{REST}\ \mathit{nelist(synsem)}\right]\right]\right]$	*trans-wd*
di-trans-wd	$\left[\text{ARG-STR} \left[\text{REST} \left[\text{REST}\ \langle\ \text{NP}[\mathit{acc}]\rangle\right]\right]\right]$	*poly-trans-wd*
to-trans-wd	$\left[\text{ARG-STR} \left[\text{REST} \left[\text{REST}\ \langle\text{PP}[\mathit{to}]\rangle\right]\right]\right]$	*poly-trans-wd*
trans-scomp-wd	$\left[\text{ARG-STR} \left[\text{REST} \left[\text{REST}\ \langle\text{XP}[\mathit{verbal}]\rangle\right]\right]\right]$	*poly-trans-wd*

Figure 31: Complement valence hierarchy diagram.



The part of speech hierarchy and the valence hierarchies classify words along three different **dimensions**

A given token of a word can possess properties from more than one of them, e.g. it can be both a verb and intransitive or take both an **NP** subject and an **NP** direct object.

Figure 32 shows the place of a mono-transitive verb such as *"like"* in terms of the different dimensions of the *word* sort. The labels for the different dimensions are placed in boxes to indicate that they are not themselves sorts and are not disjoint partitions of *word*.

The lowest subsort *np-predicator-mono-transitive-wd* inherits from all three dimensions, POS (Part of Speech), SUBJ-VAL (Subject Valence) and COMP-VAL (Complement Valence), a phenomenon known as **multiple inheritance**.

This allows us to further simplify the lexical entry for *"likes"*, to that shown below. The sort *np-predicator-mono-transitive-wd* is the meet of three sorts ($main\text{-}vb\text{-}wd \wedge np\text{-}predicator\text{-}wd \wedge mono\text{-}transitive\text{-}wd$).

$$\begin{bmatrix} \textit{np-prd-mono-tr-wd} & \\ \textsc{phon} & \langle \textit{likes} \rangle \\ \textsc{head} & \begin{bmatrix} \textsc{vform} & \textit{fin} \end{bmatrix} \end{bmatrix}$$

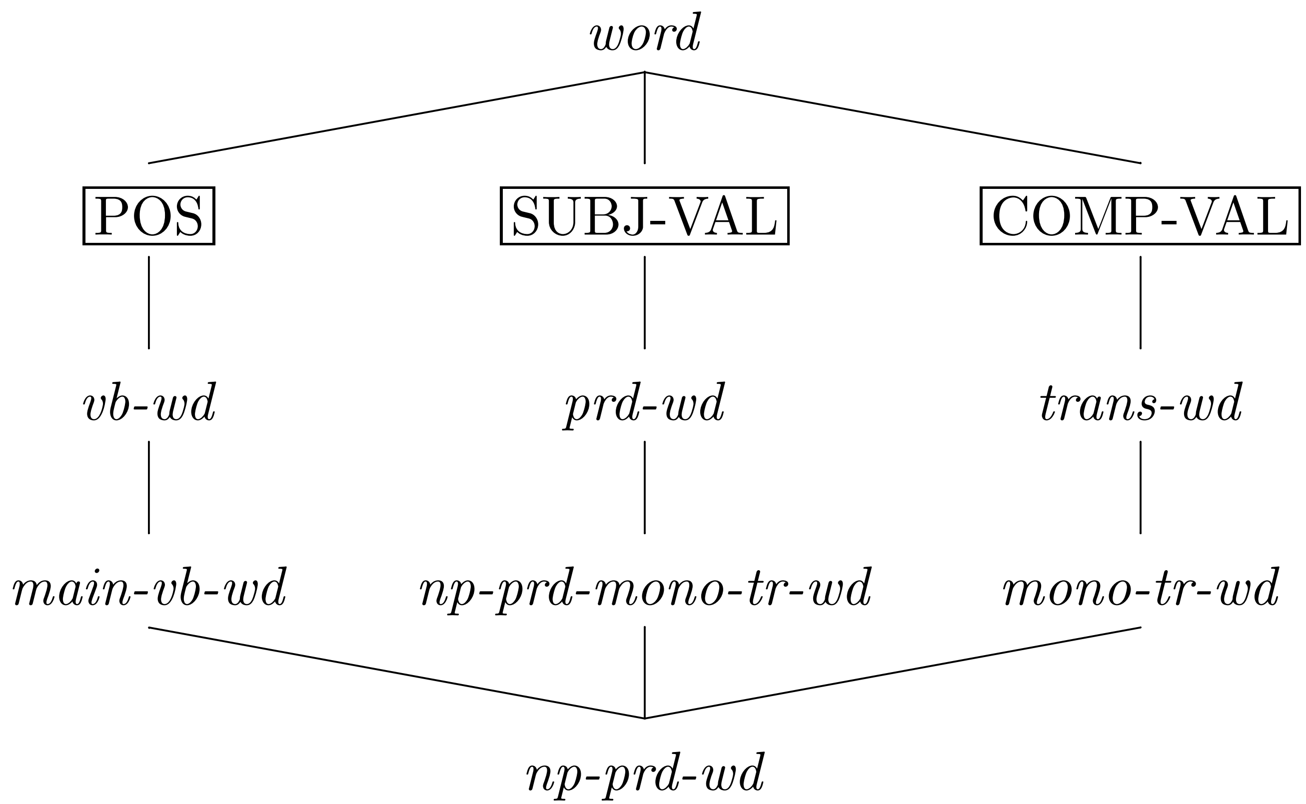


Figure 32: The place of *"like"* in the lexical hierarchy.

Ditransitive verbs such as *"give"* which take two **NP** complements, are assigned to the sort *np-predicator-di-transitive-wd*, defined as inheriting from *main-verb-wd*, *np-predicator-wd* and *di-transitive-wd*.

The lexical entry for *"gives"* is simply the following.

$$\begin{bmatrix} \textit{np-prd-di-tr-wd} & \\ \textsc{phon} & \langle \textit{gives} \rangle \\ \textsc{head} & \begin{bmatrix} \textsc{vform} & \textit{fin} \end{bmatrix} \end{bmatrix}$$

SORT	CONSTRAINT	ISA
inf-wd	$\begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{VFORM} & \textit{inf}\end{bmatrix}\end{bmatrix}$	*verb-wd*
fin-wd	$\begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{VFORM} & \textit{fin}\end{bmatrix}\end{bmatrix}$	*verb-wd*
bse-wd	$\begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{VFORM} & \textit{bse}\end{bmatrix}\end{bmatrix}$	*verb-wd*
prp-wd	$\begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{VFORM} & \textit{prp}\end{bmatrix}\end{bmatrix}$	*verb-wd*
psp-wd	$\begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{VFORM} & \textit{psp}\end{bmatrix}\end{bmatrix}$	*verb-wd*

Table 7: Lexical hierarch of VFORM values.

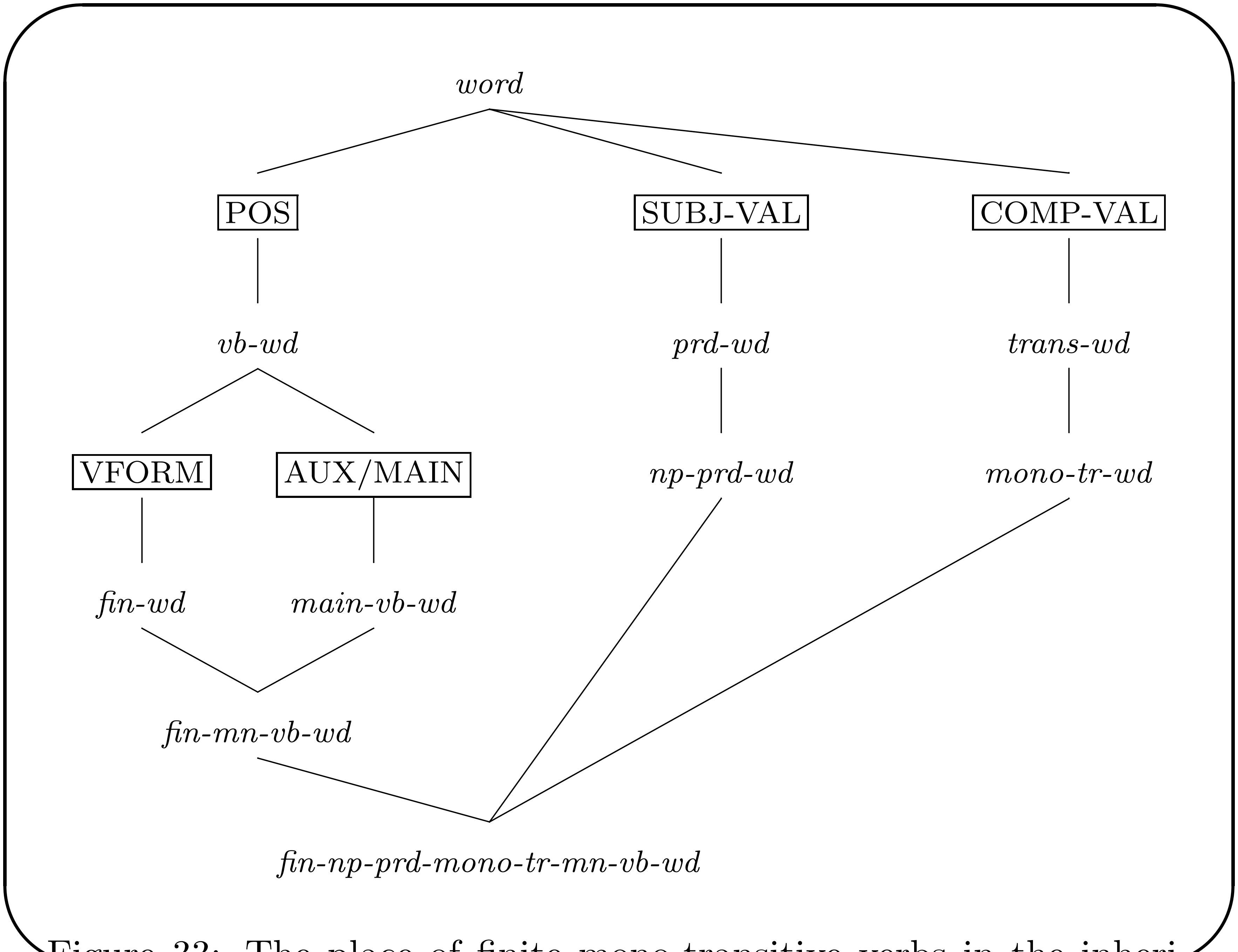


Figure 33: The place of finite mono-transitive verbs in the inheritance hierarchy

This allows us to provide the following lexical entry for a verb such as *"likes"*.

$$\begin{bmatrix} \textit{fin-np–mono-tr-vb-wd} & \\ \textsc{phon} & \langle \textit{likes} \rangle \end{bmatrix}$$

To conclude this section, we will present a classification of the auxiliaries, i.e. subsorts of *aux-verb-wd*. This is shown in table 8.

SORT	CONSTRAINT	ISA	INSTANCE
perf-cmp-aux-vb-wd	$\left[\text{COMPS} \quad \langle \text{VP}[\mathit{psp}]\rangle\right]$	*aux-vb-wd*	*“have”*
prog-cmp-aux-vb-wd	$\left[\text{COMPS} \quad \langle \text{VP}[\mathit{prp}]\rangle\right]$	*aux-vb-wd*	*“be”*
bse-cmp-aux-vb-wd	$\left[\text{COMPS} \quad \langle \text{VP}[\mathit{bse}]\rangle\right]$	*aux-vb-wd*	*“may”*
do-aux-vb-wd	$\left[\text{COMPS} \ \langle \text{VP}\begin{bmatrix}\text{VFORM} & \mathit{bse} \\ \text{AUX} & - \end{bmatrix}\rangle\right]$	*bse-cmp-aux-vb-wd*	*“do”*

Table 8: Auxiliary verb hierarchy

The constraints specify the VFORM values of the **VP** complements which these verbs select (discussed in section 3.5). We can define the lexical entry of, for example, the auxiliary *"has"* as a sort *has-wd* which inherits from the sorts *perf-comp-aux-vb-wd*, *fin-wd*, *prd-wd* and *ssr-wd*, giving simply the following.

$$\begin{bmatrix} \textit{has-wd} & \\ \textsc{phon} & \langle \textit{has} \rangle \\ \textsc{vform} & \textit{pres} \end{bmatrix}$$

This requires the feature structure corresponding to *"has"* to satisfy the following cascade of constraints. To be a *has-wd* it must be a *perf-comp-aux-vb-wd*. Therefore,

- It must be a *word* (table 4):

$$\begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{LEX} & + \\ \text{SUBJ} & \boxed{1}\, \langle \textit{synsem} \rangle \\ \text{SPR} & \boxed{2}\, \textit{list(synsem)} \\ \text{COMPS} & \boxed{3}\, \textit{list(synsem)} \\ \text{ARG-STR} & \boxed{1} \oplus \boxed{2} \oplus \boxed{3} \end{bmatrix} \end{bmatrix}$$

- It must be a *verb-wd* (table 4):

$$\begin{bmatrix} \textit{vb-wd} & \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{vform} \\ \text{AUX} & \textit{bool} \\ \text{INV} & \textit{bool} \end{bmatrix} \end{bmatrix} \\ \text{SPR} & \langle\ \rangle \end{bmatrix}$$

- It must be an *aux-verb-wd* (table 4):

$$\begin{bmatrix} \textit{aux-verb-wd} & \\ \text{CAT} & \begin{bmatrix} \text{AUX} & + \end{bmatrix} \end{bmatrix}$$

- It must be a *perf-aux-verb-wd* (table 4):

$$\begin{bmatrix}\textsc{comps} & \langle \mathrm{VP}[psp] \rangle\end{bmatrix}$$

In addition, it must unify with *fin-wd* which entails that it satisfy the following pair of constraints.

