Überlegungen zu einer beschreibungsadäquaten kompositionellen Semantik in einem constraintbasierten Grammatikformalismus

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1 Background

The main objectives are

- to define a compositional semantics with a model-theoretic interpretation for a constraint-based grammar formalism,
- to understand the possible ontologies of underspecification and their linguistic and empirical significance in a constraint-based architecture, and
- to build an architecture that takes the theoretical concerns of underspecified semantics into consideration.

We will *not* present a new semantic theory. We will develop a *meta-theory* of meaning representations in constraint-based grammars, i.e. a theory of how to use semantic representations in the theory of grammar. Two principles are important for our reasoning about semantic representations:

- *Principle of Compositionality*: The meaning of a compound expression is a function of the meanings of its parts.
- *Principle of Contextuality*: One should ask for the meaning of a word only in the context of a sentence, and not in isolation.

2 The Empirical Domain of the Proposal

- Quantifier scope ambiguities

  (1) Every student reads a book.

- Concord phenomena (negative, interrogative, temporal)

  (2) a. Personne n'a rien vu.
      b. Nikt nie pomaga nikomu.
      c. Wer hat gestern wen getroffen?
      d. Hy wou die boek gelees het.

- LF discontinuities (split readings)

  (3) Hans braucht keine Krawatte zu tragen.

- Reconstruction

  (4) a. Einen Hund kannst du damit nicht hinter dem Ofen hervorholen.

b. Ein Kennzeichen muss jedes Auto in Deutschland haben.

- Local and nonlocal semantics

(5) a. Kim pflückt eine Blume/zwei Blumen/die meisten Blumen.

b. # Kim pflückt ein Buch/zwei Bücher/die meisten Bücher.

c. [Das Institut]$_i$ steht in der Wilhelmstraße. # Es$_i$ trifft sich jede Woche einmal zum Mittagessen.

3 Framework-specific Assumptions

3.1 The Architecture of the Grammar

3.1.1 The Formalism: RSRL

Grammars and their denotation:

- A grammar consists of a **signature** and a **theory**
  - Signature: sort hierarchy, set of attributes, set of relation symbols, arity of relations, appropriateness conditions (sometimes called *feature declarations*)
  - Theory: a set of descriptions (the *principles* of grammar)
- A **model** of a grammar is a collection of objects whose components are configured in accordance with the signature; and all objects satisfy each description in the theory.
- Currently, there are essentially two explanations of the meaning of an grammar:
  - An **exhaustive model** contains "instances" of all objects that are licensed by the theory. One of the exhaustive models of the class of exhaustive models of a grammar is understood as containing the **possible tokens** of the natural language under consideration (King, 1999).
  - A collection of structures that can be construed in various ways is understood as the **types** of the natural language under consideration. The types are taken to be (a certain kind of) feature structures in Pollard and Sag (1994), but not in Pollard (1999), which takes a slightly different (more agnostic) ontological perspective.

3.1.2 Assumptions about Grammars of Natural Languages

The framework is *sign-oriented.* Signs are our basic/most important linguistic unit. This means that:

- Every sign contains morphological, phonological, syntactic and semantic structure. Following the architecture of Pollard and Sag (1994), we indicate the location of the latter three in signs:

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phonology} & \textbf{phonological structure} \\ \textsc{synsem} & \begin{bmatrix} \textsc{local} & \begin{bmatrix} \textsc{category} & \textbf{local syntactic structure} \\ \textsc{content} & \textbf{semantic structure} \end{bmatrix} \\ \textsc{nonlocal} & \textbf{unbounded dependency constructions} \end{bmatrix} \\ \textsc{daughters} & \textbf{constituent structure} \end{bmatrix}$$

- Standard core signature
- Standard core principles: Subcategorization Principle, Head Feature Principle, ID Principle, Nonlocal Feature Principle, Binding Theory, Semantics Principle
- A sentence which has only one syntactic analysis but is semantically ambiguous is modeled by two distinct signs.

3.2 Revisions

3.2.1 Terms of Ty2

We assume that the LF value of a sign is a **logical form**. In particular, we assume the language Ty2 of (Gallin, 1975), which is similar to Intensional Logic (Montague, 1974) but has technical advantages.

(6) a. Every student reads some book.

b. $\forall x[\mathsf{student}'(x) \rightarrow \exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x, y)]]$

c. $\exists y[\mathsf{book}'(y) \wedge \forall x[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x, y)]]$

(7) A description that denotes the term $\lambda x_e.\mathsf{student}'_{et}(x_e)$:

$$\begin{bmatrix} \textit{abstraction} & \\ \textsc{type} & \boxed{0}\begin{bmatrix} \textit{c-type} & \\ \textsc{in} & \boxed{1}\ \textit{entity} \\ \textsc{out} & \boxed{2}\ \textit{truth} \end{bmatrix} \\ \textsc{var} & \boxed{3}\begin{bmatrix} \textit{var} & \\ \textsc{type} & \boxed{1} \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textit{application} & \\ \textsc{func} & \begin{bmatrix} \textit{student} & \\ \textsc{type} & \boxed{0}\begin{bmatrix} \textit{c-type} & \\ \textsc{in} & \boxed{1} \\ \textsc{out} & \boxed{2} \end{bmatrix} \end{bmatrix} \\ \textsc{arg} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

Definition 1 *The **meaningful expressions of Ty2** are the smallest family* $(\mathrm{Ty2}_\tau)_{\tau \in Types}$ *such that*

for each $\tau \in Types$, $Var_\tau \cup Const_\tau \subset \mathrm{Ty2}_\tau$,

for each $\tau \in Types$, *for each* $\tau' \in Types$,

if $\alpha \in \mathrm{Ty2}_{\langle \tau', \tau \rangle}$ *and* $\beta \in \mathrm{Ty2}_{\tau'}$, *then* $\alpha(\beta) \in \mathrm{Ty2}_\tau$,

for each $\tau \in Types$, *for each* $\tau' \in Types$, *for each* $n \in \mathbb{N}$, *for each* $v_{n,\tau'} \in Var_{\tau'}$, *for each* $\alpha \in \mathrm{Ty2}_\tau$,

$(\lambda v_{n,\tau'}.\alpha) \in \mathrm{Ty2}_{\langle \tau', \tau \rangle}$,

for each $\tau \in Types$, *for each* $\alpha \in \mathrm{Ty2}_\tau$, *for each* $\beta \in \mathrm{Ty2}_\tau$,

$(\alpha = \beta) \in \mathrm{Ty2}_\tau$,

for each $\alpha \in \mathrm{Ty2}_t$,

$\neg\alpha \in \mathrm{Ty2}_t$,

for each $\alpha \in \mathrm{Ty2}_t$, *for each* $\beta \in \mathrm{Ty2}_t$,

$(\alpha \wedge \beta) \in \mathrm{Ty2}_t$, *and* *(analogously for* $\vee, \rightarrow, \leftrightarrow$*)*

for each $\tau \in Types$, *for each* $n \in \mathbb{N}$, *for each* $v_{n,\tau} \in Var_\tau$, *for each* $\alpha \in \mathrm{Ty2}_t$,

