Polysemy and coercion. A frame-based approach using LTAG and Hybrid Logic

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Introduction

Our approach to the syntax-semantics interface:

- Semantic composition is triggered by syntactic composition.
- Every meaning component is linked to some fragment of the syntactic structure.
- Semantic composition is monotonic.

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Our approach to the syntax-semantics interface:

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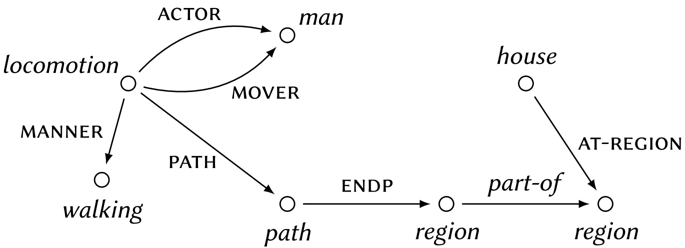
- Every meaning component is linked to some fragment of the syntactic structure.
- Semantic composition is monotonic.

Particularly challenging: **coercion** phenomena, where meaning "changes" in an apparently non-monotonic way, often explained by the presence of some hidden operator.

(1) a. Mary began the book.
    b. John left the party.
    c. Mary mastered the heavy book on magic.

Proposal: **Frames** as a way to represent rich lexical content.

- Semantic frames are commonly depicted as **graphs** with labeled nodes and edges, where **nodes** correspond to entities (individuals, events, ...) and **edges** to functional (or non-functional) relations between these entities.



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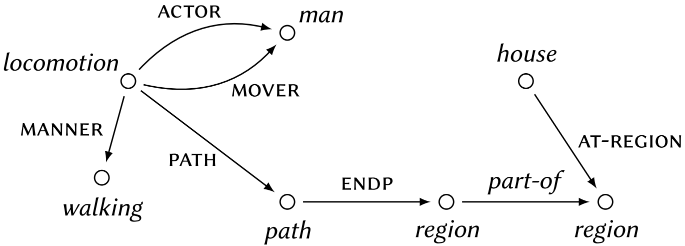

- Frames in this sense can be formalized as **feature structures** with types and relations (e.g. Kallmeyer & Osswald, 2013).

Introduction

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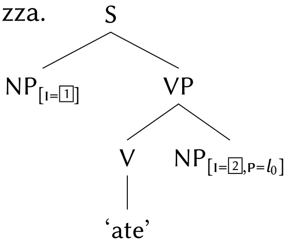
- In combination with frames, we need a syntactic framework that allows to represent constructions. Our choice: **Lexicalized Tree Adjoining Grammars (LTAG)**.
- Furthermore, we need the possibility of underspecification and quantification concerning the way we formulate constraints on frames. Our choice: **Hybrid Logic (HL)** and **underspecification** in the sense of hole semantics (Kallmeyer et al., 2016).

Introduction

(2) John ate pizza.



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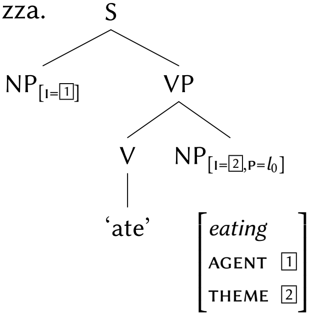

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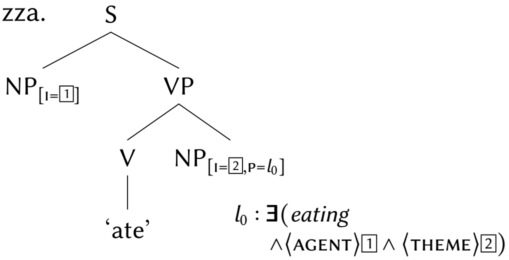

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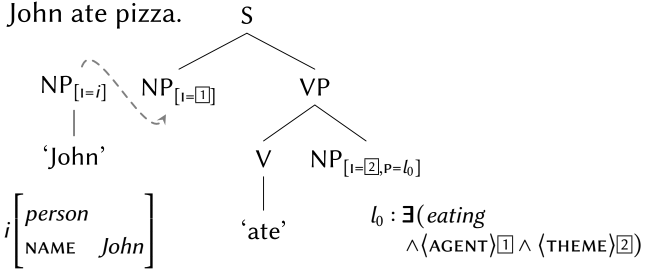

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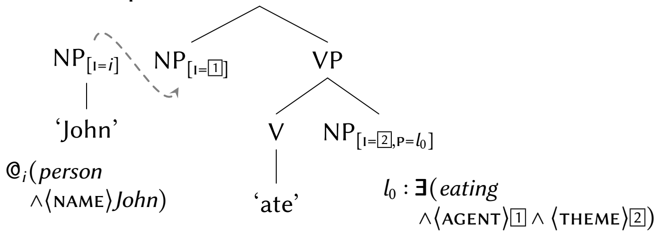