- It must be a *verb-wd* (table 7).
- It must be a *fin-wd* (table 7):

$$\begin{bmatrix} \textit{fin-wd} & \\ \textsc{head} & \begin{bmatrix} \textsc{vform} & \textit{fin} \end{bmatrix} \end{bmatrix}$$

It must also unify with *prd-wd* which requires that it satisfy the following constraint (table 5).

- $\begin{bmatrix} \textit{prd-wd} & \\ \textsc{subj} & \langle \textit{synsem} \rangle \end{bmatrix}$

It must unify with *ssr-wd* which entails that it satisfy in addition the following cascade of constraints.

- It must be an *intran-xcomp-wd* (table 6).

$$\begin{bmatrix} \textit{intran-xcomp-wd} & \\ \textsc{comps} & \langle \text{XP}[\textsc{subj}\ \langle \textit{synsem} \rangle] \rangle \end{bmatrix}$$

- It must be an *ssr-wd* (table 6).

$$\begin{bmatrix} \textit{ssr-wd} & \\ \textsc{subj} & \boxed{1} \\ \textsc{comps} & \begin{bmatrix} \textsc{subj} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

And, finally,

- it must satisfy the constraints stipulated in its lexical entry:

$$\begin{bmatrix} \text{PHON} & \langle \textit{has} \rangle \\ \text{VFORM} & \textit{pres} \end{bmatrix}$$

The unification of all of these constraints results in the description in figure 34.

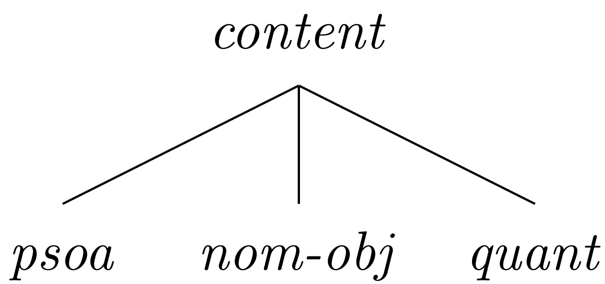
$$
\begin{bmatrix}
\textit{word} & \\
\text{PHON} & \langle \textit{has} \rangle \\
\text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{VFORM} & \textit{fin} \\ \text{AUX} & + \\ \text{INV} & \textit{bool} \end{bmatrix} \\
\text{LEX} & + \\
\text{SUBJ} & \boxed{1} \\
\text{SPR} & \boxed{2}\langle\ \rangle \\
\text{COMPS} & \boxed{3}\langle \text{VP}\begin{bmatrix}\text{SUBJ} & \boxed{1}\langle \textit{synsem}\rangle\end{bmatrix}\rangle \\
\text{ARG-STR} & \boxed{1}\oplus\boxed{2}\oplus\boxed{3}
\end{bmatrix}
\end{bmatrix}
$$

Figure 34: AVM for auxiliary *“has”*.

5 Semantics

$$\begin{bmatrix} \textit{sign} & \\ \textsc{synsem} & \begin{bmatrix} \textit{synsem} & \\ \textsc{local} & \begin{bmatrix} \textit{local} & \\ \textsc{cat} & \textit{category} \\ \textsc{content} & \textit{content} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

content forms the top of sortal hierarchy with subsorts *parameterised-state-of-affairs*, *nominal-object* and *quantifier*, as shown below.



These three sorts are used to define the semantics for different classes of syntactic objects.

Verbs and verbal projections have *psoa* CONTENT values,

nouns and nominal projections *nom-obj* values and

determiners *quantifier* values.

The sort *psoa* corresponds very roughly in FOL terms to a predicate whose argument positions are occupied by variables (the 'parameters' of the name). It has the following constraint.

$$\begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \textit{list(quantifier)} \\ \textsc{nucleus} & \textit{relation} \end{bmatrix}$$

The value of NUCLEUS is the sort *relation*. The idea is that in *psoa*s the quantificational information appears as the value of QUANTS and is segregated from the quantifier-free component of the semantics in NUCLEUS. Let us move rapidly to a concrete example by giving the CONTENT value for *"like"*.

$$\begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{like-rel} & \\ \textsc{liker} & \textit{index} \\ \textsc{liked} & \textit{index} \end{bmatrix} \end{bmatrix}$$

Relations form a sortal hierarchy, which permits a systematic structuring of lexical relations.

QUANTS has the empty list as value because this is an unquantified expression.

The CONTENT of **NPs** is of sort *nominal-object* and has the following attributes.

$$\begin{bmatrix} \textit{nom-obj} & \\ \textsc{index} & \textit{index} \\ \textsc{restriction} & \textit{set(psoa)} \end{bmatrix}$$

The sort *index* is further partitioned into subsorts *referential*, *there* and *it*.

The *referential* indices are used for contentful nouns and **PPs** in argument positions;

there and *it* for the non-referential 'dummy' **NPs** *"there"* and *"it"* in sentences such as *"There appears to be a unicorn in the garden"* or *"It is easy to see you don't like ice cream"*.

To be interpreted, an index needs to model-theoretically anchored to some appropriate real-world entity.

The sort *index* has the following constraint.

$$\begin{bmatrix} \textit{index} & \\ \text{PERSON} & \textit{person} \\ \text{NUMBER} & \textit{number} \\ \text{GENDER} & \textit{gender} \end{bmatrix}$$

The sign for a proper noun such as *"Toby"* will have the following CONTENT value, in which the value of the RESTRICTION attribute is empty,

$$\begin{bmatrix} \text{PHON} & \langle \textit{Toby} \rangle \\ \text{CONTENT} & \begin{bmatrix} \textit{nom-obj} & \\ \text{INDEX} & \begin{bmatrix} \textit{ref} & \\ \text{PERSON} & \textit{3} \\ \text{NUMBER} & \textit{sing} \\ \text{GENDER} & \textit{masc} \end{bmatrix} \\ \text{RESTR} & \{\ \} \end{bmatrix} \end{bmatrix}$$

A common noun, such as *"book"*, will look like the following.

$$
\begin{bmatrix}
\text{PHON} & \langle \textit{book} \rangle \\
\text{CONTENT} & \begin{bmatrix}
\textit{nom-obj} & \\
\text{INDEX} & \boxed{1} \begin{bmatrix} \textit{ref} & \\ \text{PERSON} & \mathit{3} \\ \text{NUMBER} & \textit{sing} \\ \text{GENDER} & \textit{neut} \end{bmatrix} \\
\text{RESTR} & \left\{ \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{book-rel} & \\ \text{INSTANCE} & \boxed{1} \end{bmatrix} \end{bmatrix} \right\}
\end{bmatrix}
\end{bmatrix}
$$

The RESTRICTION value for *"book"* corresponds to the FOL *book1(x)*.

5.1 The semantics of verbs.

Abbreviation	Simplified AVM
NP$_{\boxed{i}}$	$\left[\text{LOC} \left[\begin{array}{ll} \text{CAT} & \left[\begin{array}{ll} \text{HEAD} & \textit{noun} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \end{array}\right] \\ \text{CONTENT} \mid \text{INDEX} & \boxed{i} \end{array}\right]\right]$

Figure 35: Abbreviation for the **NP** SYNSEM value.

$$
\begin{bmatrix}
\textit{word} & \\
\text{PHON} & \langle \textit{likes} \rangle \\
\text{LOCAL} & \begin{bmatrix}
\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{SUBJ} & \langle \boxed{1}\,\text{NP}[\textit{nom}]_{\boxed{i}[\textit{3rd, sing}]} \rangle \\ \text{COMPS} & \langle \boxed{2}\,\text{NP}[\textit{acc}]_{\boxed{j}} \rangle \\ \text{ARG-STR} & \langle \boxed{1}, \boxed{2} \rangle \end{bmatrix} \\
\text{CONTENT} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCL} & \begin{bmatrix} \textit{like-rel} & \\ \text{LIKER} & \boxed{i} \\ \text{LIKED} & \boxed{j} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Figure 36: The syntax and semantics of *“likes”*.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \text{LAUGHS} \rangle \\ \text{SUBJ} & \langle \boxed{1}\,\text{NP}[\textit{nom}]_{\boxed{i}[\text{3RD, SING}]} \rangle \\ \text{ARG-STR} & \langle \boxed{1} \rangle \\ \text{CONT} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCL} & \begin{bmatrix} \textit{laugh-rel} & \\ \text{LAUGHER} & \boxed{i} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(a)

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \text{GIVES} \rangle \\ \text{SUBJ} & \langle \boxed{1}\,\text{NP}[\textit{nom}]_{\boxed{i}[\text{3RD, SING}]} \rangle \\ \text{COMPS} & \langle \boxed{2}\,\text{NP}[\textit{acc}]_{\boxed{j}},\ \boxed{3}\,\text{PP}[\textit{to}]_{\boxed{k}} \rangle \\ \text{ARG-STR} & \langle \boxed{1}, \boxed{2}, \boxed{3} \rangle \\ \text{CONT} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCL} & \begin{bmatrix} \textit{give-rel} & \\ \text{GIVER} & \boxed{i} \\ \text{GIVEN} & \boxed{k} \\ \text{GIFT} & \boxed{j} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(b)

Figure 37: Simplified AVMs for *“laughs”* and *“gives”*.

The Content Principle

$$hd\text{-}nexus\text{-}ph \quad \Longrightarrow \begin{bmatrix} \text{CONTENT} & \boxed{1} \\ \text{HD-DTR} & \begin{bmatrix} \text{CONTENT} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

This is a constraint on *head-nexus-phrase*, which subsumes all subsorts of *headed-phrase* except *head-adjunct-phrase*.

It will therefore be applicable to all the structures that we have discussed so far in this chapter.

We will briefly illustrate its effect with respect to two examples: (32) with normal constituent order and (33) its counterpart with a UDC in which the complement **NP** has been displaced to the front of the clause.

(32) *"Toby likes Andrew."*

(33) *"Andrew, Toby likes."*

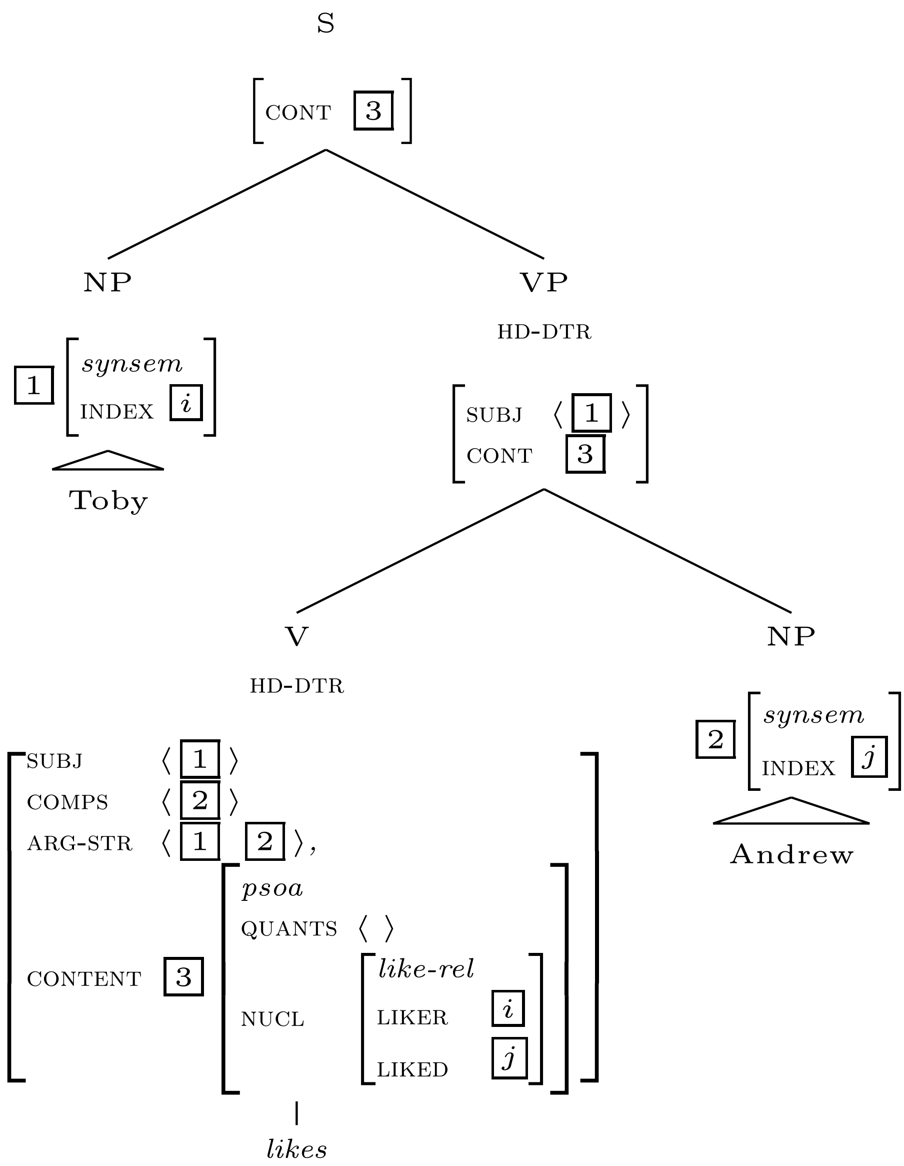


Figure 38: The CONTENT values of *"Toby likes Andrew"*.