$\exists v_{n,\tau}\alpha \in \mathrm{Ty2}_t$. *(and analogously for* $\forall$*)*

(8) A signature specification for a grammar of Ty2 expressions:

```
ty2
   me   type:type
      variable index:integer
      constant
         student
         walk
         read
         john
         mary
      application functor:me arg:me
      abstraction var:variable arg:me
      equation arg1:me arg2:me
      negation arg:me
      l-const arg1:me arg2:me
         disjunction
         conjunction
         implication
         bi-implication
      quantifiers var:variable scope:me
         universal
         existential
  type
     atomic-type
        entity
        truth
        w-index
     complex-type in:type out:type
  integer
     zero
     n-zero pre:integer
relations
member/2
component/2
copy/2
```

(9) The principle of integers:
$integer \rightarrow \; \exists x \; {}^{x}\big[zero\big]$

(10) Principles for type restrictions on the non-logical constants:

$(john \vee mary) \rightarrow \big[\text{TYPE}\ [entity]\big]$,

$(student \vee walk) \rightarrow \left[\text{TYPE}\ \begin{bmatrix} \textit{complex-type} & \\ \text{IN} & entity \\ \text{OUT} & truth \end{bmatrix}\right]$,

$read \rightarrow \left[\text{TYPE}\ \begin{bmatrix} \textit{complex-type} & \\ \text{IN} & entity \\ \text{OUT} & \begin{bmatrix} \text{IN} & entity \\ \text{OUT} & truth \end{bmatrix} \end{bmatrix}\right]$

(11) Principles for type restrictions on logical operators:

$appl \rightarrow \begin{bmatrix} \text{TYPE} & \boxed{2} \\ \text{FUNC TYPE} & \begin{bmatrix} \text{IN} & \boxed{1} \\ \text{OUT} & \boxed{2} \end{bmatrix} \\ \text{ARG TYPE} & \boxed{1} \end{bmatrix}$,

$$abstr \rightarrow \begin{bmatrix} \text{TYPE} & \begin{bmatrix} \text{IN} & \boxed{1} \\ \text{OUT} & \boxed{2} \end{bmatrix} \\ \text{VAR TYPE} & \boxed{1} \\ \text{ARG TYPE} & \boxed{2} \end{bmatrix},$$

$$equ \rightarrow \begin{bmatrix} \text{TYPE} & truth \\ \text{ARG1 TYPE} & \boxed{1} \\ \text{ARG2 TYPE} & \boxed{1} \end{bmatrix},$$

$$neg \rightarrow \begin{bmatrix} \text{TYPE} & truth \\ \text{ARG TYPE} & truth \end{bmatrix},$$

$$l\text{-}const \rightarrow \begin{bmatrix} \text{TYPE} & truth \\ \text{ARG1 TYPE} & truth \\ \text{ARG2 TYPE} & truth \end{bmatrix},$$

$$quant \rightarrow \begin{bmatrix} \text{TYPE} & truth \\ \text{SCOPE TYPE} & truth \end{bmatrix}$$

(12) Auxiliary specification: the `component` relation

Assume that $\mathcal{A}$ is our set of attributes, $\mathcal{A}$ finite. `component` is a binary relation symbol in our signature. The set of clauses of `component` is the smallest set C such that

$\texttt{component}(x, y) \overset{\forall}{\Longleftarrow} x = y \ \in C$, and
for each $\alpha \in \mathcal{A}$,
$\texttt{component}(x, y) \overset{\forall}{\Longleftarrow} {}^{y}\!\left[\alpha\ \boxed{1}\right] \wedge \texttt{component}(x, \boxed{1}) \ \in C.$

(13) The Ty2 Non-Cyclicity Principle:

$ty2 \rightarrow$

$$\forall\boxed{1} \left(\left(\bigvee_{\alpha\in\mathcal{A}}\left[\alpha\ \boxed{1}\right]\right) \rightarrow \neg\, \texttt{component}(:, \boxed{1})\right)$$

(14) The Ty2 Finiteness Principle:

We presuppose that we have already specified a reasonable meaning for the symbol `member`.

$ty2 \rightarrow$

$$\exists\boxed{1}\forall\boxed{2} \left(\texttt{component}(\boxed{2}, :) \rightarrow \texttt{member}\left(\boxed{2}, \boxed{1}\left[chain\right]\right)\right)$$

(15) Auxiliary specification: the `copy` relation

Assume that the set of attributes, $\mathcal{A}$, and the set of maximally specific sorts, $\mathcal{S}$, are finite.

$$\begin{aligned} &\texttt{copy}(x, y) \overset{\forall}{\Longleftarrow} \\ &\qquad \bigvee_{\sigma\in\mathcal{S}} \left({}^{x}\!\left[\sigma\right] \wedge {}^{y}\!\left[\sigma\right]\right) \wedge \\ &\qquad \bigwedge_{\alpha\in\mathcal{A}} \left(\forall\boxed{1}\left({}^{x}\!\left[\alpha\ \boxed{1}\right] \rightarrow \exists\boxed{2}\left({}^{y}\!\left[\alpha\ \boxed{2}\right] \wedge \texttt{copy}(\boxed{1}, \boxed{2})\right)\right)\right) \end{aligned}$$

y is a copy of x if x and y have the same species (second line), and if an attribute α with value $\boxed{1}$ is defined on x, then α is also defined on y, and $\boxed{1}$ and the value of α on y, $\boxed{2}$, are in the `copy` relation (third line).

In the Ty2 Identity Principle, we require that all the corresponding entities in the `copy` relation of representations of Ty2 expressions be identical:

(16) The Ty2 Identity Principle:

$ty2 \rightarrow$

$$\forall\boxed{1}\forall\boxed{2}\left(\texttt{copy}(\boxed{1}, \boxed{2}) \rightarrow \boxed{1} = \boxed{2}\right)$$

3.2.2 Revised Assumptions about Grammars of Natural Languages

Separation of local and nonlocal semantics:

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phonology} & \textbf{phonological structure} \\ \textsc{synsem} & \begin{bmatrix} \textsc{local} & \begin{bmatrix} \textsc{category} & \textbf{local syntactic structure} \\ \textsc{content} & \textbf{local semantic structure} \end{bmatrix} \\ \textsc{nonlocal} & \textbf{unbounded dependency constructions} \end{bmatrix} \\ \textsc{daughters} & \textbf{constituent structure} \\ \textsc{lf} & \textbf{compositional semantics: Expressions of Ty2} \end{bmatrix}$$

The theory of grammar now contains the grammar of Ty2 expressions and a compositional semantics that determines the modes of combinations of the semantic contributions of syntactic daughters at their mother node.