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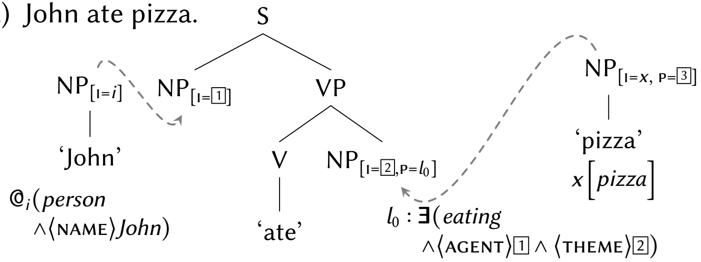

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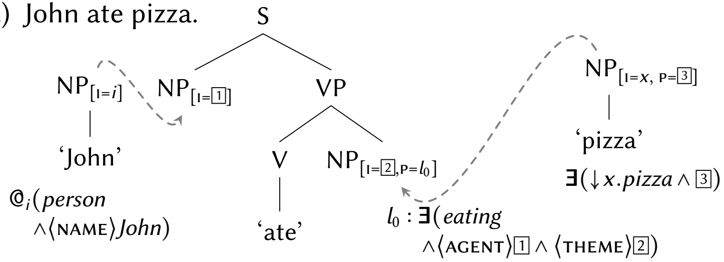

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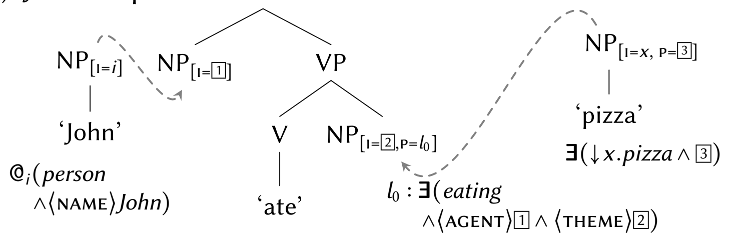
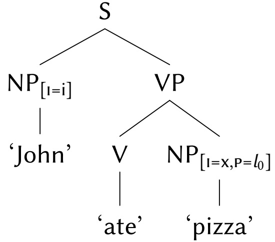


resulting derived tree-frame pair:



$@_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{John})$
$\exists(\downarrow x.\mathit{pizza} \wedge \exists(\mathit{eating} \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{theme} \rangle x))$

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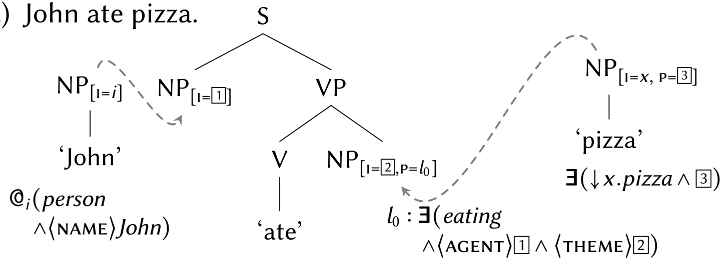

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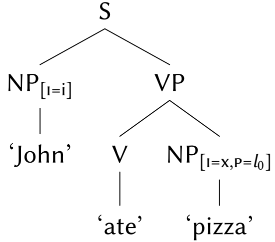

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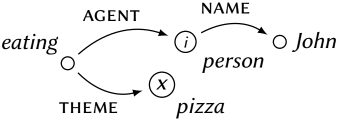
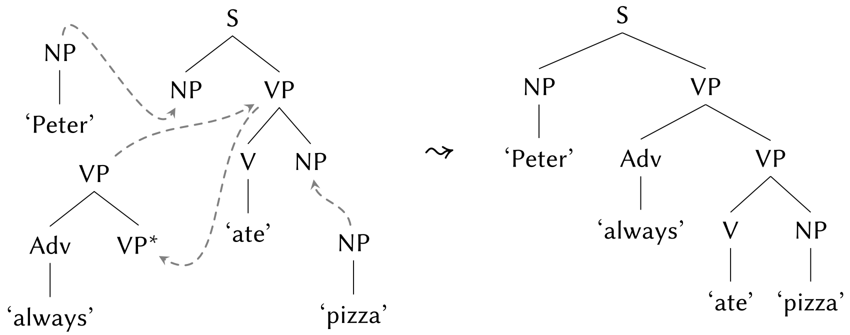


Lexicalized Tree Adjoining Grammar (LTAG, Joshi & Schabes 1997; Abeillé & Rambow 2000):

- Finite set of **elementary trees**.
- Larger trees are derived via the tree composition operations **substitution** (replacing a leaf with a new tree) and **adjunction** (replacing an internal node with a new tree).



Components of the syntax semantics interface (Kallmeyer & Osswald, 2013; Kallmeyer et al., 2016):

- Semantic representations are linked to entire elementary trees.
- Semantic representations: frames, expressed as typed feature structures, or rather HL formulas that describe frames.
- Interface features relate nodes in the syntactic tree to nodes in the frame graph.
- Composition by unification is triggered by substitution and adjunction.

Polysemy, dot objects and coercion

(3) a. The book is heavy. *phys-obj*

b. The book is interesting. *information*

The noun 'book' is inherently polysemous between a physical object interpretation and an information content interpretation (**dot object** nominals, Pustejovsky, 1995, 1998).