The CONTENT value of the whole sentence is

$$\begin{bmatrix} \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{like-rel} & \\ \text{LIKER} & \boxed{i} \\ \text{LIKED} & \boxed{j} \end{bmatrix} \end{bmatrix}$$

where the tags $\boxed{i}$ and $\boxed{j}$ are keyed to the individuals denoted by the subject and object **NPs** *"Toby"* and *"Andrew"* respectively. This NUCLEUS value is identical to that of the head verb *"likes"* and is shared by each of the projections of the head daughter as a consequence of the Content Principle.

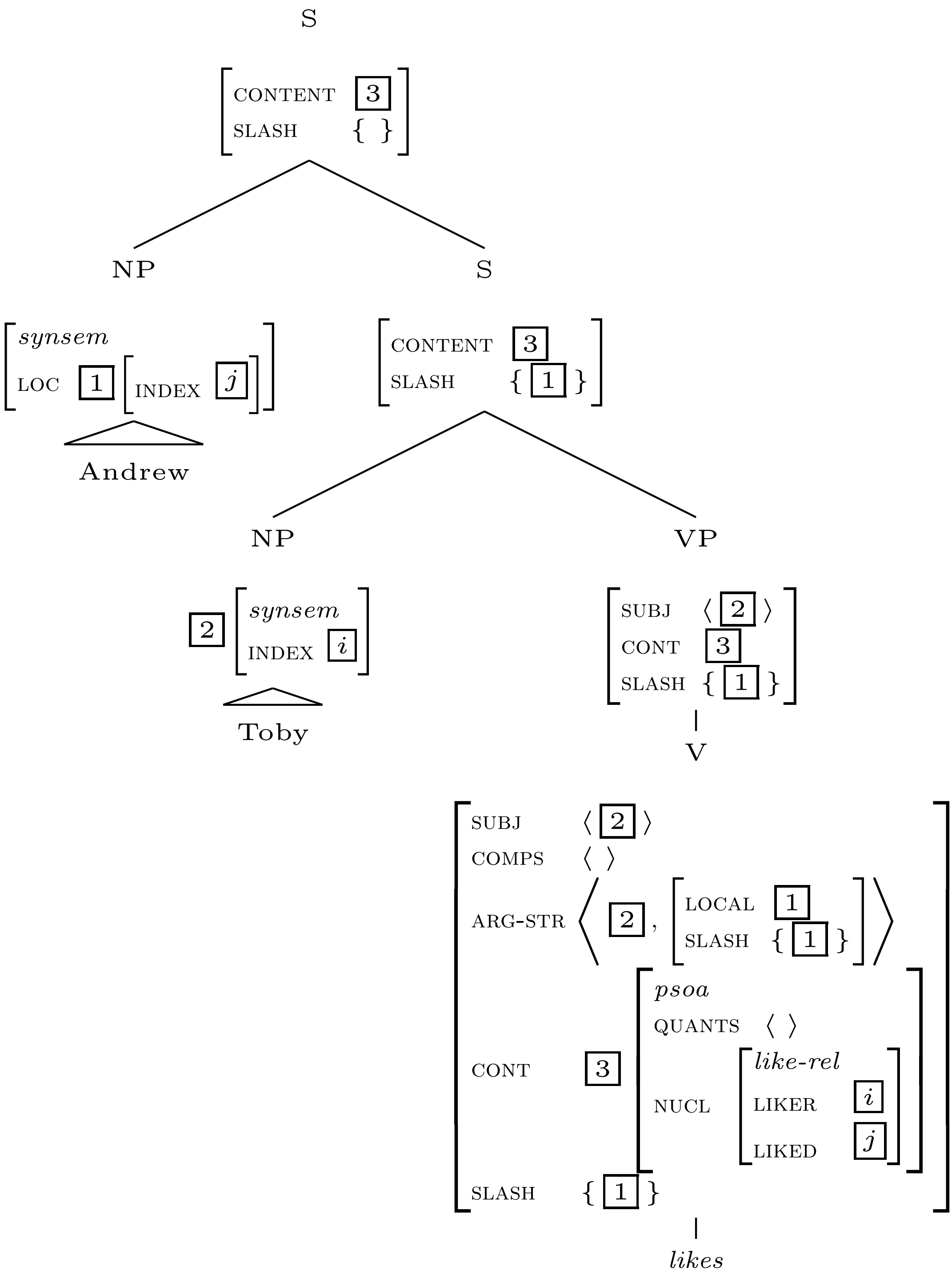


Figure 39: The CONTENT values of the UDC *"Andrew, Toby likes"*.

The second example (33), whose tree is given in figure 39, is particularly interesting from the point of view of its semantics, because, despite its radically different syntax, absolutely nothing more needs to be said about CONTENT values. The values of the roles LIKER and LIKED are supplied by the INDEX values of the members of the ARG-STR list of the head verb *"likes"*, in exactly the same way as for (32). The structure sharing of LOCAL values in UDCs ensures that this relationship between a head and its arguments is preserved in the UDC.

5.1.1 Context

In figure 39 we have lost information about the names of the individuals involved in the liking relationship. In FOL terms, we have a representation akin to $like1(x, y)$, with x and y anchored to two individuals in the Universe of Discourse.

The HPSG solution to this omission is to assume that meaning not only consists of CONTENT values, but also includes contextual information. With this information added, the structure of *sign*s looks like this:

$$
\left[\begin{array}{ll}
\textit{sign} & \\
\textsc{synsem} & \left[\begin{array}{ll}
\textsc{cat} & \textit{cat} \\
\textsc{content} & \textit{content} \\
\textsc{context} & \left[\begin{array}{ll}
\textsc{contextual-indices} & \left[\begin{array}{ll}
\textsc{speaker} & \textit{index} \\
\textsc{hearer} & \textit{index} \\
\ldots &
\end{array}\right] \\
\textsc{background} & \textit{set(relation)}
\end{array}\right]
\end{array}\right]
\end{array}\right]
$$

Adding BACKGROUND information to the lexical entry for a proper noun such as *"Toby"* gives the following:

$$\begin{bmatrix} \textsc{phon} & \langle \textit{Toby} \rangle \\ \textsc{synsem} & \begin{bmatrix} \textsc{content} & \begin{bmatrix} \textit{nom-obj} & & \\ \textsc{index} & \boxed{1} & \begin{bmatrix} \textit{ref} & \\ \textsc{person} & \textit{3} \\ \textsc{number} & \textit{sing} \\ \textsc{gender} & \textit{masc} \end{bmatrix} \\ \textsc{restr} & \{\ \} & \end{bmatrix} \\ \textsc{context} & \begin{bmatrix} \textsc{bkgrnd} & \left\{ \begin{bmatrix} \textit{name-rel} & \\ \textsc{bearer} & \boxed{1} \\ \textsc{name} & \textit{Toby} \end{bmatrix} \right\} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

The contribution of BACKGROUND values to the larger structures in which they occur is determined by the following constraint:

Principle of Contextual Consistency

> The CONTEXT|BACKGROUND value of a given phrase is the union of the CONTEXT|BACKGROUND values of the daughters.

CONTENT value for *"Toby likes Andrew"*

$$
\left[\begin{array}{ll}
\text{SS} & \left[\begin{array}{ll}
\text{CONT} & \boxed{2}\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{psoa}} \\
\text{QUANTS} & \langle\ \rangle \\
\text{NUCL} & \left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{like-rel}} \\
\text{LIKER} & \boxed{i} \\
\text{LIKED} & \boxed{j}
\end{array}\right] \\
\text{CXT} & \left[\begin{array}{ll}
\text{BKGRND} & \left\{\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{name-rel}} \\
\text{BEARER} & \boxed{i} \\
\text{NAME} & \textit{Toby}
\end{array}\right], \left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{name-rel}} \\
\text{BEARER} & \boxed{j} \\
\text{NAME} & \textit{Andrew}
\end{array}\right]\right\}
\end{array}\right]
\end{array}\right]
\end{array}\right]
\end{array}\right]
$$

5.2 Prepositional Phrases

In section 3.4 we discussed the syntax of those **PP**s that occur on the argument structure list of another head, as in examples like *"Toby gave a drink to Andrew"*.

From a semantic point of view, apart from indicating that Andrew is the recipient of the drink, the preposition *"to"* does not have any significant semantic content.

This can be accounted for if we assign such prepositions the following kind of feature structure.

$$\begin{bmatrix} \textsc{phon} & \langle \textit{to} \rangle \\ \textsc{comps} & \langle \text{NP}[\textsc{content}\ \boxed{1}] \rangle \\ \textsc{content} & \boxed{1} \end{bmatrix}$$

According to this, the CONTENT of the preposition is simply the CONTENT of its NP complement. Because the value of this CONTENT is of sort *nominal-object*, the Content Principle requires that any PP of which this preposition is the head daughter has an identical CONTENT value, and so the PP inherits an NP denotation.

6 Lexical Relations

Consider the following pair of sentences.

(34) *"Andrew gave Toby scotch"*

(35) *"Toby was given scotch by Andrew"*

There are obvious systematic syntactic and semantic relationships between such pairs.

- They have the same truth conditions
- The subject of (34) appears as the object of the preposition *"by"* in (35)
- The direct object of (34) appears as the subject in (35)
- The verb of (34) appears in a related form in (35) and is preceded by a form of the auxiliary verb *"be"*

Sentences like (34) are called **active** sentences and those like (35) are called **passive** sentences, and any descriptively adequate account of English grammmar should explicitly recognise the existence of such systematic correspondences. A long-standing way of doing this is to take one of the sentences as being more basic (typically the active one) and to map it onto the other. More recently, in highly lexicalised frameworks, such as HPSG, it is argued that the relationship can be captured in terms of a relationship between the active and passive forms of verbs (e.g. *"give"* and *"given"*).

Figure 40: Lexical entries for the active and passive forms of the verb *"give"*.

active	$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{give} \rangle \\ \textsc{head} & \left[\begin{array}{ll} \textsc{vform} & \textit{bse} \end{array}\right] \\ \textsc{arg-str} & \langle \boxed{1}\mathrm{NP}_{\boxed{i}},\ \boxed{2}\mathrm{NP}_{\boxed{j}},\ \boxed{3}\mathrm{PP}[\textit{to}]_{\boxed{k}} \rangle \\ \textsc{subj} & \langle \boxed{1} \rangle \\ \textsc{comps} & \langle \boxed{2},\ \boxed{3} \rangle \\ \textsc{cont} & \left[\begin{array}{ll} \textsc{quants} & \langle\ \rangle \\ \textsc{nucl} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{give-rel}} \\ \textsc{giver} & \boxed{i} \\ \textsc{gift} & \boxed{j} \\ \textsc{recipient} & \boxed{k} \end{array}\right] \end{array}\right] \end{array}\right]$

passive	$\begin{bmatrix} \text{PHON} & \langle \textit{given} \rangle \\ \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{pas} \end{bmatrix} \\ \text{ARG-STR} & \langle \boxed{1}\text{NP}_{\boxed{j}}, \ \boxed{2}\text{PP}[\textit{to}]_{\boxed{k}}, \ \boxed{3}\text{PP}[\textit{by}]_{\boxed{i}} \rangle \\ \text{SUBJ} & \langle \boxed{1} \rangle \\ \text{COMPS} & \langle \boxed{2}, \boxed{3} \rangle \\ \text{CONT} & \begin{bmatrix} \text{QUANTS} & \langle \ \rangle \\ \text{NUCL} & \begin{bmatrix} \textit{give-rel} & \\ \text{GIVER} & \boxed{i} \\ \text{GIFT} & \boxed{j} \\ \text{RECIPIENT} & \boxed{k} \end{bmatrix} \end{bmatrix} \end{bmatrix}$

If we look at AVMs for the active and passive forms of the verb *“give”*, shown in figure 40, it is easy to see the general nature of the relationship. From a comparison of the two AVMs, it is clear that, although they differ in a number of respects, quite a lot of information is also shared between the two forms.

There are a number of different ways in HPSG of treating this kind of relationship. The most traditional approach is is to map one form onto the other, preserving the similarities and that is what we will sketch out here. This kind of mapping is called a **lexical rule**.

Lexical rules are statements of the form “if a word of form A (the ‘input’ to the rule) exists in the lexicon, then a word of form B (the ‘output’ of the rule) is also in the lexicon”, where B is the result of applying some function to A.