4 LF-Ty2 (Richter and Sailer, 1999a,b; Sailer, 2003)

4.1 A Sketch

LF-Ty2 is based on the flexible type shifting system of Hendriks (1993) (see also Dekker (1993), Bouma (1994)):

- there is a basic translation for every word
- type shifting rules can freely apply to the translation of words
- the logical form of a phrase is the (intensional) functional application of the logical forms of its daughters.

Basic translations:

(17) a. *read* $\leadsto \lambda y \lambda x.\mathsf{read}'(x,y)$

b. *book* $\leadsto \lambda y.\mathsf{book}'(y)$

c. *student* $\leadsto \lambda y.\mathsf{student}'(y)$

d. *some* $\leadsto \lambda P \lambda Q.\exists y[P(x) \wedge Q(x)]$

e. *every* $\leadsto \lambda P \lambda Q.\forall y[P(y) \rightarrow Q(y)]$

Type shifting rule:

(18) Argument Raising:
$\lambda x_1 \ldots \lambda x_i \ldots \lambda x_n.\phi \longrightarrow_{AR_i} \lambda x_1 \ldots \lambda X_i \ldots \lambda x_n.X_i(\lambda x_i.\phi)$

Figures 1 and 2 illustrate the derivation of the meaning representations of the sentence *Every student reads some book.*

Advantages of the new architecture according to (Sailer, 2003, p. 383–384):

1. The new representations are familiar to most linguists within formal linguistics
2. The semantic representation of a sign is located in the value of one attribute only.
3. Clear position about the ontological status of the LF value.
4. Concrete semantic representation language
5. Direct link between the logical form of a sign and its model theoretic meaning
6. Account of scope ambiguity without syntactic movement or storage mechanisms

Figure 1: The ∀∃ reading of the sentence *Every student reads some book*:

- S: $\forall x[\mathsf{student}'(x) \to \exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$
  $\uparrow \lambda$
  $[\lambda x.\exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]](\lambda Q.\forall x[\mathsf{student}'(x) \to Q(x)])$
  - NP: $\lambda Q.\forall x[\mathsf{student}'(x) \to Q(x)]$
    $\triangle$ *every student*
  - VP: $\lambda x.\exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]$
    $\uparrow \lambda$
    $[\lambda Y \lambda x.Y(\lambda y.\mathsf{read}'(x,y))](\lambda S.\exists y[\mathsf{book}'(y) \wedge S(y)])$
    - V: $\lambda Y \lambda x.Y(\lambda y.\mathsf{read}'(x,y))$
      $\uparrow$ AR1
      $\lambda y \lambda x.\mathsf{read}'(x,y)$
      reads
    - NP: $\lambda S.\exists y[\mathsf{book}'(y) \wedge S(y)]$
      $\triangle$ *some book*

Figure 2: The ∃∀ reading of the sentence *Every student reads some book*:

- S: $\exists y[\mathsf{book}'(y) \wedge \forall x[\mathsf{student}'(x) \to \mathsf{read}'(x,y)]]$
  $\uparrow \lambda$
  $[\lambda X.\exists y[\mathsf{book}'(y) \wedge X(\lambda x.\mathsf{read}'(x,y))]](\lambda Q.\forall x[\mathsf{student}'(x) \to Q(x)])$
  - NP: $\lambda Q.\forall x[\mathsf{student}'(x) \to Q(x)]$
    $\triangle$ *every student*
  - VP: $\lambda X.\exists y[\mathsf{book}'(y) \wedge X(\lambda x.\mathsf{read}'(x,y))]$
    $\uparrow \lambda$
    $[\lambda Y \lambda X.Y(\lambda y.X(\lambda x.\mathsf{read}'(x,y)))](\lambda S.\exists y[\mathsf{book}'(y) \wedge S(y)])$
    - V: $\lambda Y \lambda X.Y(\lambda y.X(\lambda x.\mathsf{read}'(x,y)))$
      $\uparrow$ AR1
      $\lambda y \lambda X.X(\lambda x.\mathsf{read}'(x,y))$
      $\uparrow$ AR2
      $\lambda y \lambda x.\mathsf{read}'(x,y)$
      reads
    - NP: $\lambda S.\exists y[\mathsf{book}'(y) \wedge S(y)]$
      $\triangle$ *some book*

4.2 Problems with Naive Compositionality

4.2.1 Concord in Polish

N-Words are inherently negative:

(19) a. Kogo widziałeś? Nikogo.
Who have you seen? Nobody.GEN/ACC.

b. Ile przeczytałeś książek?
How many books have you read?

Żadnej./ Żadną.
None.GEN./ None.ACC.

(20) Chcę poślubić albo Piotra, albo nikogo.
I will marry either Piotr or nobody

(21) Kocham ją jak [żadną inną].
I love her.ACC as [no other].ACC

? Kocham ją jak [żadnej innej].
I love her.ACC as [no other].GEN

'I love her more than (I love) any other (girl).'

Non-negative n-words?

- *Nie* is obligatory in verbal contexts:

(22) Janek *(nie) pomaga nikomu.
Janek NM helped nobody
'Janek didn't help anybody.'
$ 'Janek didn't help nobody.'

- More than one n-word can occur, without there being a DN reading

(23) Nikt *(nie) pomaga nikomu.
Nobody NM helped nobody
'Nobody helped anybody.'

- Semantic material can intervene between the negation and the scope of the n-word:

(24) a. Janek nie szuka żadnego jednorożca.
Janek NM seeks no unicorn

b. Janek nie może nic czytać.
Janek NM can nothing read
'Janek is not allowed to read anything.'

- N-words occur in other contexts:

(25) Zaczął bez czekania na nikogo.
he-started without waiting for nobody
'He started without waiting for anybody.'

...but not in:

(26) * Widziałeś nikogo?
you-saw nobody
$ 'Did you see anybody?'

Observation

1. In all the grammatical examples we can postulate the presence of a negation at the logical form.
2. Polish n-words are not NPIs since they do not occur in the same environments as NPIs (only negative contexts).

There *exists* evidence for the inherently negative character of Polish n-words.
There is *no* evidence for an inherently non-negative character.

4.2.2 Discontinuity: Negation in German

The semantic contribution of a word is not realized as one subexpression in the overall logical form.