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The noun 'book' is inherently polysemous between a physical object interpretation and an information content interpretation (**dot object** nominals, Pustejovsky, 1995, 1998).

(4) a. John read the book.
    b. John read the story.
    c. John read the blackboard.

- The verb 'read' allows for the direct selection of the dot object *book* (4a).
- It also enables coercion of its complement from the type *information* (4b) as well as from the type *phys-obj* (4c).

Polysemy, dot objects and coercion

Semantics of the dot object nominal ‘book’ (Babonnaud et al., 2016):

- Background constraints:

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  $$\underset{\circ}{\mathit{info\text{-}carrier}} \rightsquigarrow \underset{\circ}{\mathit{info\text{-}carrier} \wedge \mathit{phys\text{-}obj}} \xrightarrow[\textsc{content}]{} \underset{\circ}{\mathit{information}}$$

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  $\forall(\textit{info-carrier} \rightarrow \textit{phys-obj} \wedge \langle\textsc{content}\rangle\textit{information})$

  $$\overset{\textit{info-carrier}}{\circ} \quad \rightsquigarrow \quad \overset{\textit{info-carrier} \wedge \textit{phys-obj}}{\circ} \xrightarrow[\textsc{content}]{} \overset{\textit{information}}{\circ}$$

- The lexical entry of 'book' only specifies that the word contributes an element of type *book*.

  By the above constraints, it follows that a *book* "node" is of type *info-carrier* (supertype of *book*) and *phys-obj* (supertype of *info-carrier*), and that it has an attribute ⟨CONTENT⟩ with a value of type *information*.

Polysemy, dot objects and coercion

Semantics of ‘read’ (inspired by Pustejovsky, 1998):

- Reading events consist of two subevents, the action of looking at a physical object (the **perception**) and the action of processing the provided information (the **comprehension**).

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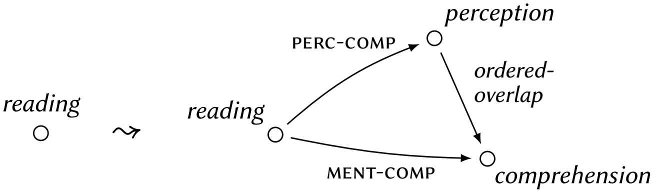
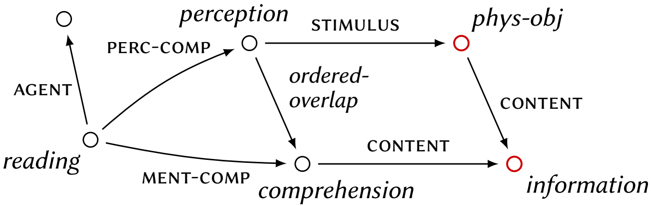
$$\forall(\mathit{reading} \to \exists v.\langle \textsc{perc-comp}\rangle(\mathit{perception} \wedge \langle \mathit{ordered\text{-}overlap}\rangle\, v) \\ \wedge \langle \textsc{ment-comp}\rangle(\mathit{comprehension} \wedge v))$$



Polysemy, dot objects and coercion

Semantics of 'read' (continued):

- The *perception* component has an attribute STIMULUS of type *phys-obj* and the *comprehension* node has an attribute CONTENT whose value is the *information* that is being read and which coincides with the CONTENT of the STIMULUS.



Polysemy, dot objects and coercion

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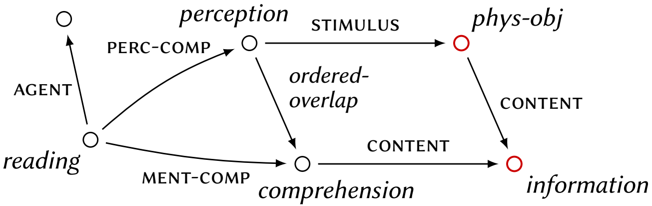
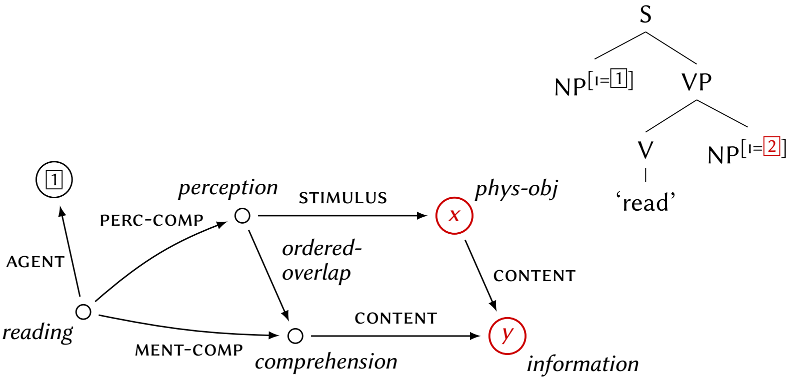


- The argument of ‘read’ can provide either the stimulus of the perception (*phys-obj*) or its content (*information*).