For example, a lexical rule for passive verbs might look like figure 41.

$$\begin{bmatrix} \textit{trans-mn-vb-wd} & \\ \text{PHON} & \langle \boxed{1} \rangle \\ \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{bse} \end{bmatrix} \\ \text{ARG-STR} & \langle \boxed{2}_{\boxed{i}}, \boxed{3} \rangle \oplus \boxed{4} \\ \text{CONT} & \boxed{5} \end{bmatrix} \Longrightarrow \begin{bmatrix} \textit{pass-mn-vb-wd} & \\ \text{PHON} & \langle f_{\boxed{pass}}(\boxed{1}) \rangle \\ \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{pas} \end{bmatrix} \\ \text{ARG-STR} & \langle \boxed{3} \rangle \oplus \boxed{4} \oplus (\langle \text{PP}[\textit{by}]_{\boxed{i}} \rangle) \\ \text{CONT} & \boxed{5} \end{bmatrix}$$

Figure 41: Passive lexical rule.

The derived lexical entry for passive verbs, together with other constraints of the grammar of English, will give us passive verb phrases containing passive verbs and there complements, but we also need some way of allowing passive **VP**s to form sentences. Passive **VP**s can appear in a range of constructions.

(36) *"Duncan was killed by Macbeth"*

(37) *"Painted by Leonardo, the Mona Lisa is one of the most famous paintings in the world"*

(38) *"I'm looking for a book written by a linguist"*

Here will limit ourselves to sentential passives like (36).

These are introduced by the auxiliary BE. We already have a lexical entry for BE (figure 20 on 66), but that entry specifies that its complement must be a verb phrase bearing the specification [VFORM *prp*]. It would, of course, be possibly to simply add another lexical entry, identical to figure 20, except for the specification [VFORM *prp*], but a further look at BE suggests that this would not be a good move.

BE is not restricted to taking the two sorts of complements (**VP**[VFORM *prp*] and **VP**[VFORM *pas*]) that we have encountered so far.

(39) *"Macbeth is in Glamis."* (**PP**)

(40) *"Duncan was (the) king of Scotland."* (**NP**)

(41) *"Toby is fond of scotch."* (**AP**)

To accommodate these additional examples, we would need a proliferation of BEs.

Items that can occur as complements of BE are traditionally known as 'predicative complements', which suggests that we could capture their distribution in terms of a boolean-valued head feature PRED.

All the kinds of constituents that can appears as complements to BE are [PRED +], those that cannot are [PRED -]. Passive and progressive verbs are [PRED +], other forms of verbs (finite, past participle) are [PRED -].

The lexical entry for BE is modified that that in figure 42

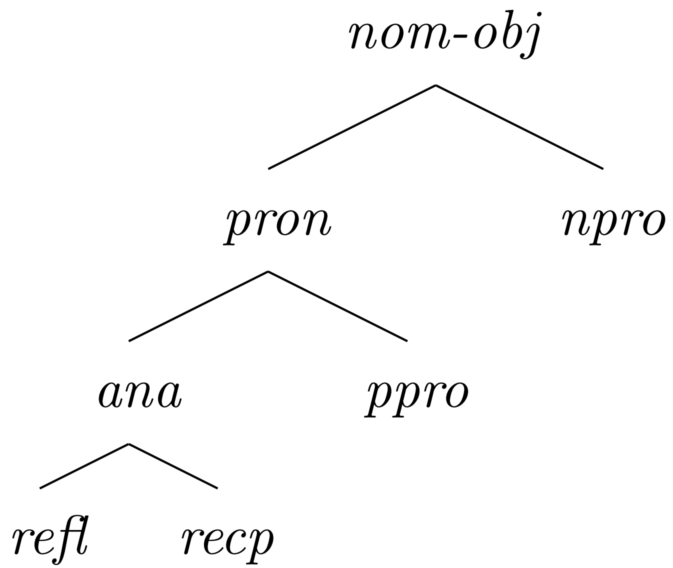
$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{AUX} & + \end{bmatrix} \\ \text{SUBJ} & \boxed{6} \\ \text{COMPS} & \left\langle \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{PRED} & + \end{bmatrix} \\ \text{SUBJ} & \boxed{6} \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Figure 42: Revised lexical entry for the auxiliary verb *"be"*.

7 Binding Theory

(42)
$$\begin{bmatrix} \textit{local} & \\ \text{CAT} & \textit{category} \\ \text{CONTENT} & \begin{bmatrix} \textit{nom-obj} & \\ \text{INDEX} & \begin{bmatrix} \textit{index} & \\ \text{PER} & \textit{person} \\ \text{NUM} & \textit{number} \\ \text{GEND} & \textit{gender} \end{bmatrix} \\ \text{RESTRICTION} & \textit{set(psoa)} \end{bmatrix} \end{bmatrix}$$

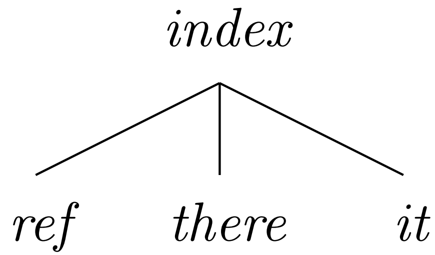
(43) Sortal hierarchy of nominal-objects



(44)

pron	pronoun	
ana	anaphor	
refl	reflexive pronoun	herself etc.
recp	reciprocal pronoun	each other
ppro	personal pronoun	she, he
npro	nonpronominal	Kim, Sandy, the book

(45) Sortal hierarchy of *index* objects



(46) Some nominal objects

herself

$$\begin{bmatrix} \textit{refl} & \\ \textsc{index} & \begin{bmatrix} \textit{ref} & \\ \textsc{per} & \mathit{3} \\ \textsc{num} & \textit{sing} \\ \textsc{gend} & \textit{fem} \end{bmatrix} \\ \textsc{restriction} & \{\} \end{bmatrix}$$

they

$$\begin{bmatrix} \textit{ppro} & \\ \textsc{index} & \begin{bmatrix} \textit{ref} & \\ \textsc{per} & \mathit{3} \\ \textsc{num} & \textit{plur} \end{bmatrix} \\ \textsc{restriction} & \{\} \end{bmatrix}$$

there

$$\begin{bmatrix} \textit{ppro} & \\ \text{INDEX} & \begin{bmatrix} \textit{there} & \\ \text{PER} & \mathit{3} \end{bmatrix} \\ \text{RESTRICTION} & \{\} \end{bmatrix}$$

it

$$\begin{bmatrix} \textit{ppro} & \\ \text{INDEX} & \begin{bmatrix} \textit{it} & \\ \text{PER} & \mathit{3} \\ \text{NUM} & \textit{sing} \end{bmatrix} \\ \text{RESTRICTION} & \{\} \end{bmatrix}$$

(47) Argument structure

$$\begin{bmatrix} \textit{cat} & \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{head} \\ \text{SUBJ} & \boxed{1}\,\textit{list(synsem)} \\ \text{COMPS} & \boxed{2}\,\textit{list(synsem)} \\ \text{ARG-STR} & \boxed{1} \oplus^{a} \boxed{2} \end{bmatrix} \end{bmatrix}$$

[a] $\alpha \otimes \beta = \text{append}(\alpha, \beta)$

(48) <u>Obliqueness</u>

One *synsem* object is more oblique than another provided it appears to the right of the other on the ARG-STR list of a word.

(49) <u>O-command</u>

One referential *synsem* locally o-commands another provided that the second is more oblique than the first.

One referential *synsem* α o-commands another β provided that α locally o-commands a third *synsem* γ which dominates β.

(50) <u>O-binding</u>

One referential *synsem* o-binds another provided that it o-commands and is coindexed with the other. If an item is not o-bound, it is *o-free*.

(51) Binding theory

a. Principle A: A locally o-commanded anaphor must be locally o-bound

b. Principle B: A personal pronoun must be locally o-free

c. Principle C: A non-pronoun must be o-free

(52) a. Sandy$_i$ likes himself$_i$

b. $\left[\text{ARG-STR} \quad \langle \text{ NP} : \mathit{npro}_{\boxed{i}} \text{ , NP} : \mathit{refl}_{\boxed{i}} \rangle\right]$

(53) a. *Sandy$_i$ likes him$_i$

b. $\left[\text{ARG-STR} \quad \langle \text{ NP} : \mathit{npro}_{\boxed{i}} \text{ , NP} : \mathit{ppro}_{\boxed{i}} \rangle\right]$

(54) a. *He$_i$ likes Sandy$_i$

b. $\left[\text{ARG-STR} \quad \langle \text{ NP} : \mathit{ppro}_{\boxed{i}} \text{ , NP} : \mathit{npro}_{\boxed{i}} \rangle\right]$

(55) a. *Sandy$_i$ says that Mary $_j$ likes himself$_i$

b. Argument structure of *likes*:

$\left[\text{ARG-STR} \quad \langle \text{ NP} : \mathit{npro}_{\boxed{j}} \text{ , NP} : \mathit{refl}_{\boxed{i}} \rangle\right]$

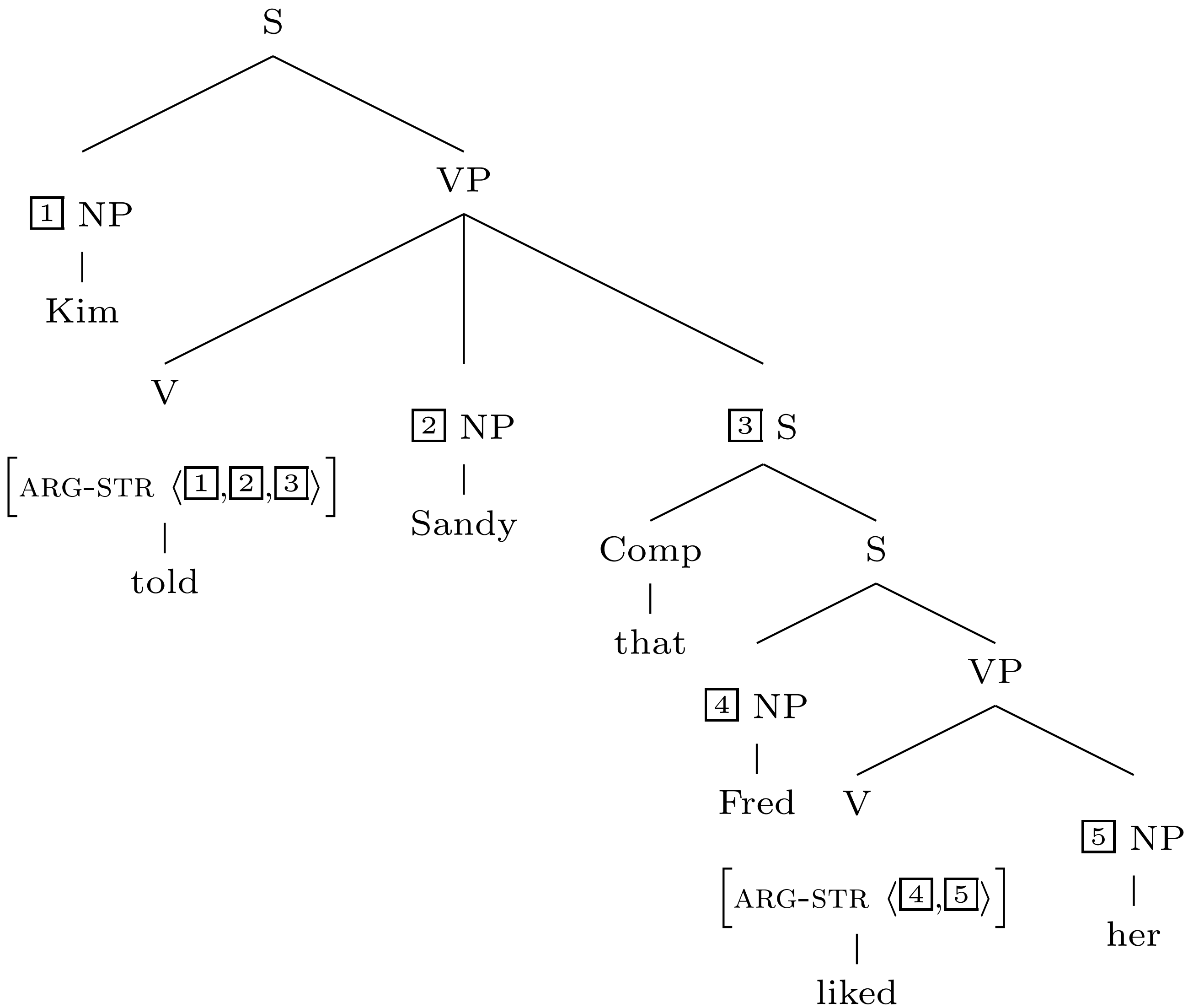
(56) a. *Himself$_i$ likes Sandy$_i$

b. Argument structure of *likes*:

$\left[\textsc{arg-str} \quad \langle \text{NP}[\text{CASE } acc\ ], \text{ NP } \rangle\right]$

(57) a. $\mathrm{Kim_i}$ told $\mathrm{Sandy_j}$ that $\mathrm{Fred_k}$ liked $\mathrm{her_{i/j}}$

b.



(58) a. John$_i$ was going to get even with Mary. That picture of himself$_i$ in the paper would really annoy her, as would the other stunts he had planned.

b. *Mary was quite taken aback by the publicity John$_i$ was receiving. That picture of himself$_i$ in the paper had really annoyed her, and there was not much she could do about it.

c. $\left[\text{ARG-STR} \quad \langle \text{NP}_{\boxed{i}} \rangle\right]$

d. The reflexive takes as its antecedent an NP whose referent is the individual whose viewpoint or perspective is somehow being reflected in a given text

(59) a. The picture of himself$_i$ in Newsweek bothered John$_i$.

b. *The picture of himself$_i$ in Newsweek bothered John$_i$'s father.

c. The bearer of the experiencer role (the direct object of *bother* is the individual whose viewpoint is being reflected

d. The picture of himself$_i$ in Newsweek made John$_i$'s day.