(27) a. Chris sucht keine Wohnung.

b. *de re*: $\neg\exists x[\mathsf{apartment}'(w,x) \wedge \mathsf{seek}'(w,c,\lambda w.\lambda P.P(w,x))]$
(there is no apartment x sth. Chris seeks x)

c. *de dicto*: $\neg[\mathsf{seek}'(w,c,\lambda w.\lambda P.\exists x[\mathsf{apartment}'(w,x) \wedge P(w,x)])]$
(it is not the case that Chris seeks an apartment)

The *de dicto* reading cannot be dealt with in LF-Ty2 if we assume: *kein-* $\leadsto \lambda P \lambda Q.\neg\exists x[P(x) \wedge Q(x)]$

(28) a. Hans muss keine Krawatte tragen.

b. 'It is not the case that Hans must wear a tie.'
$\neg\mathsf{must}'(w,h,\lambda w.\exists x[\mathsf{tie}'(w,x) \wedge \mathsf{wear}'(w,h,x)])$

c. 'What Hans must do is not wear a tie.'
$\mathsf{must}'(w,h,\lambda w.\neg\exists x[\mathsf{tie}'(w,x) \wedge \mathsf{wear}'(w,h,x)])$

d. 'There is no tie such that Hans must wear that tie.'
$\neg\exists x[\mathsf{tie}'(w,x) \wedge \mathsf{must}'(w,h,\lambda w.\mathsf{wear}'(w,h,x))]$

4.2.3 Conclusion

Reasons for abandoning LF-Ty2:

- analysis of negative concord in Polish
- discontinuity effects combined with assumptions about syntactic structure
- explosion of derivations for scope ambiguities (computational problem)
- attractive option of applying new, framework-specific techniques in the definition of semantic composition (identities)

5 Underspecification

Questions: What's the ontological status of underspecified representations? Do they belong to language itself, or to some level of the description of language and to language processing?

5.1 From the Literature

There are various reasons to ascribe some sort of reality to underspecification:

- spoken language understanding
- improved efficiency in processing (monotonically extended constraint sets)
- incremental architecture (speech recognition, syntax, semantic analysis, reasoning)
- robust processing

- humans seem to be able to make use of underspecified output of the semantic analysis as witnessed by inferences on an underspecified understanding of highly ambiguous sentences
- truth-conditionally irrelevant layer of information that might be indispensable for discourse-semantics
- distinction between a language-oriented level of semantic representation and a non-linguistic processing level

5.2 Underspecification with RSRL?

The most natural notion of "*underspecification*" in HPSG is *underspecification at the description level.*

- *Underspecification in the lexicon*: a lexical entry is a description. A lexical entry is underspecified if there is some attribute whose value is not fully determined by the lexical entry. For example, for auxiliary verbs in English, the grammar in Pollard and Sag (1994) leaves the value of the INVERTED attribute underspecified. In every sentence, however, the value of this attribute is either *plus* or *minus.*
- Typical semantic instances of that kind of underspecification in the lexicon of Pollard and Sag (1994) are "CONTENT raisers" like the verbs *to* and *be.*
- In the grammar of Pollard and Sag (1994) sentence (6) receives a single syntactic analysis. The SEMANTICS PRINCIPLE leaves some freedom as to the place where quantifiers are inserted into the CONTENT value of a sign. In this sense, the SEMANTICS PRINCIPLE is underspecified.
- Observation: At least for some phenomena which are ideal candidates for underspecification, it can be shown that underspecification cannot be a property of the linguistic entities in question.

Three criteria for semantic systems for HPSG:

1. **discontinuous representation**: the semantic contribution of words is not a single term but a collection of terms; these terms are usually discontinually distributed over the logical form of bigger syntactic units.
2. **underspecified denotation**: the CONTENT value represents an underspecified semantic term.
3. **indirect representation**: meta-variables occur in the CONTENT value.

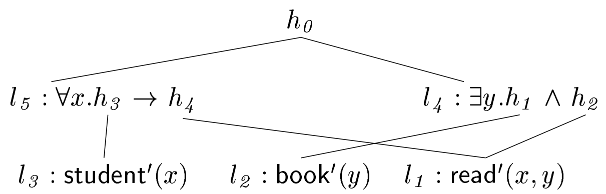
Table 1: Classification of the semantic systems discussed in this presentation

Approach	underspecified den.	indirect repr.	discontinuous repr.
Ty2U	+	+	+
Ty2U^P	-	+	+
LRS	-	-	+
LF-Ty2	-	-	-

5.3 Ty2U (Richter and Sailer, 1999c)

5.3.1 Bos (1996)

(29) An underspecified representation of the sentence *every student reads some book.*:



Underspecified Representation:

(30) a. A set of holes:

$\{h_0, h_1, h_2, h_3, h_4\}$,

b. A set of labeled formulae:

$\{l_1 : \mathsf{read}'(x,y), \quad l_2 : \mathsf{book}'(y), \quad l_3 : \mathsf{student}'(x), l_4 : \exists y.h_1 \wedge h_2, \quad l_5 : \forall x.h_3 \rightarrow h_4\}$

c. A set of constraints:

$\{l_1 \leq h_0, \quad l_2 \leq h_0, \quad l_4 \leq h_0, \quad l_2 \leq h_1, \quad l_1 \leq h_2, \quad l_3 \leq h_0, \quad l_5 \leq h_0, \quad l_3 \leq h_3, \quad l_1 \leq h_4\}$

Plugging: bijection from holes to labels

(31) a. $\forall x.[\mathsf{student}'(x) \rightarrow \exists y.[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$
$P1 = \{h_0 = l_5, \quad h_1 = l_2, \quad h_2 = l_1, \quad h_3 = l_3, \quad h_4 = l_4\}$

b. $\exists y.[\mathsf{book}'(y) \wedge \forall x.[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x,y)]]$
$P2 = \{h_0 = l_3, \quad h_1 = l_2, \quad h_2 = l_5, \quad h_3 = l_4, \quad h_4 = l_1\}$

5.3.2 A Sketch

Signature for **underspecified representations**:

(32) a. *undersp.-repr*

HOLES	*list(hole)*
LABELS	*list(label)*
CONSTR(AINTS)	*list(constraint)*
MAIN	*label*
TOP	*hole*

b.

$$\begin{array}{ccc} & \textit{meta} & \\ \swarrow & & \searrow \\ \textit{label} & & \textit{hole} \end{array}$$

c. *constraint* A1 *meta*
A2 *meta*

Relevant parts of some lexical entries:

(33) a.

$$\begin{bmatrix} \textsc{phon}\ \langle \textit{reads} \rangle \\ \textsc{synsem loc} \begin{bmatrix} \textsc{cat} \begin{bmatrix} \textsc{head} & \textit{verb} \\ \textsc{subcat} & \langle \mathrm{NP},\ \mathrm{NP} \rangle \end{bmatrix} \\ \textsc{content} \begin{bmatrix} \textit{ur} & \\ \textsc{holes} & \langle h_0 \rangle \\ \textsc{labels} & \langle \boxed{1} \lambda y \lambda x.\mathsf{read}'(x,y) \rangle \\ \textsc{constr} & \langle \boxed{1} \leq h_0 \rangle \\ \textsc{main} & \boxed{1} \\ \textsc{top} & h_0 \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

b.