Polysemy, dot objects and coercion

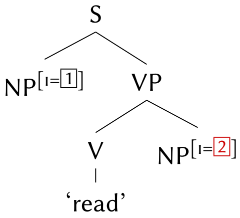
Semantics of ‘read’ and lexical anchoring:



$\boxed{2} \leftrightarrow x \vee \boxed{2} \leftrightarrow y$

Polysemy, dot objects and coercion

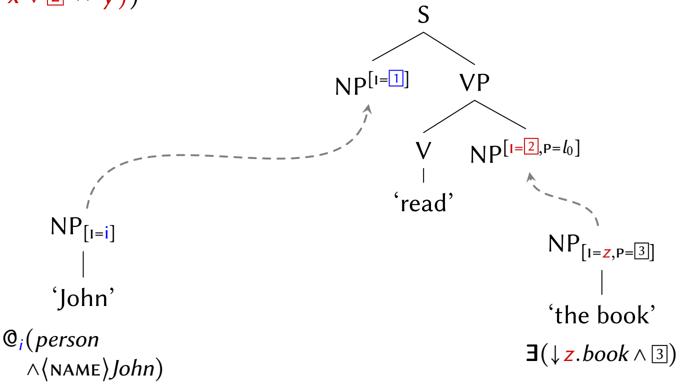
Semantics of ‘read’ and lexical anchoring:



$$
\begin{aligned}
\exists x.\exists y.\boldsymbol{\exists}(\mathit{reading} \wedge \langle \text{AGENT} \rangle \boxed{1} \\
&\wedge \langle \text{PERC-COMP} \rangle \langle \text{STIMULUS} \rangle x \\
&\wedge \langle \text{MENT-COMP} \rangle \langle \text{CONTENT} \rangle y \\
&\wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \text{CONTENT} \rangle (\mathit{information} \wedge y)) \\
&\wedge (\boxed{2} \leftrightarrow x \vee \boxed{2} \leftrightarrow y))
\end{aligned}
$$

Compositional derivation of 'John read the book' [= (4a)]

$$\begin{aligned} l_0 : \exists x.\exists y.\mathbf{\exists}(&\mathit{reading} \wedge \langle \textsc{agent} \rangle \boxed{1} \\ &\wedge \langle \textsc{perc-comp} \rangle \langle \textsc{stimulus} \rangle x \wedge \langle \textsc{ment-comp} \rangle \langle \textsc{content} \rangle y \\ &\wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \textsc{content} \rangle (\mathit{information} \wedge y)) \\ &\wedge (\boxed{2} \leftrightarrow x \vee \boxed{2} \leftrightarrow y)) \end{aligned}$$



Compositional derivation of ‘John read the book’ [= (4a)]

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l_0 : \exists x.\exists y.\mathbf{\exists}(&\mathit{reading} \wedge \langle \textsc{agent} \rangle i \\
&\wedge \langle \textsc{perc-comp} \rangle \langle \textsc{stimulus} \rangle x \wedge \langle \textsc{ment-comp} \rangle \langle \textsc{content} \rangle y \\
&\wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \textsc{content} \rangle (\mathit{information} \wedge y)) \\
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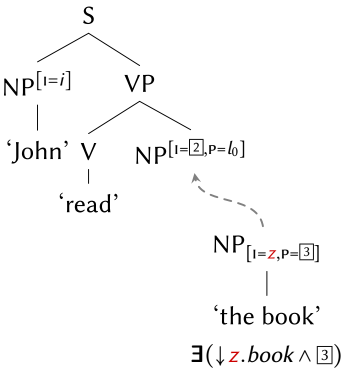
$$@_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{John})$$



Polysemy, dot objects and coercion

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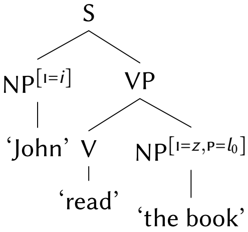
& \quad \wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \textsc{content} \rangle (\mathit{information} \wedge y)) \\
& \quad \wedge (z \leftrightarrow x \vee z \leftrightarrow y)) \\
& @_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{John}) \\
& \mathbf{\exists}(\downarrow z.\mathit{book} \wedge l_0)
\end{aligned}
$$



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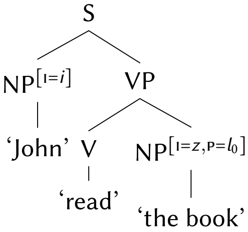

$x \leftrightarrow z$ because of the types

Polysemy, dot objects and coercion

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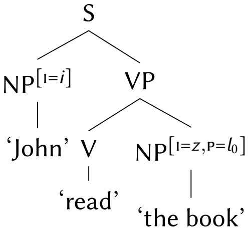

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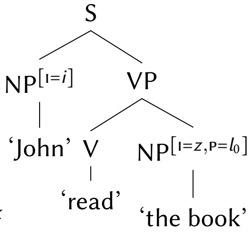

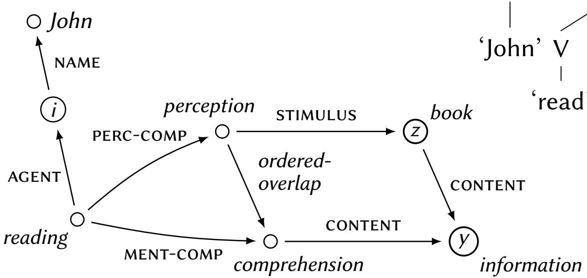

Polysemy, dot objects and coercion

(5) John read the story [= (4b)]

- Background constraints:

  $\forall(\mathit{story} \rightarrow \mathit{information})$

  $\forall(\mathit{phys\text{-}obj} \rightarrow \neg \mathit{information})$

- Therefore, when combining ‘story’ as a direct object with the above tree-frame pair for ‘read’, we obtain $y \leftrightarrow z$.