8 Control and raising

8.1 Introduction – semantics

(60) a. They try to run

b. $$\begin{bmatrix} \textit{try-rel} & \\ \text{TRYER} & \boxed{7} \\ \text{SOA-ARG} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{run-rel} & \\ \text{RUNNER} & \boxed{7}\ \textit{ref} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

c. They tend to run

d. $$\begin{bmatrix} \textit{tend-rel} & \\ \textsc{soa-arg} & \begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{run-rel} & \\ \textsc{runner} & \boxed{7}\ \textit{ref} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

8.2 Syntax

(61) try

$$\begin{bmatrix} \textsc{arg-st} & \left\langle \text{NP}_{\boxed{1}}, \text{VP}[\textit{inf}, \text{SUBJ } \langle \text{NP}_{\boxed{1}} \rangle] : \boxed{2} \right\rangle \\ \textsc{content} & \begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{try-rel} & \\ \textsc{tryer} & \boxed{1}\,\textit{ref} \\ \textsc{soa-arg} & \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(62) tend

$$\begin{bmatrix} \textsc{arg-st} & \left\langle \boxed{1}, \text{VP}[\textit{inf}, \text{SUBJ} \langle \boxed{1} \rangle] : \boxed{2} \right\rangle \\ \textsc{content} & \begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{tend-rel} & \\ \textsc{soa-arg} & \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

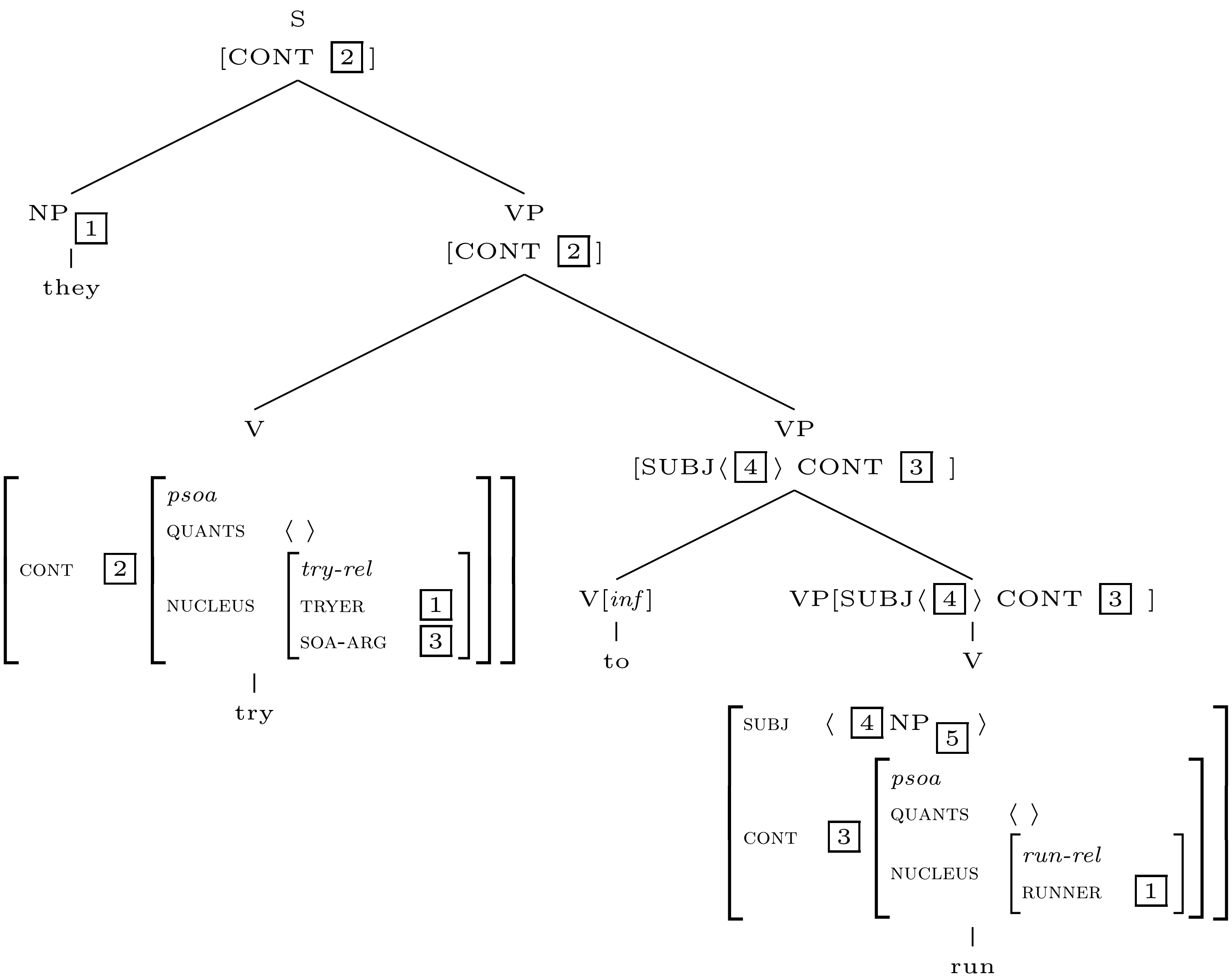
(63) persuade

$$\begin{bmatrix} \textsc{arg-st} & \left\langle \mathrm{NP}_{\boxed{1}},\ \mathrm{NP}_{\boxed{2}},\ \mathrm{VP}[\mathit{inf},\ \mathrm{SUBJ}\ \langle \mathrm{NP}_{\boxed{2}} \rangle] : \boxed{3} \right\rangle \\ \textsc{content} & \begin{bmatrix} \mathit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \mathit{persuade\text{-}rel} & \\ \textsc{persuader} & \boxed{1}\ \mathit{ref} \\ \textsc{persuadee} & \boxed{2}\ \mathit{ref} \\ \textsc{soa-arg} & \boxed{3} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

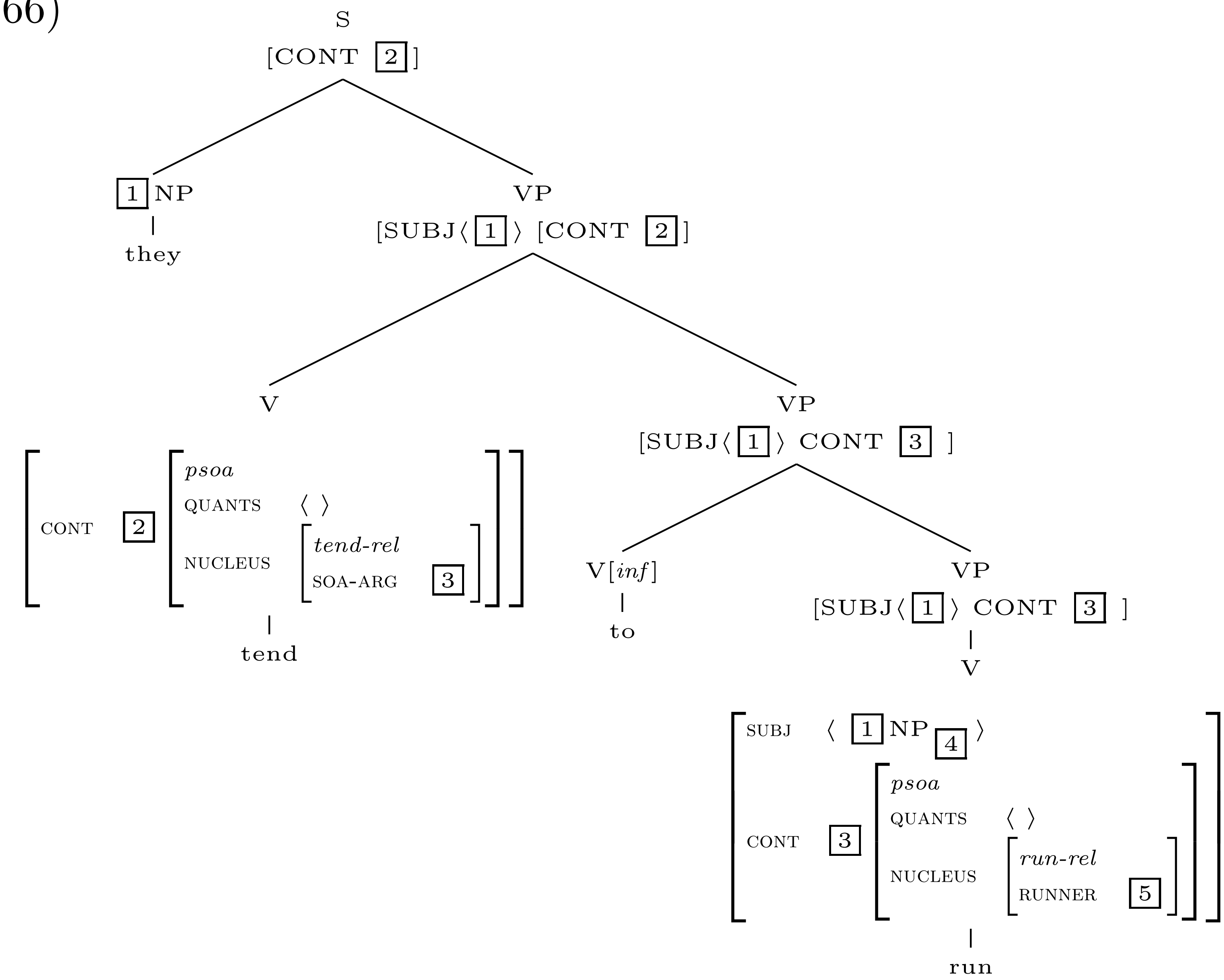
(64) believe

$$\begin{bmatrix} \text{ARG-ST} & \left\langle \boxed{1}\text{NP}_{\boxed{2}},\ \boxed{3},\ \text{VP}[\textit{inf},\ \text{SUBJ}\ \langle \boxed{3} \rangle] : \boxed{4} \right\rangle \\ \text{CONTENT} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{believe-rel} & \\ \text{BELIEVER} & \boxed{2} \\ \text{SOA-ARG} & \boxed{4} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(65)


S
[CONT 2]
NP 1
they
VP
[CONT 2]
V
CONT 2 psoa QUANTS ⟨ ⟩ NUCLEUS try-rel TRYER 1 SOA-ARG 3
try
VP
[SUBJ⟨ 4 ⟩ CONT 3]
V[inf]
to
VP[SUBJ⟨ 4 ⟩ CONT 3]
V
SUBJ ⟨ 4 NP 5 ⟩ CONT 3 psoa QUANTS ⟨ ⟩ NUCLEUS run-rel RUNNER 1
run

(66)


S
[CONT 2]
1 NP
they
VP
[SUBJ⟨1⟩ [CONT 2]]
V
CONT 2 psoa
QUANTS ⟨ ⟩
NUCLEUS tend-rel
SOA-ARG 3
tend
VP
[SUBJ⟨1⟩ CONT 3]
V[inf]
to
VP
[SUBJ⟨1⟩ CONT 3]
V
SUBJ ⟨ 1 NP 4 ⟩
CONT 3 psoa
QUANTS ⟨ ⟩
NUCLEUS run-rel
RUNNER 5
run

(67) a. try to run

b.

$$
\begin{bmatrix}
\textsc{cont} & \begin{bmatrix}
\textit{psoa} & \\
\textsc{quants} & \langle\ \rangle \\
\textsc{nucleus} & \begin{bmatrix}
\textit{try-rel} & \\
\textsc{tryer} & \boxed{1} \\
\textsc{soa-arg} & \begin{bmatrix}
\textit{psoa} & \\
\textsc{quants} & \langle\ \rangle \\
\textsc{nucleus} & \begin{bmatrix}
\textit{run-rel} & \\
\textsc{runner} & \boxed{1}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