$$\begin{bmatrix} \textsc{phon}\ \langle \textit{book} \rangle \\ \textsc{synsem loc} \begin{bmatrix} \textsc{cat head}\ \textit{noun} \\ \textsc{content} \begin{bmatrix} \textit{ur} & \\ \textsc{holes} & \langle h_0 \rangle \\ \textsc{labels} & \langle \boxed{2} \lambda y.\mathsf{book}'(y) \rangle \\ \textsc{constr} & \langle \boxed{2} \leq h_0 \rangle \\ \textsc{main} & \boxed{2} \\ \textsc{top} & h_0 \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

c.

$$\begin{bmatrix} \textsc{phon}\ \langle \textit{student} \rangle \\ \textsc{synsem loc} \begin{bmatrix} \textsc{cat head}\ \textit{noun} \\ \textsc{content} \begin{bmatrix} \textit{ur} & \\ \textsc{holes} & \langle h_0 \rangle \\ \textsc{labels} & \langle \boxed{3} \lambda x.\mathsf{student}'(x) \rangle \\ \textsc{constr} & \langle \boxed{3} \leq h_0 \rangle \\ \textsc{main} & \boxed{3} \\ \textsc{top} & h_0 \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

d. $\begin{bmatrix} \textsc{phon}\ \langle \textit{some} \rangle & \\ \textsc{synsem loc} & \begin{bmatrix} \textsc{cat head} & \textit{determiner} \\ \textsc{content} & \begin{bmatrix} \textit{ur} & \\ \textsc{holes} & \langle h_0, h_1, h_2 \rangle \\ \textsc{labels} & \langle \boxed{4} \exists y[h_1 \wedge h_2] \rangle \\ \textsc{contr} & \langle \boxed{4} \leq h_0 \rangle \\ \textsc{main} & \boxed{4} \\ \textsc{top} & h_0 \end{bmatrix} \end{bmatrix} \end{bmatrix}$

e. $\begin{bmatrix} \textsc{phon}\ \langle \textit{every} \rangle & \\ \textsc{synsem loc} & \begin{bmatrix} \textsc{cat head} & \textit{determiner} \\ \textsc{content} & \begin{bmatrix} \textit{ur} & \\ \textsc{holes} & \langle h_0, h_3, h_4 \rangle \\ \textsc{labels} & \langle \boxed{5} \forall y[h_3 \rightarrow h_4] \rangle \\ \textsc{contr} & \langle \boxed{5} \leq h_0 \rangle \\ \textsc{main} & \boxed{5} \\ \textsc{top} & h_0 \end{bmatrix} \end{bmatrix} \end{bmatrix}$

(34) The SEMANTICS PRINCIPLE:

In each phrase:

1. HOLES: is a concatenation of the values at the daughters
2. LABELS: is a concatenation of the values at the daughters
3. MAIN: is identical to the head daughter's value
4. TOP: is identical at the mother and the daughters
5. CONSTR: contains exactly
   (a) all elements of the daughters' CONSTR lists,
   (b) in *head-adjunct-phrase*:
   head's main $\leq$ adjunct's main
   adjunct's main $\leq$ top
   (c) in *head-complement-phrase*:
   head's main $\leq$ complement's nucleus
   complement's main $\leq$ top
   (d) in a nominal projection:
   head's main $\leq$ quantifier's restriction

(35) a. description of the CONTENT value for the sentence *Every student reads some book*:

$$\begin{bmatrix} \textsc{holes} & \langle h_0, h_1, h_2, h_3, h_4 \rangle \\ \textsc{labels} & \langle \boxed{1}, \boxed{2}, \boxed{3}, \boxed{4}, \boxed{5} \rangle \\ \textsc{constr} & \langle \boxed{1} \leq h_0, \boxed{2} \leq h_0, \boxed{4} \leq h_0, \boxed{2} \leq h_1, \boxed{1} \leq h_2, \boxed{3} \leq h_0, \boxed{5} \leq h_0, \boxed{3} \leq h_3, \boxed{1} \leq h_4 \rangle \\ \textsc{main} & \boxed{1} \\ \textsc{top} & h_0 \end{bmatrix}$$

b. This describes an underspecified representation which is like (30).

c. This underspecified representation has the pluggings in (31)

5.3.3 Problematic Data

In Ty2U scope resolution is not part of the grammar. Therefore, it is impossible to exclude a sentence whose ungrammaticality is due to conflicting scoping requirements.

Example 1: interrogatives in German (Beck, 1996)