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- In addition, from the *reading* frame, we infer that there is a physical object that the story is written on and that John perceives this object while comprehending the story.

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- In addition, from the *reading* frame, we infer that there is a physical object that the story is written on and that John perceives this object while comprehending the story.

- In other words, the physical object is not contributed by the lexical entry of 'story' but by coercion, which means in our case by unification and subsequent extension of frames.

Further examples of coercion

(6) John left the party. [= (1b)]

leaving has a ⟨THEME⟩ attribute whose value is of type *location*.

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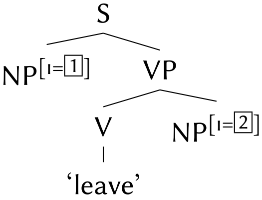
leaving has a ⟨THEME⟩ attribute whose value is of type *location*.

It is either the frame provided by the object NP or the value of the ⟨LOCATION⟩ attribute in that frame.



$$
\begin{aligned}
\exists x.\boldsymbol{\exists}(&\mathit{leaving} \wedge \langle\textsc{agent}\rangle\boxed{1} \\
&\wedge \langle\textsc{theme}\rangle(\mathit{location} \wedge x) \\
&\wedge (\boxed{2} \leftrightarrow x \vee @_{\boxed{2}}(\langle\textsc{location}\rangle x)))
\end{aligned}
$$

Further examples of coercion

(7) Mary mastered the heavy book on magic. [= (1c)]

While both ‘heavy’ and ‘on magic’ act as modifiers of ‘book’, they access different components of the underlying dot object.

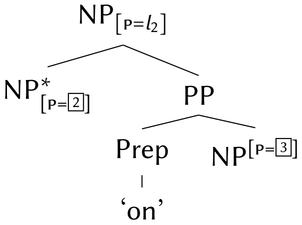
Further examples of coercion

(7) Mary mastered the heavy book on magic. [= (1c)]

While both ‘heavy’ and ‘on magic’ act as modifiers of ‘book’, they access different components of the underlying dot object.

The following (simplified) semantic representation of ‘on’ allows for the modification of the *information* aspect of the modified noun:

$$
\begin{aligned}
l_2 : \boxed{2} \wedge \exists x.(x \vee \langle \textsc{content} \rangle x) \\
\wedge\, @_x(\mathit{knowledge} \wedge \langle \textsc{topic} \rangle \boxed{3})
\end{aligned}
$$



Background constraint:

$$\forall(\mathit{knowledge} \rightarrow \mathit{information} \wedge \langle \textsc{topic} \rangle \top)$$

Quantification and polysemous nouns

The "**Quantification Puzzle**" (Asher & Pustejovsky, 2005, 2006)

(8) a. Mary carried off every book in the library.

b. Mary read every book in the library.

Quantification and polysemous nouns

The "**Quantification Puzzle**" (Asher & Pustejovsky, 2005, 2006)

(8) a. Mary carried off every book in the library.
    b. Mary read every book in the library.

Issues related to the analysis of (8b):

- Usually there is **no one-to-one correspondence** between the physical books in the library and the book contents.
- Moreover, (8b) may be true even if **no physical copy** from the library has been ever used by Mary.

Quantification and polysemous nouns

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Asher's (2011) proposal:

- Reification of dot type objects; the different aspects of a dot object are accessed via functors (using a category theoretic approach).

Quantification and polysemous nouns

Our proposal:

- Keep the basic representation of books as **physical information carriers**.
- **Embed** the basic structure in an **underspecified representation** which allows the referential index of the NP to refer to the physical or to the informational component.

Quantification and polysemous nouns

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- **Embed** the basic structure in an **underspecified representation** which allows the referential index of the NP to refer to the physical or to the informational component.

Further complications (not taken into account in the following):

- In **multi-volume editions** of collected works, one novel can be **distributed** over two volumes, and the second volume may contain another novel in addition to the final part of the first novel.
- Consequence: Need to quantify over the elements of an appropriate **segmentation** of a (**mereological**) **sum** of the CONTENT values of the (physical) books in the library.