(68) a. tend to run

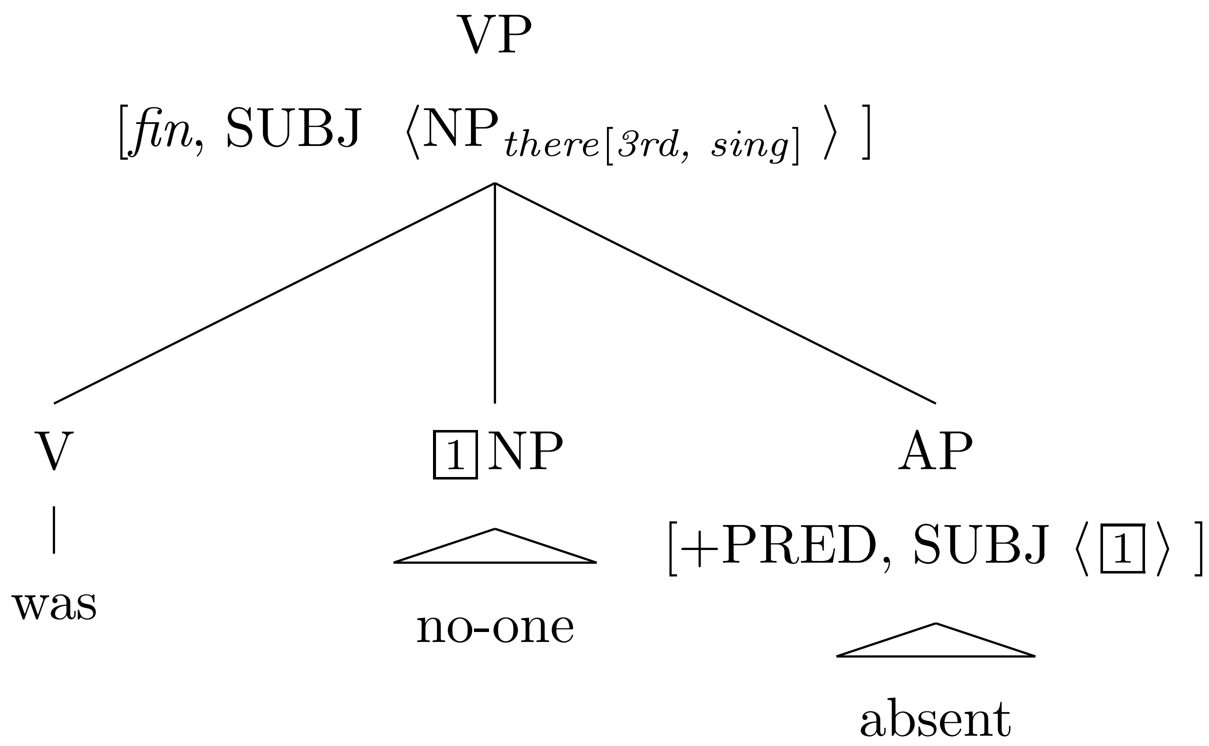
b.

$$\begin{bmatrix} \text{CONT} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{tend-rel} & \\ \text{SOA-ARG} & \begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle\ \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{run-rel} & \\ \text{RUNNER} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

8.3 Expletives

(69) be

$$\begin{bmatrix} \textsc{cat} & \begin{bmatrix} \textsc{head} & verb[\ +\text{AUX}] \\ \textsc{arg-st} & \langle \text{NP}_{there[\text{NUM}\ \boxed{1}]}, \boxed{2}\,\text{NP}_{[\text{NUM}\ \boxed{1}]}, \text{XP}[+\text{PRED}, \text{SUBJ}\ \langle \boxed{2} \rangle]{:}\boxed{3} \rangle \end{bmatrix} \\ \textsc{cont} & \boxed{3} \end{bmatrix}$$



(70) bother: that Sandy snores bothers Kim

$$\begin{bmatrix} \textsc{arg-st} & \langle \text{CP}[\textit{fin}], \text{NP}_{\boxed{1}\,ref} \rangle \\ \textsc{cont} & \begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{bother-rel} & \\ \textsc{bothered} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(71) bother: it bothers Kim that Sandy snores

$$\begin{bmatrix} \textsc{arg-st} & \langle \text{NP}_{it}, \text{CP}[\textit{fin}], \text{NP}_{\boxed{1}\,ref} \rangle \\ \textsc{cont} & \begin{bmatrix} \textit{psoa} & \\ \textsc{quants} & \langle\ \rangle \\ \textsc{nucleus} & \begin{bmatrix} \textit{bother-rel} & \\ \textsc{bothered} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(72) Lexical rule

$$\left[\text{ARG-ST} \quad \langle \text{CP}[\textit{fin}], \text{NP}_{\boxed{1}\,ref} \rangle \right] \Longrightarrow \left[\text{ARG-ST} \quad \langle \text{NP}_{it}, \text{CP}[\textit{fin}], \text{NP}_{\boxed{1}\,ref} \rangle \right]$$

9 Unbounded dependency constructions

(73) *“Ice cream, I like.”*

Unbounded dependency constructions (UDCs) have the following characteristics.

- there is a dependency between the displaced constituent, the ‘filler,’ and its ‘original’ position, the ‘gap’ – if one of them is filled, the other must be empty
- the distance which can intervene between the filler and the gap is potentially unbounded, subject to performance considerations – *“Ice cream, he said that she said that he said that she said . . . I like.”*

UDCs cover a range of more specific constructions, including **topicalisation** (42), ***wh*-questions** (43) and **relative clauses** (44), **cleft sentences** (45) and **pseudo-clefts** (46), among others.

(74) *"Which ice cream do you like?"*

(75) *"The ice cream which I like is very expensive."*

(76) *"It is Portia who I like."*

(77) *"What I like is ice-cream."*

UDCs are handled in HPSG by the SYNSEM||NONLOCAL attribute. This takes as its value a feature structure of sort *nonlocal* which is appropriate for the features SLASH, REL and QUE, which all take sets of various sorts as values, as shown in figure 43.

$$\left[\begin{array}{ll} \text{SYNSEM} & \left[\begin{array}{ll} \textit{synsem} & \\ \text{NONLOCAL} & \left[\begin{array}{ll} \textit{nonlocal} & \\ \text{SLASH} & \textit{set(local)} \\ \text{REL} & \textit{set(ref-index)} \\ \text{QUE} & \textit{set(quantifiers)} \end{array}\right] \end{array}\right] \end{array}\right]$$

Figure 43: NONLOCAL values.

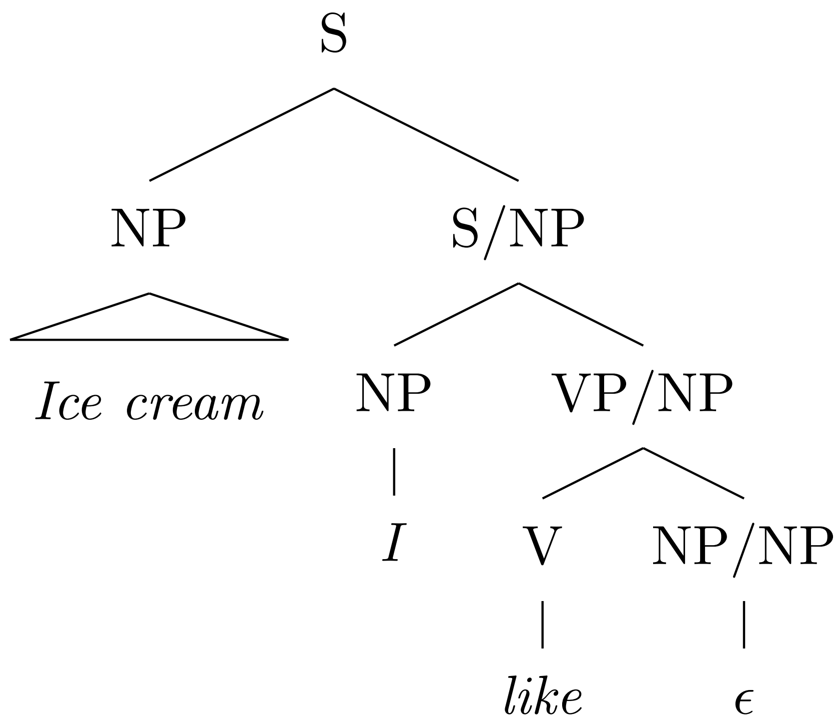


Figure 44: *"Ice cream, I like."*

UDCs can be decomposed into three components:

the top, where the unbounded dependency is introduced,

the bottom, where it is resolved, and

the middle, where the dependency passes through the intervening structure.

In Phrase Structure grammar terms, for the top we require a rule of roughly the following kind.

$$\mathsf{S} \quad \rightarrow \quad \mathsf{XP} \quad \mathsf{S/XP}$$

The intended interpretation of this rule is that a sentence may consist of some phrase XP, followed by a sentence which contains a gap of the same type (XP).

For the bottom, we require a lexical entry of the following kind,

$$\mathbf{XP/XP} \quad \longrightarrow \quad \epsilon$$

which states that the ‘empty category’ **XP/XP** has no phonetic realisation.

For the middle, we require some general principle which determines how the slash value is shared between mother and daughters.

In translating these informal ideas into HPSG, we will start with the top of the construction, which is defined as a phrase of sort *head-filler-ph* (cf. figure 5 on page 11.), with **XP** being the filler and **S/XP** being the head. The sort *head-filler-ph* has the following constraints.

Head Filler Phrase

$$
\textit{hd-filler-ph} \implies \begin{bmatrix} \text{NONLOC} & \begin{bmatrix} \text{SLASH} & \{\ \} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{LEX} & - \\ \text{SLASH} & \{\boxed{1}\} \end{bmatrix} \\ \text{NON-HD-DTR} & \left\langle \begin{bmatrix} \text{LOC} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix}
$$

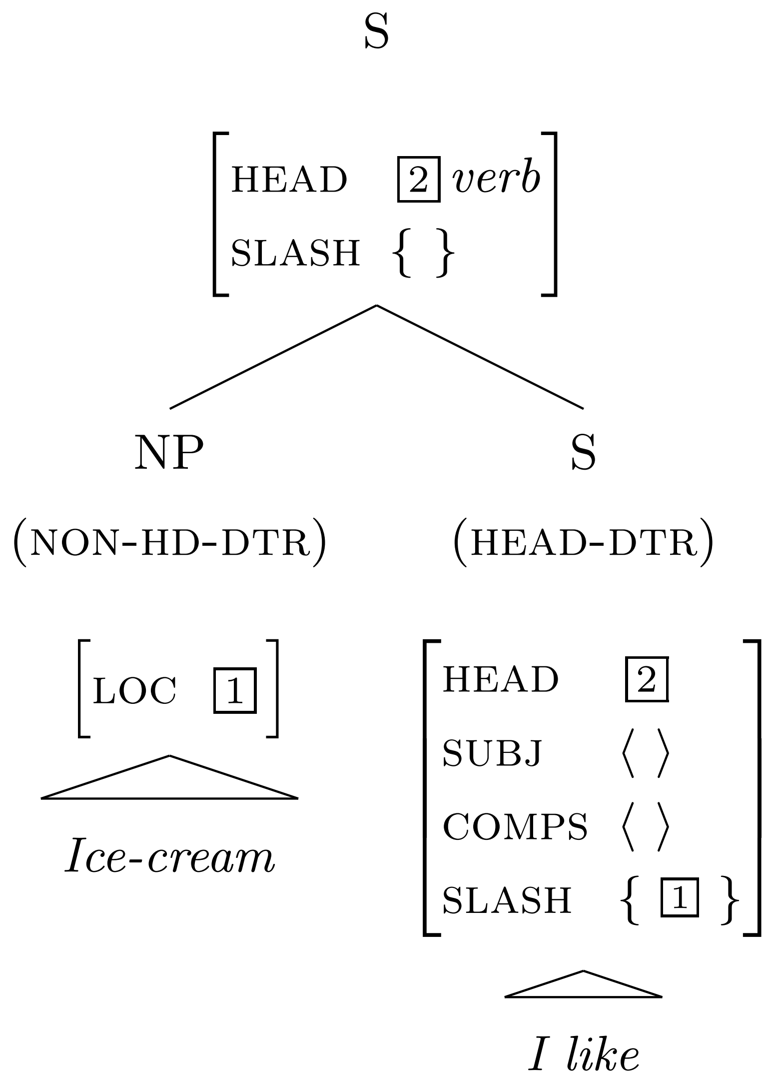


Figure 45: The top of an unbounded **NP** dependency.

For the bottom of a UDC we have the following lexical entry for an 'empty category' – also called a **trace**.

The Lexical entry for trace

$$\begin{bmatrix} \textit{sign} & \\ \text{PHONOLOGY} & \langle\ \rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{1} \\ \text{NONLOCAL} & \begin{bmatrix} \text{SLASH} & \{\boxed{1}\} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Here the value of the attribute PHONOLOGY is the empty list and the sign's LOCAL value is shared with the only member of the NONLOCAL||SLASH value. (The counterpart of **XP/XP**).

Finally, we provide a general constraint on *head-valence-ph* that handles the middle of a UDC.

Slash Inheritance Principle

> In a object of sort *head-valence-ph*, the value of SLASH is the set union of the SLASH values of the daughters.

In addition, we need now to specify that all lexical entries with the exception of the empty category above contain [NONLOCAL$\|$SLASH $\{\}$].