(36) a. * Wann hat niemand wem geholfen?
when has nobody whom helped

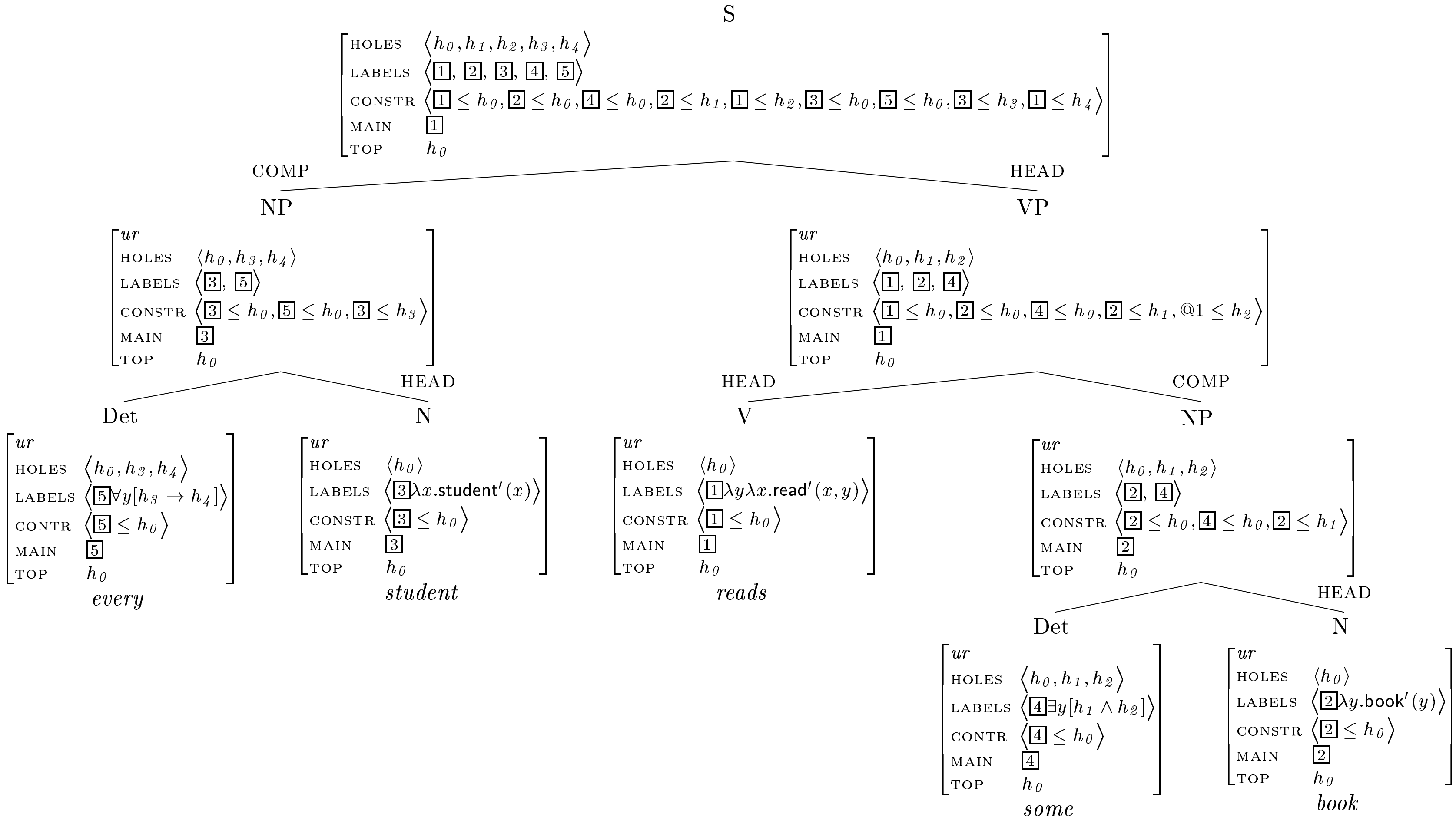


Figure 3: The analysis of the sentence *Every student reads some book.*:

b. Wann hat wem niemand geholfen?
when has whom nobody helped

'When did nobody help whom'
$\lambda p.\exists t \exists x[p = \lambda w.\neg\exists y[y \text{ helps } x \text{ at } t]]$

Assumptions:

1. Assume a quantificational analysis of interrogatives, i.e.,
wer (*who*) $\rightsquigarrow$ $\lambda P \lambda Q \lambda p.\exists x[P_w(x) \wedge p = \lambda w.Q_w(x)]$.
2. Assume that the relative scope of a negation and a quantifier is (largely) determined by word order.
3. The quantifier contributed by the in-situ interrogative pronoun *wem* ($\exists y$) must outscope the interrogative operator ($p = \lambda w.\phi$).

$\rightarrow$ With (1) and (2) it follows that
(i) the negation must be in the scope of the fronted interrogative pronoun, and (ii) the quantifier contributed by the in-situ interrogative must be in the scope of the negation.

With (3) it follows that the quantifier contributed by *wem* must outscope the interrogative operator.

Thus, we get a contradiction for (36a) but nor for (36b).

Example 2: n-words in Polish (Przepiórkowski and Kupść, 1999)
In Polish, the preverbal particle *nie* is systematically ambiguous between eventuality negation and non-eventuality negation (pleonastic or other). N-words such as *nikt* (*nobody*) must co-occur with the particle *nie* (*not*), but can do so only in its eventuality negation reading.

(37) a. Omal jej nie przewróciłem.
almost her NM I overturned

'I almost knocked her over.'

b. ?* Omal nikogo nie przewróciłem.
almost nobody not I overturned

5.3.4 Technical Difficulties

- What kind of constraints are necessary? In Bos (1996) only constraints of the kind *"is subterm of/is in the scope of"* are possible. In Egg (1998) there are constraints of the forms *"is possibly in the immediate scope of"* and *"cannot possibly be in the immediate scope of"*. In Frank and Reyle (1995) there are even constraints of the form "$l_1 \leq l_2 \Rightarrow l_3 \leq l_4$".
- It is hard to express more complex constraints:

(38) In a sentence S, if one in-situ interrogative pronoun takes scope over clause C then so does every clausemate in-situ interrogative pronoun.

(39) a. Wer weiß, wem Maria wann was gegeben hat?
who knows whom Maria when what given has

b. $\lambda p.\exists x[p = \lambda w.[\mathsf{know'}_w(x, \lambda p.\exists y \exists z \exists t[\text{Maria gives } z \text{ to } y \text{ at } t])]]$

c. $\lambda p.\exists x \exists z \exists t[p = \lambda w.[\mathsf{know'}_w(x, \lambda p.\exists y[\text{Maria gives } z \text{ to } y \text{ at } t])]]$

d. \$ $\lambda p.\exists x \exists z[p = \lambda w.[\mathsf{know'}_w(x, \lambda p.\exists y \exists t[\text{Maria gives } z \text{ to } y \text{ at } t])]]$

e. \$ $\lambda p.\exists x \exists t[p = \lambda w.[\mathsf{know'}_w(x, \lambda p.\exists y \exists z[\text{Maria gives } z \text{ to } y \text{ at } t])]]$

- Well-formedness constraints on underspecified representations are quite awkward to state such as the requirements
  - that the constraints should not lead to a cyclic plugging.
  - that every occurrence of a variable be properly bound.
- Depending on the semantic analysis, the two readings of (40) cannot be given a single underspecified representation.

(40) Mary observed a man with a telescope.

- In Frank and Reyle (1995) and Egg (1998), the scope of a quantifier is underspecified but not its "reading", i.e., whether it is used distributively or collectively etc.

(41) Wer hat jedem bei der Vorbereitung geholfen? (Pafel, 1998)
who has everyone with the preparation helped
'Who helped everyone with the preparation?'

a. Detmar.

b. Frank helped Manfred; Janina helped Frank; Manfred helped Sabine; . . . .

- It is unclear for which phenomena underspecification should be chosen.

5.3.5 Summary

Systems with underspecified denotation raise conceptual questions about the limits of grammar and have serious technical limitations.

6 LRS (Richter and Sailer, 2001a,b, 2003)

6.1 A Sketch

(42) The sort *lrs*

$$\begin{array}{lll} \textit{lrs} & \textsc{excont} & \textit{me} \\ & \textsc{intcont} & \textit{me} \\ & \textsc{parts} & \textit{list(me)} \end{array}$$

(43) Every student reads some book
$\forall x[\mathsf{student}'(x) \rightarrow \exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$
$\exists y[\mathsf{book}'(y) \wedge \forall x[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x,y)]]$

Relevant parts of the lexical entries:

(44) a. *read*: $\begin{bmatrix} \textit{lrs} & \\ \textsc{excont} & \textit{me} \\ \textsc{intcont} & \boxed{1}\ (\mathsf{read}'y)x \\ \textsc{parts} & \left\langle x, y, \boxed{1}, \boxed{1a}\mathsf{read}'y, \boxed{1b}\mathsf{read}' \right\rangle \end{bmatrix}$

b. *book* : $\begin{bmatrix} \textsc{excont} & \begin{bmatrix} \textit{quantifier} \\ \textsc{var}\ y \end{bmatrix} \\ \textsc{intcont} & \boxed{2}\mathsf{book}'(y) \\ \textsc{parts} & \left\langle y, \boxed{2}, \boxed{2a}\mathsf{book}' \right\rangle \end{bmatrix}$

c. *student*: $\begin{bmatrix} \textsc{excont} & \begin{bmatrix} \textit{quantifier} \\ \textsc{var}\ x \end{bmatrix} \\ \textsc{intcont} & \boxed{3}\mathsf{student}'(x) \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{student}' \right\rangle \end{bmatrix}$

d. *some*: $\begin{bmatrix} \textsc{excont} & \textit{me} \\ \textsc{intcont} & \boxed{4}\exists y[\alpha \wedge \beta] \\ \textsc{parts} & \left\langle y, \boxed{4}, \boxed{4a}\ [\alpha \wedge \beta] \right\rangle \end{bmatrix}$

e. *every*: $\begin{bmatrix} \textsc{excont} & \textit{me} \\ \textsc{intcont} & \boxed{5}\forall x[\gamma \rightarrow \delta] \\ \textsc{parts} & \left\langle x, \boxed{5}, \boxed{5a}\ [\gamma \rightarrow \delta] \right\rangle \end{bmatrix}$

(45) $\begin{bmatrix} \textit{lrs} & \\ \textsc{excont} & \textit{me} \\ \textsc{intcont} & \boxed{5} \begin{bmatrix} \textit{universal} & \\ \textsc{var} & x \\ \textsc{scope} & \boxed{5a} \begin{bmatrix} \textit{implication} \\ \textsc{arg1}\ \gamma\ \textit{me} \\ \textsc{arg2}\ \delta\ \textit{me} \end{bmatrix} \end{bmatrix} \\ \textsc{parts} & \left\langle \boxed{5}, \boxed{5a}, x \right\rangle \end{bmatrix}$

Compositional Semantics:
We impose two well-formedness conditions on *lrs*:

(46) The INTCONT PRINCIPLE (IntcontP):
In each *lrs*, the INTCONT value is an element of the PARTS list and a component of the EXCONT value.

(47) The EXCONT PRINCIPLE (ExcontP):

1. In every phrase, the EXCONT value of the non-head daughter is an element of the non-head daughter's PARTS list.
2. In every utterance, every subterm of the EXCONT value of the utterance is an element of its PARTS list, and every element of the utterance's PARTS list is a subterm of the EXCONT value.

(48) Semantics Principle

In each *headed-phrase*,

1. the EXCONT value of the head and the mother are identical,
2. the INTCONT value of the head and the mother are identical,[1]
3. the PARTS value contains exactly all elements of the PARTS values of the daughters,
4. the following conditions hold:
   (a) if the nonhead is a quantifier then its INCONT value is of the form $Qx[\rho \circ \nu]^2$, the INTCONT value of the head is a component of ρ, and the EXCONT value of the head is identical with the INTCONT value of the non-head,
   (b) if the non-head is a quantified NP with an EXCONT value of the form $Qx[\rho \circ \nu]$, then the INTCONT value of the head is a component of ν,
   (c) in a *head-marker-phrase*, the EXCONT value of the non-head is identical to the EXCONT value of the mother.
   (d) in a *head-adjunct-phrase*, the EXCONT value of the non-head is a component of the EXCONT value of the head, and
      i. if the non-head is an intersective modifier, then its EXCONT value is of the form $\alpha \wedge \beta$ and the INTCONT value of the head is a component of β.
      ii. if the nonhead is a non-intersective modifier, then it is of the form $\alpha(\beta)$ and the INTCONT value of the head is a component of β.
   (e) ...

6.2 Negative Concord in Polish

6.3 LRS Analysis

Description of the word *nie przyszedł* (*NM came*):

(49)
$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{nie przyszedł} \rangle \\ \text{SYNS LOC CONT} & \textit{cont} \\ \text{LF} & \begin{bmatrix} \textit{lrs} & \\ \text{EXCONT} & \boxed{0} \\ \text{INTCONT} & \boxed{1}\ \mathsf{come}'(x) \\ \text{PARTS} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}', \boxed{2}\neg\alpha, \right\rangle \end{bmatrix} \end{bmatrix}$$

$\& \ \boxed{1} \triangleleft \alpha \wedge \ \boxed{2} \triangleleft \boxed{0}$

Relevant parts of the lexical entry of *nikt* (*nobody*):

(50)
$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{nikt} \rangle \\ \text{SYNS LOC CONT} & \textit{cont} \\ \text{LF} & \begin{bmatrix} \textit{lrs} & \\ \text{EXCONT} & \boxed{5}\ \exists x[\gamma \wedge \delta] \\ \text{INTCONT} & \boxed{3}\ \mathsf{human}'(x) \\ \text{PARTS} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{human}', \boxed{4}\neg\beta, \boxed{5}, \boxed{5a}[\gamma \wedge \delta] \right\rangle \end{bmatrix} \end{bmatrix}$$

$\& \ \boxed{5} \triangleleft \beta$
$\& \ \boxed{3} \triangleleft \gamma$

The analysis of *Nikt nie przyszedł* (*Nobody came*):

[1] We take the noun to be the head of a quantified NP.

[2] $Qx[\rho \circ \nu]$ is shorthand for the description $\begin{bmatrix} \textit{quantifier} & \\ \text{VAR} & \textit{var} \\ \text{SCOPE} & \begin{bmatrix} \textit{l-const} & \\ \text{ARG1} & \rho \\ \text{ARG2} & \nu \end{bmatrix} \end{bmatrix}$.