Quantification and polysemous nouns

Revision of the lexical entry of 'book':

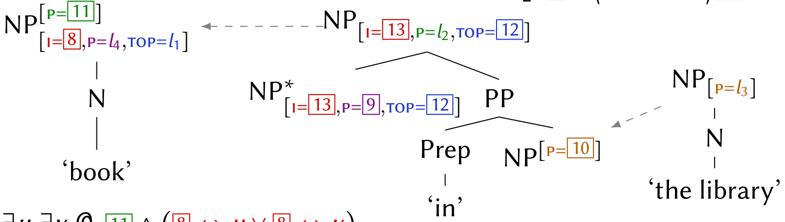
- 'book' explicitly provides an **underspecified I feature** at the syntax-semantics interface.
- The value of this feature can either be a variable referring to the *phys-obj* node or a variable referring to the *information* node (expressed by a disjunction in the HL formula).

$$
\begin{array}{l}
\mathrm{NP}^{[\textsc{p}=\boxed{11}]}_{[\textsc{i}=\boxed{8},\textsc{p}=l_4,\textsc{top}=l_1]} \\
\quad | \\
\quad \mathrm{N} \qquad l_1 \colon \exists u.\exists v.@_u\boxed{11} \wedge (\boxed{8} \leftrightarrow u \vee \boxed{8} \leftrightarrow v), \\
\quad | \qquad\quad l_4 \colon \mathit{book} \wedge \langle \textsc{content} \rangle (\mathit{information} \wedge v) \\
\text{`book'}
\end{array}
$$

⇒ The contributed frame structure remains the same but the contribution to predicate argument structure is underspecified.

(9) every book in the library

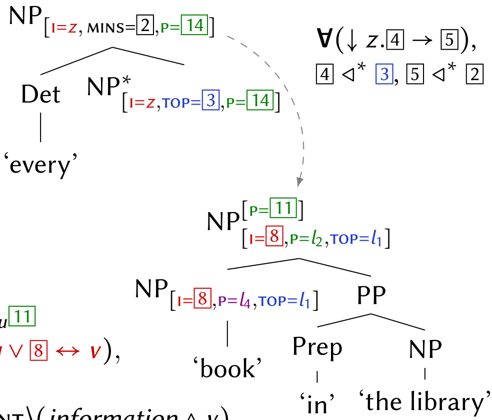
l_2: $\boxed{9} \wedge \langle \text{LOCATION} \rangle \boxed{10}$



l_1: $\exists u.\exists v.@_u \boxed{11} \wedge (\boxed{8} \leftrightarrow u \vee \boxed{8} \leftrightarrow v)$,
l_4: $\mathit{book} \wedge \langle \text{CONTENT} \rangle (\mathit{information} \wedge v)$

l_3: $\mathit{library}$

(9) every book in the library

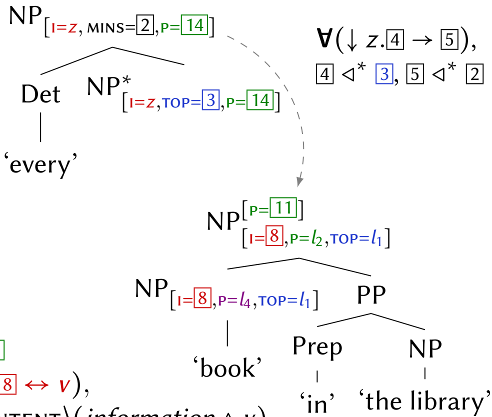


$\forall(\downarrow z.\boxed{4} \rightarrow \boxed{5})$,
$\boxed{4} \triangleleft^* \boxed{3}$, $\boxed{5} \triangleleft^* \boxed{2}$

l_1: $\exists u.\exists v.@_u\boxed{11}$
$\quad\wedge(\boxed{8} \leftrightarrow u \vee \boxed{8} \leftrightarrow v)$,
l_4: *book*
$\quad\wedge\langle\text{CONTENT}\rangle(\textit{information} \wedge v)$,
l_2: $l_4 \wedge \langle\text{LOCATION}\rangle l_3$
l_3: *library*

Quantification and polysemous nouns

(9) every book in the library

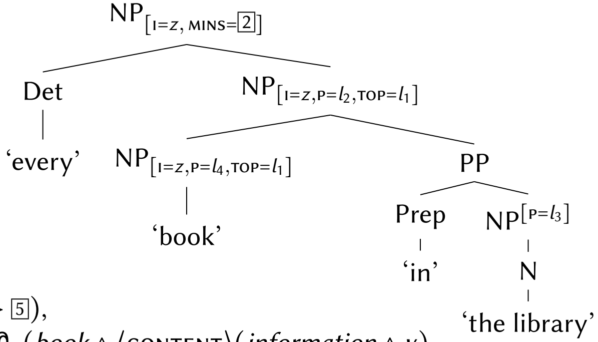


$\forall(\downarrow z.\boxed{4} \rightarrow \boxed{5}),$
$\boxed{4} \lhd^{*} \boxed{3},\ \boxed{5} \lhd^{*} \boxed{2}$

l_1: $\exists u.\exists v.@_u\boxed{11}$
$\quad \wedge(\boxed{8} \leftrightarrow u \vee \boxed{8} \leftrightarrow v),$
l_2: $\mathit{book} \wedge \langle \textsc{content} \rangle(\mathit{information} \wedge v)$
$\quad \wedge \langle \textsc{location} \rangle \mathit{library}$

Quantification and polysemous nouns

Resulting derived tree–frame pair (including top-bottom unification at the NP root):