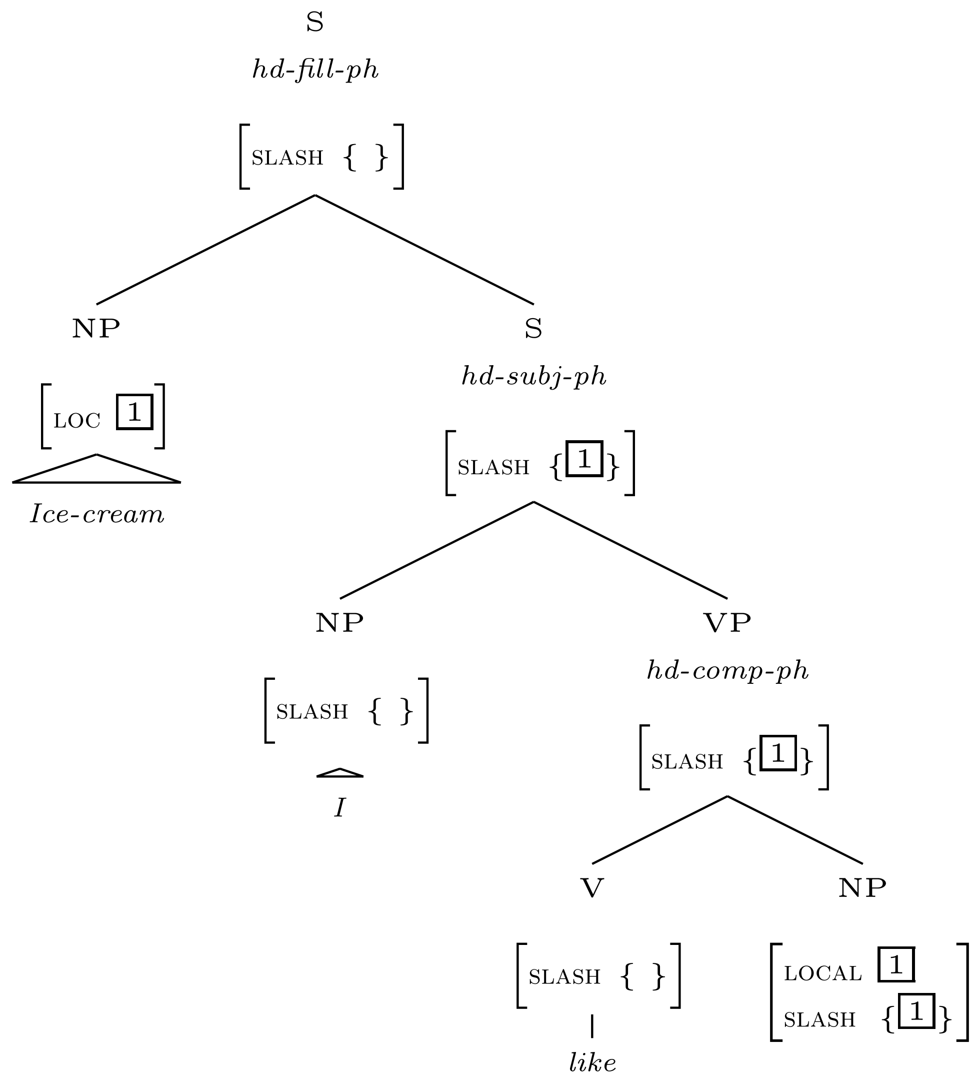


Figure 46: HPSG analysis of *“Ice cream, I like”*.

The coindexing of the LOCAL values of the filler and the gap ensures that they have the same syntactic category, in this case **NP**.

Note that CASE is also a part of LOCAL, so that the case specification of the filler and gap will be identical, guaranteeing that only (i) is defined as well-formed.

(i) *"Me, he likes."*

(ii) * *"I, he likes."*

A more recent alternative treatment of unbounded dependencies in HPSG proposes the abandonment of the empty category approach to unbounded dependencies in favour of a lexical one.

This alternative exploits the strongly lexicalist nature of HPSG.

Every lexical sign already encodes, via its valence attributes, the syntactic arguments with which it combines to form phrases. It is not necessary, therefore, to actually build phrases in order to specify that one or more arguments may be missing. This can be accomplished by modifying the information contained in the lexical entry itself.

The lexical version of UDCs requires a number of modifications to our earlier account. The first is that we modify the constraints associated with the sort *word* to include the following.

The Slash Amalgamation Constraint

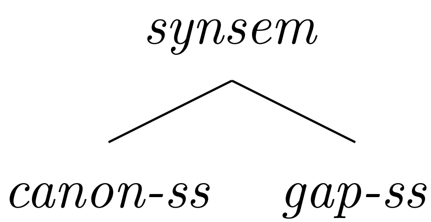
$$\textit{word} \Longrightarrow \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{ARG-STR} & \left\langle \begin{bmatrix}\text{SLASH } \boxed{1}\end{bmatrix}, \ldots, \begin{bmatrix}\text{SLASH } \boxed{n}\end{bmatrix} \right\rangle \\ \text{BIND} & \boxed{2} \end{bmatrix} \\ \text{NONLOC} & \begin{bmatrix} \text{SLASH} & (\boxed{1} \uplus \ldots \uplus^{a} \boxed{n}) - \boxed{2} \end{bmatrix} \end{bmatrix}$$

$\uplus$ denotes the **disjoint union** of two sets:
$A \uplus B \equiv A \cup B \wedge (A \cap B = \emptyset)$. If, for example, $A \uplus B = \{a, b, c\}$, then A and B can have the following values:

$\{\}$	$\{a, b, c\}$
$\{a\}$	$\{b, c\}$
$\{a, b\}$	$\{c\}$
$\{a, b, c\}$	$\{\}$

In contrast to normal set union, what is not possible is
$A = \{a, b\} \wedge B = \{b, c\}$.

The second modification is to partition the sort *synsem* into two subsorts, called *canonical-synsem* and *gap-synsem*.



The sort *canonical-synsem* is just the set of SYNSEM values that we have been using so far. The sort *gap-synsem* is defined as follows.

$$\begin{bmatrix} \textit{gap-synsem} & \\ \text{LOCAL} & \boxed{1} \\ \text{NONLOCAL} & \begin{bmatrix} \text{SLASH} & \{\boxed{1}\} \end{bmatrix} \end{bmatrix}$$

In contrast to all previous examples, no actual lexical item in English (or any other language) contains a non-canonical SYNSEM value.

The third modification is to change the constraint on the sort *word* which relates the values of the SUBJ, SPR, COMPS and ARG-STR attributes. Instead of simply relating them via **append**, we have the more complex Argument Realisation Constraint.

The Argument Realisation Constraint

$$
\textit{word} \quad \Longrightarrow \quad \begin{bmatrix} \text{SUBJ} & \boxed{1} \\ \text{SPR} & \boxed{2} \\ \text{COMPS} & \boxed{3}\, \textit{list(canon-ss)} \\ \text{ARG-STR} & \boxed{1} \oplus \boxed{2} \oplus (\boxed{3} \bigcirc \textit{list(gap-ss)}) \end{bmatrix}
$$

The symbol $\bigcirc$ represents the **sequence union** or **shuffle** operator. The shuffle relation holds of three sequences A, B and C if C is a sequence that contains all and only the elements of A and B, and the relative order of the elements in A and the relative order of the elements in B are both preserved in C. Suppose that $C = \langle a, b, c \rangle$ then $A \bigcirc B$ is true of each of the following pairs of values of A and B.

A	B
$\langle a, b, c\rangle$	$\langle\ \rangle$
$\langle a, b\rangle$	$\langle c\rangle$
$\langle a, c\rangle$	$\langle b\rangle$
$\langle a\rangle$	$\langle b, c\rangle$
$\langle b, c\rangle$	$\langle a\rangle$
$\langle b\rangle$	$\langle a, c\rangle$
$\langle c\rangle$	$\langle a, b\rangle$
$\langle\ \rangle$	$\langle a, b, c\rangle$

Suppose that the ARG-STR value of some head is $\langle \mathrm{NP}_1, \mathrm{NP}_2, \mathrm{PP} \rangle$ and that there is no specifier (i.e. the value of the tag $\boxed{2}$ is the empty list). The bracketing of the ARG-STR list in the definition of the Argument Realisation Constraint indicates that the shuffle relation is defined only over arguments to the right of the specifier, so the tag $\boxed{1}$ always has the value $\langle \mathrm{NP}_1 \rangle$.

If both the remaining arguments are of sort *canonical-synsem* then the other values in the Argument Realisation Constraint have the following values,

$\boxed{3} = \langle \mathrm{NP}_2, \mathrm{PP} \rangle$ and *list(gap-ss)* $= \langle\ \rangle$.

If, say, **PP** is of sort *gap-synsem*, then the values are: $\boxed{3} = \langle \mathrm{NP}_2 \rangle$ and *list(gap-ss)* $= \langle \mathrm{PP} \rangle$.

If both the second and third arguments are of sort *gap-synsem*, then the values are: $\boxed{3} = \langle\ \rangle$ and *list(gap-ss)* $= \langle \mathrm{NP}_2, \mathrm{PP} \rangle$.

A more subtle effect of the Argument Realisation Constraint is that it says nothing about SUBJ values; it does not constrain them to be canonical, but, at the same time, it does not allow them to be 'transferred' to the SLASH value. In contrast to complements, whatever appears in first position on the ARG-STR list also appears on the SUBJ list. We will return to the issue of subjects and gaps in section 7.1.

The final modification needed is to the Slash Inheritance Principle . The mother now simply inherits the SLASH value of its head daughter.

Slash Inheritance Principle - Revised version

$$\textit{hd-valence-ph} \implies \begin{bmatrix} \text{SLASH} & \boxed{1} \\ \text{HD-DTR} & \begin{bmatrix} \text{SLASH} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Let us now put all these changes together and show their effect on a mono-transitive verb such as *"likes"*. The lexical entry for *"likes"* is described by the following AVM.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{likes} \rangle \\ \text{ARG-STR} & \left\langle \begin{bmatrix} \text{LOC} & \text{NP} \\ \text{SLASH} & \boxed{1} \end{bmatrix}, \begin{bmatrix} \text{LOC} & \text{NP}[\textit{acc}] \\ \text{SLASH} & \boxed{2} \end{bmatrix} \right\rangle \\ \text{SLASH} & \boxed{1} \uplus \boxed{2} \end{bmatrix}$$

The COMPS value of this lexical entry can satisfy the Argument Realisation Constraint in either of the two ways shown in figure 47.

$$\begin{bmatrix} \textit{word} & \\ \textsc{phon} & \langle \textit{likes} \rangle \\ \textsc{subj} & \left\langle \boxed{1} \begin{bmatrix} \textit{ss} & \\ \textsc{loc} & \text{NP} \\ \textsc{slash} & \boxed{2} \end{bmatrix} \right\rangle \\ \textsc{comps} & \left\langle \boxed{3} \begin{bmatrix} \textit{canon-ss} & \\ \textsc{loc} & \text{NP}[\textit{acc}] \\ \textsc{slash} & \boxed{4} \end{bmatrix} \right\rangle \\ \textsc{arg-str} & \langle \boxed{1}, \boxed{3} \rangle \\ \textsc{slash} & \boxed{2} \uplus \boxed{4} \end{bmatrix}$$

(a)

$$\begin{bmatrix} \textit{word} & \\ \textsc{phon} & \langle \textit{likes} \rangle \\ \textsc{subj} & \left\langle \boxed{1} \begin{bmatrix} \textit{ss} & \\ \textsc{loc} & \text{NP} \\ \textsc{slash} & \boxed{2} \end{bmatrix} \right\rangle \\ \textsc{comps} & \langle \ \rangle \\ \textsc{arg-str} & \left\langle \boxed{1}, \begin{bmatrix} \textit{gap-ss} & \\ \textsc{loc} & \boxed{4} \\ \textsc{slash} & \left\{ \boxed{4} \right\} \end{bmatrix} \right\rangle \\ \textsc{slash} & \boxed{2} \uplus \left\{ \boxed{4}\text{NP}[\textit{acc}] \right\} \end{bmatrix}$$

(b)

Figure 47: Argument realisation for a mono-transitive verb.

Figure 47(a) is the kind of feature structure which occurs in sentences in which there is no UDC (e.g. (47)),

and also in sentences in which the SLASH value of the complement is non-empty, in which case the gap appears *within* the complement, as in (48).

(78) *"Toby likes every kind of scotch."*

(79) *"Scotch, Toby like every kind of."*

In figure 47(b), the second argument is a *gap-ss* and appears in the SLASH set of *"likes"* and is therefore realised as a gap, as in (49)

(80) *"Scotch, Toby likes"*

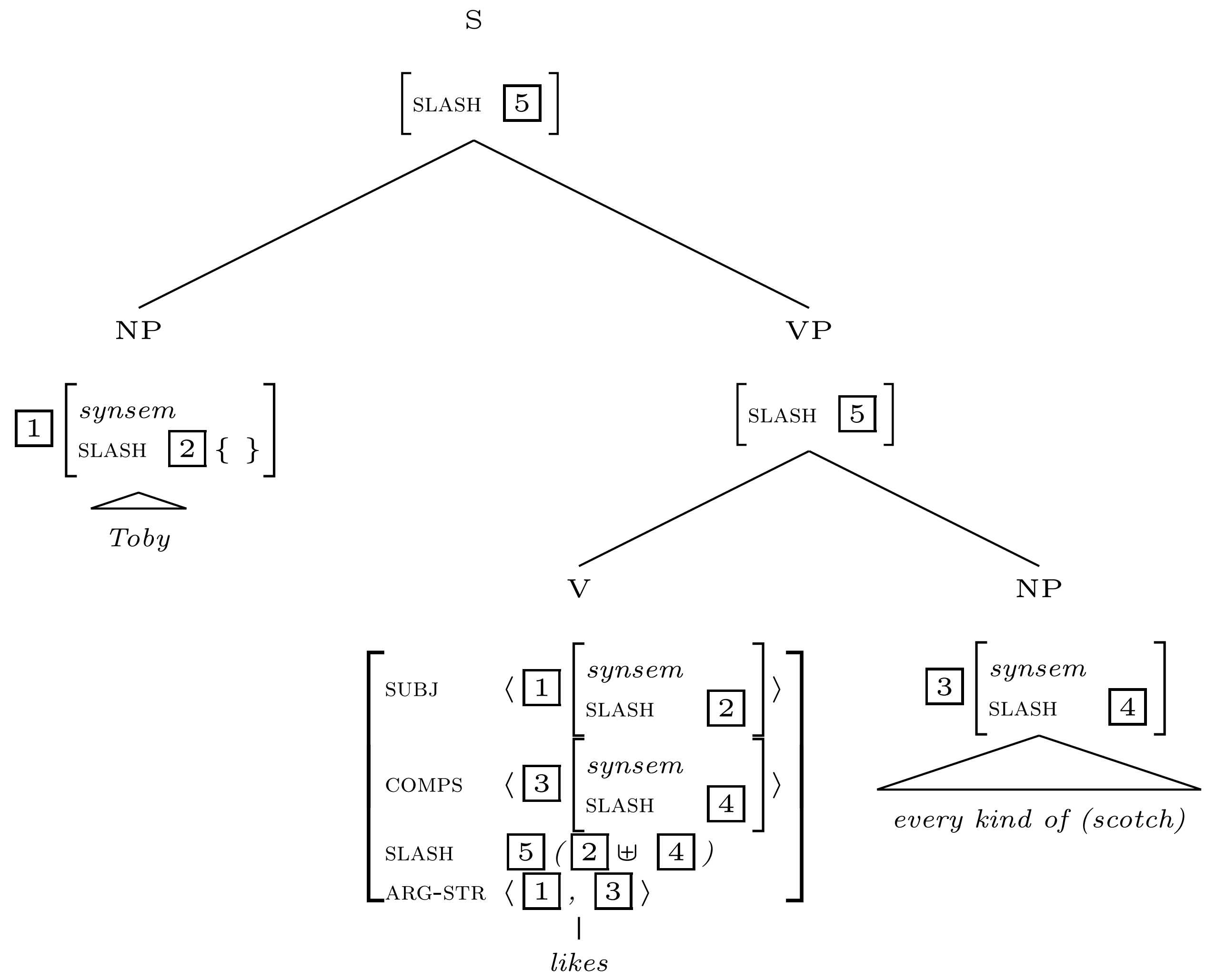


Figure 48: The Slash Inheritance Principle.