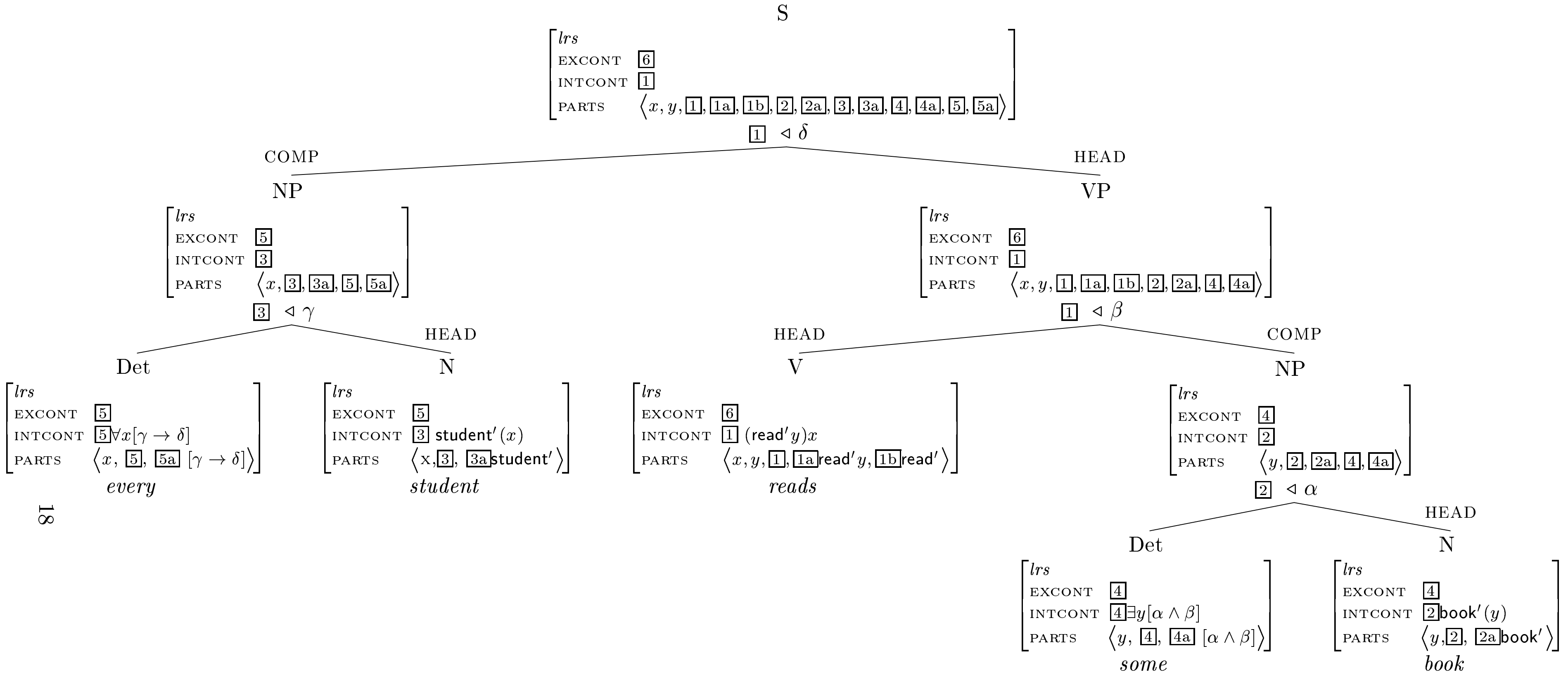


Figure 4: The LRS analysis of the sentence *Every student reads some book.*:

(51)

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{0} \\ \textsc{intcont} & \boxed{1} \\ \textsc{parts} & \left\langle x, x, \boxed{1}, \boxed{1a}, \boxed{2}, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{array}\right]$$

Nikt

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{5} \\ \textsc{intcont} & \boxed{3} \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{array}\right]$$

nie przyszedł

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{0} \\ \textsc{intcont} & \boxed{1} \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}, \boxed{2} \right\rangle \end{array}\right]$$

$$\begin{array}{l} \& \ \boxed{1} \lhd \alpha \\ \& \ \boxed{2} \lhd \boxed{0} \\ \& \ \boxed{5} \lhd \beta \\ \& \ \boxed{3} \lhd \gamma \\ \& \ \boxed{1} \lhd \delta \end{array}$$

The following EXCONT values are possible:

(52) a. $\neg\neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{4} \lhd \boxed{2} = \boxed{0})$ $= \exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$

b. $\neg\exists x \neg[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{2} \lhd \boxed{4} = \boxed{0})$ $= \forall x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$

c. $\neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{2} = \boxed{4} = \boxed{0})$

As only the third reading is available in Polish, we introduce the following, language-specific constraint:

The Negation Complexity Constraint:

(53) The NEGATION COMPLEXITY CONSTRAINT

For each sign, there may be at most one negation that is a component of the EXCONT value and has the INTCONT value as its component.

(54) Poślubię albo tę dziewczynę z Poznania, albo żadnej dziewczyny z żadnego miasta.
I will marry either [this girl].ACC from Poznan or [no girl].GEN from no city.
'I will either marry this girl from Poznan or no girl from any city.'

(55) Tomek nie może nie znać Marii.
Tomek NM may NM know Maria
'It is not the case that it is possible that Tomek does not know Maria.'

The Neg Criterion:

(56) The NEG CRITERION:

For every verb, if there is a negation in the EXCONT value of the verb that has scope over the verb's INTCONT value, then that negation must be an element of the verb's PARTS list.

(57) a. * Nikt przyszedł.
Nobody came

b. Relevant parts of the lexical entry of *przyszedł* (*came*):

$$\left[\begin{array}{ll} \multicolumn{2}{l}{\textit{word}} \\ \textsc{phon} & \langle \textit{przyszedł} \rangle \\ \textsc{synsem loc cont} & \textit{cont} \\ \textsc{lf} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{lrs}} \\ \textsc{excont} & \textit{me} \\ \textsc{intcont} & \boxed{1}\mathsf{come}'(x) \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}' \right\rangle \end{array}\right] \end{array}\right]$$

c.

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{4}\ \neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)] \\ \textsc{intcont} & \boxed{1}\ \mathsf{come}'(x) \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{array}\right]$$

Nikt

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{5}\ \exists x[\gamma \wedge \delta] \\ \textsc{intcont} & \boxed{3}\ \mathsf{human}'(x) \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{human}', \boxed{4}\neg\beta, \boxed{5}, \boxed{5a}[\gamma \wedge \delta] \right\rangle \end{array}\right]$$

przyszedł

$$\left[\begin{array}{ll} \textsc{excont} & \boxed{4} \\ \textsc{intcont} & \boxed{1}\ \mathsf{come}'(x) \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}' \right\rangle \end{array}\right]$$

$$\begin{array}{l} \& \ \boxed{5} \lhd \beta \\ \& \ \boxed{3} \lhd \gamma \\ \& \ \boxed{1} \lhd \delta \end{array}$$

6.4 Comments on the analysis

- Our analysis avoids mechanisms such as *negative absorption*:
  $\forall x_1 \neg \forall x_2 \ldots \neg \forall x_n \neg \phi \Longrightarrow \forall x_1 \forall x_2 \ldots \forall x_n \neg \phi$
- instead, it uses *identities*:
  - identities are the major analytical device of HPSG
  - identities arise wherever possible, so NC languages are predicted to be the unmarked case.
- The Negation Complexity Constraint and the Neg Criterion are adaptations of standard principles.
- The analysis of Polish n-words as inherently negative provide a basis for an account of the *almost* data.
- An LF-Ty2 analysis of the same empirical domain is much more complex (Richter and Sailer, 1999b).

6.5 Summary

- LRS does not introduce an additional level of "underspecification" but makes use of the fact that
  - a sign contains its logical form as its component
  - one description can characterize many distinct objects
  - as these objects are terms, we have a natural place for "underspecification" in the grammar,
  - but this does not lead to an underspecification in the denotation nor to an indirect representation.
- the empirical and the technical problems of denotationally underspecified or indirect systems are avoided.

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