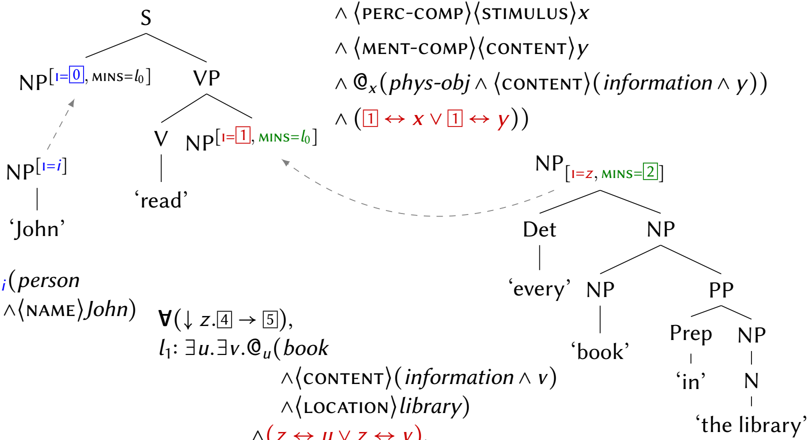


$$
\begin{aligned}
&\forall(\downarrow z.\boxed{4} \rightarrow \boxed{5}),\\
&l_1\text{: } \exists u.\exists v.@_u(\mathit{book} \wedge \langle\textsc{content}\rangle(\mathit{information} \wedge v)\\
&\qquad\qquad\qquad \wedge\langle\textsc{location}\rangle \mathit{library})\\
&\qquad\quad \wedge(z \leftrightarrow u \vee z \leftrightarrow v),\\
&\boxed{4} \triangleleft^* l_1,\ \boxed{5} \triangleleft^* \boxed{2}
\end{aligned}
$$

Quantification and polysemous nouns

Combining the quantified NP with ‘read’ and ‘John’:

$$
\begin{aligned}
l_0 : \exists x.\exists y.\mathbf{\exists}(&\mathit{reading} \wedge \langle\textsc{agent}\rangle\boxed{0}\\
&\wedge \langle\textsc{perc-comp}\rangle\langle\textsc{stimulus}\rangle x\\
&\wedge \langle\textsc{ment-comp}\rangle\langle\textsc{content}\rangle y\\
&\wedge @_x(\mathit{phys\text{-}obj} \wedge \langle\textsc{content}\rangle(\mathit{information} \wedge y))\\
&\wedge (\boxed{1} \leftrightarrow x \vee \boxed{1} \leftrightarrow y))
\end{aligned}
$$



$@_i(\mathit{person}$
$\wedge\langle\textsc{name}\rangle\mathit{John})$

$$
\begin{aligned}
&\mathbf{\forall}(\downarrow z.\boxed{4} \rightarrow \boxed{5}),\\
&l_1 : \exists u.\exists v.@_u(\mathit{book}\\
&\qquad\wedge\langle\textsc{content}\rangle(\mathit{information} \wedge v)\\
&\qquad\wedge\langle\textsc{location}\rangle\mathit{library})\\
&\quad\wedge(z \leftrightarrow u \vee z \leftrightarrow v),\\
&\boxed{4} \lhd^* l_1,\ \boxed{5} \lhd^* \boxed{2}
\end{aligned}
$$

Quantification and polysemous nouns

Performing the unifications and collecting the HL formula yields the following underspecified HL representation:

$$
\begin{aligned}
&\boldsymbol{\forall}(\downarrow z.\boxed{4} \rightarrow \boxed{5}),\\
&l_1\colon \exists u.\exists v.@_u(\mathit{book} \wedge \langle \textsc{content}\rangle(\mathit{information} \wedge v)\\
&\qquad\qquad\qquad\qquad \wedge\langle \textsc{location}\rangle \mathit{library})\\
&\qquad\quad \wedge(z \leftrightarrow u \vee z \leftrightarrow v),\\
&l_0\colon\ \exists x.\exists y.\boldsymbol{\exists}(\mathit{reading} \wedge \langle \textsc{agent}\rangle i\\
&\qquad\qquad \wedge\langle \textsc{perc-comp}\rangle\langle \textsc{stimulus}\rangle x\\
&\qquad\qquad \wedge\langle \textsc{ment-comp}\rangle\langle \textsc{content}\rangle y\\
&\qquad\qquad \wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \textsc{content}\rangle(\mathit{information} \wedge y))\\
&\qquad\qquad \wedge(z \leftrightarrow x \vee z \leftrightarrow y)),\\
&@_i(\mathit{person} \wedge \langle \textsc{name}\rangle \mathit{John})\\
&\boxed{4} \lhd^*\ l_1,\ \ \boxed{5} \lhd^*\ l_0
\end{aligned}
$$

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&\qquad\qquad\qquad\qquad \wedge\langle\textsc{location}\rangle \mathit{library})\\
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&\qquad\qquad\quad \wedge\langle\textsc{perc-comp}\rangle\langle\textsc{stimulus}\rangle x\\
&\qquad\qquad\quad \wedge\langle\textsc{ment-comp}\rangle\langle\textsc{content}\rangle y\\
&\qquad\qquad\quad \wedge @_x(\mathit{phys\text{-}obj} \wedge \langle\textsc{content}\rangle(\mathit{information} \wedge y))\\
&\qquad\qquad\quad \wedge(z \leftrightarrow x \vee z \leftrightarrow y)),\\
&@_i(\mathit{person} \wedge \langle\textsc{name}\rangle \mathit{John})\\
&\boxed{4} \lhd^* l_1,\ \boxed{5} \lhd^* l_0
\end{aligned}
$$

The final disambiguation necessarily yields $\boxed{4} \rightarrow l_1$ and $\boxed{5} \rightarrow l_0$.