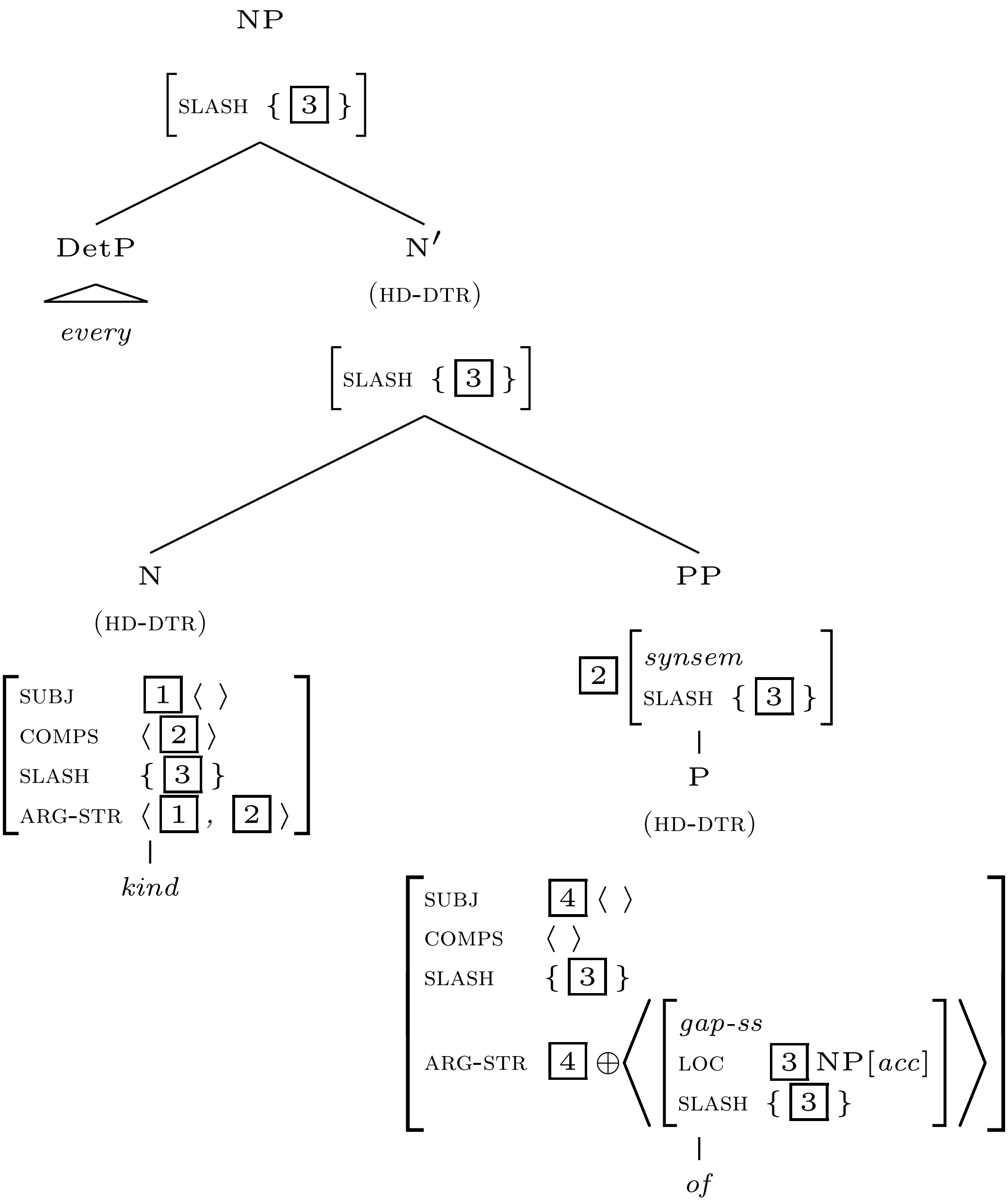


Figure 49: An NP containing an NP gap.

9.1 Subject extraction

There is a well-known restriction on the distribution of subject gaps in English (and many other languages), namely that they cannot occur immediately after a complementiser, as shown by the contrast between (50) and (51).

(81) * *"Who did Andrew say that ___ liked scotch?"*

(82) *"Who did Andrew say ___ liked scotch?"*

The lexical analysis of UDCs described in the preceding section places no sortal restriction on the SYNSEM value of subjects. Consequently, the theory permits signs such as the following.

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{liked} \rangle \\ \text{SUBJ} & \left\langle \boxed{1} \begin{bmatrix} \textit{gap-ss} & \\ \text{LOC} & \boxed{2} \\ \text{SLASH} & \{\boxed{2}\} \end{bmatrix} \right\rangle \\ \text{COMPS} & \langle \boxed{3}\text{NP}[\textit{acc}] \rangle \\ \text{ARG-STR} & \langle \boxed{1}, \boxed{3} \rangle \\ \text{SLASH} & \{\boxed{2}\} \end{bmatrix}$$

This word, together with the other principles of HPSG, licenses phrases like that shown in figure 50.

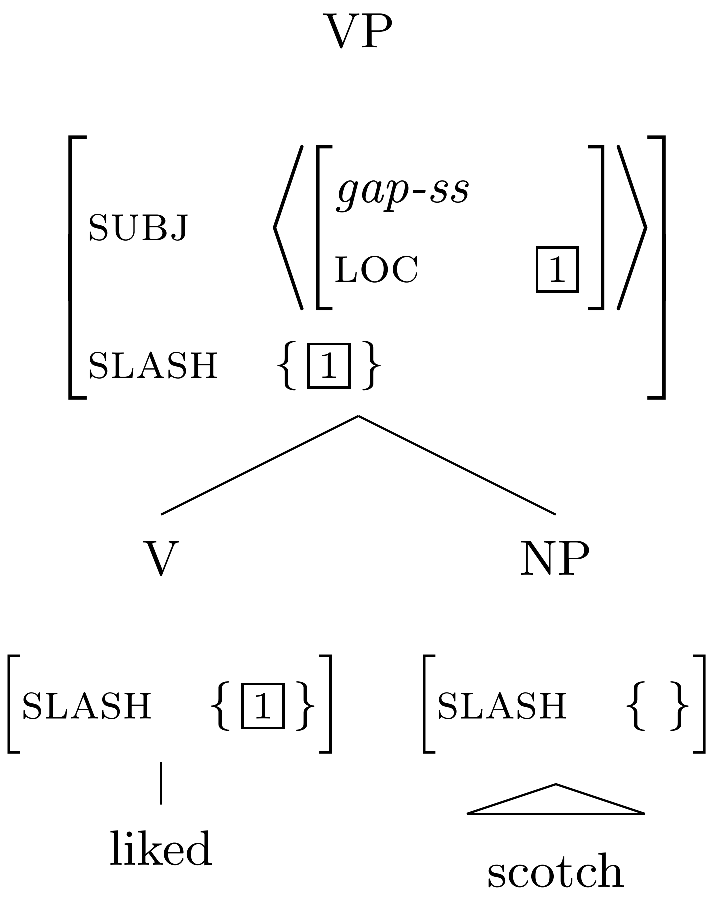


Figure 50: **VP** with a *gap-synsem* SUBJ value.

Examples like (51) can be accounted for if verbs such as *"say"* are specified having the particular lexical property of taking,

not a [SUBJ $\langle\ \rangle$] complement, but

a complement specified as [SUBJ *list(gap-ss)*].

This means that such a verb can combine with the SYNSEM component of signs like that in figure 50, as shown in figure 51.

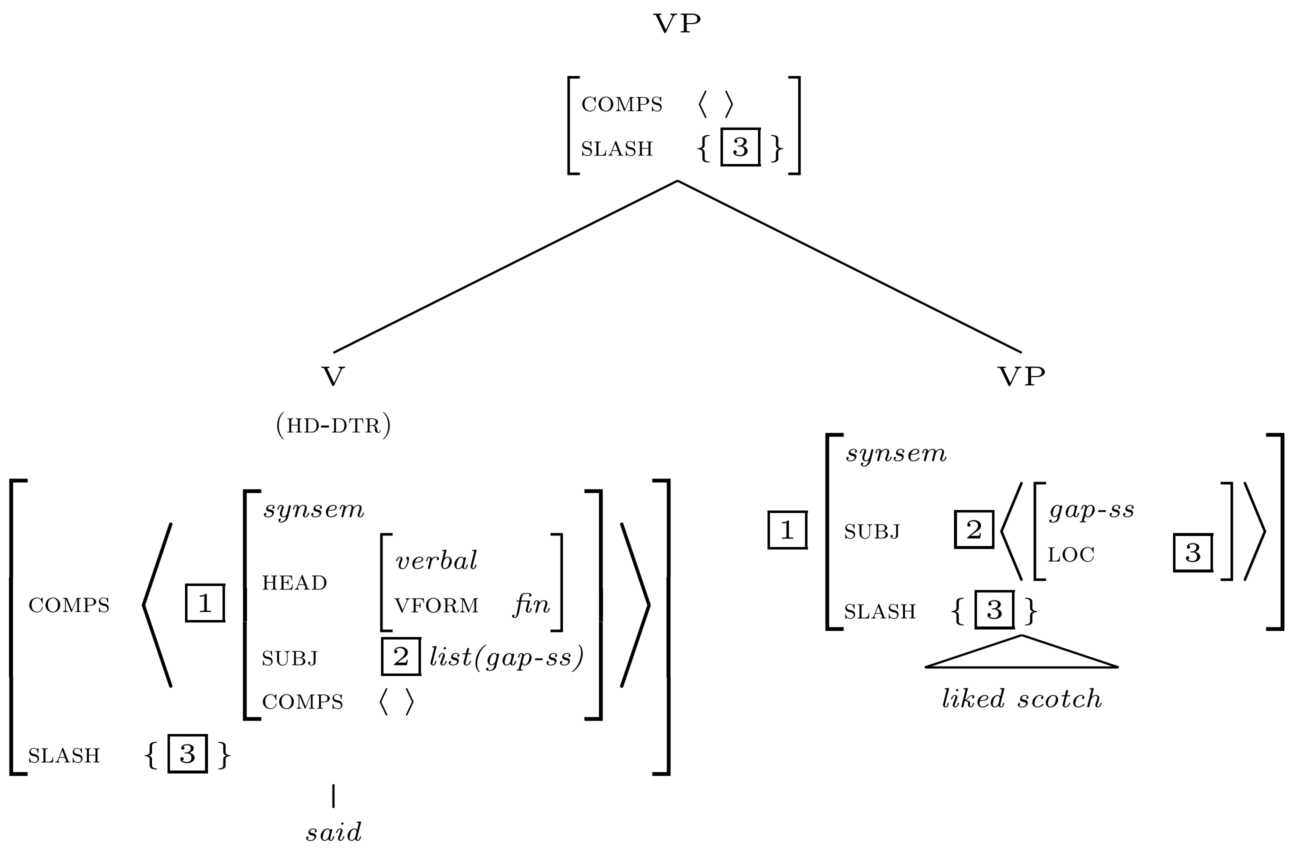


Figure 51: A subject ‘gap’ in an unbounded dependency.

If, on the other hand, the complementiser *"that"* is specified as requiring a [SUBJ $\langle\ \rangle$] complement, (50) is automatically disallowed.

Note that [SUBJ $\langle\ \rangle$] is one of the possibilities subsumed by [SUBJ *list(gap-ss)*] (since *elist* is a subsort of *list*), which means that verbs such as *"say"* may also take the saturated clausal complements **S** and **CP**.