Quantification and polysemous nouns

Final conjoined HL formula after disambiguation:

$$
\begin{aligned}
&\boldsymbol{\forall}(\downarrow z.\exists u.\exists v.@_u(\mathit{book} \wedge \langle \textsc{content} \rangle(\mathit{information} \wedge v) \\
&\qquad\qquad\qquad\qquad\qquad \wedge \langle \textsc{location} \rangle \mathit{library}) \\
&\qquad\qquad\qquad \wedge (z \leftrightarrow u \vee z \leftrightarrow v) \\
&\quad \rightarrow \exists x.\exists y.\boldsymbol{\exists}(\mathit{reading} \wedge \langle \textsc{agent} \rangle i \\
&\qquad\qquad\qquad \wedge \langle \textsc{perc-comp} \rangle \langle \textsc{stimulus} \rangle x \\
&\qquad\qquad\qquad \wedge \langle \textsc{ment-comp} \rangle \langle \textsc{content} \rangle y \\
&\qquad\qquad\qquad \wedge @_x(\mathit{phys\text{-}obj} \wedge \langle \textsc{content} \rangle(\mathit{information} \wedge y)) \\
&\qquad\qquad\qquad \wedge (z \leftrightarrow x \vee z \leftrightarrow y))) \\
&\wedge @_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{John})
\end{aligned}
$$

Quantification and polysemous nouns

Final conjoined HL formula after disambiguation:

$$
\begin{aligned}
&\mathbf{\forall}(\downarrow z.\exists u.\exists v.@_u(book \wedge \langle \textsc{content} \rangle (information \wedge v) \\
&\qquad\qquad\qquad\qquad\qquad\qquad \wedge \langle \textsc{location} \rangle library) \\
&\qquad\qquad\qquad \wedge (z \leftrightarrow u \vee z \leftrightarrow v) \\
&\qquad \to \exists x.\exists y.\mathbf{\exists}(reading \wedge \langle \textsc{agent} \rangle i \\
&\qquad\qquad\qquad\qquad \wedge \langle \textsc{perc-comp} \rangle \langle \textsc{stimulus} \rangle x \\
&\qquad\qquad\qquad\qquad \wedge \langle \textsc{ment-comp} \rangle \langle \textsc{content} \rangle y \\
&\qquad\qquad\qquad\qquad \wedge @_x(phys\text{-}obj \wedge \langle \textsc{content} \rangle (information \wedge y)) \\
&\qquad\qquad\qquad\qquad \wedge (z \leftrightarrow x \vee z \leftrightarrow y))) \\
&\wedge @_i(person \wedge \langle \textsc{name} \rangle John)
\end{aligned}
$$

Two options for interpreting the quantified variable z:

1. quantification over physical objects: $z \leftrightarrow u$ and $z \leftrightarrow x$, or
2. quantification of informational contents: $z \leftrightarrow v$ and $z \leftrightarrow y$.

Quantification and polysemous nouns

The corresponding readings are:

1. Quantification over physical objects: For every physical copy of a book in the library, it holds that John read exactly this copy.
2. Quantification of informational contents: For every content of a book in the library, it holds that John read some physical information carrier with exactly this content.

Quantification and polysemous nouns

The second (weaker) reading can be characterized as follows in terms of frame graphs:

1. $\textit{person}\ (i) \xrightarrow{\textsc{name}} \circ\ \textit{John}$

Quantification and polysemous nouns

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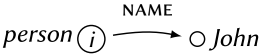
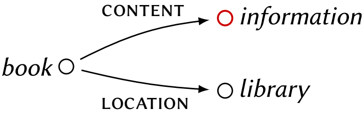
1. 

2. and



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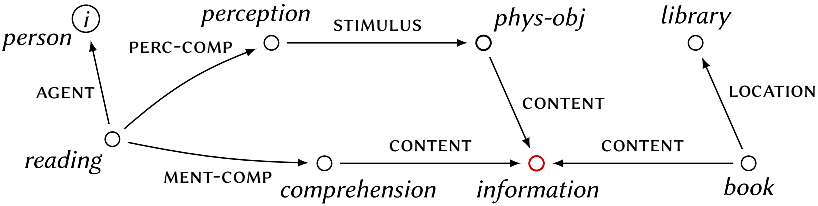

Conclusion & future work

- We presented a flexible model of the syntax-semantics interface that allows us to account for polysemy and for different coercion phenomena in a monotonic and compositional way without assuming any hidden operators.

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- Possible next step: A more systematic analysis of the various kinds of dot object nouns studied in the literature.

Conclusion & future work

- We presented a flexible model of the syntax-semantics interface that allows us to account for polysemy and for different coercion phenomena in a monotonic and compositional way without assuming any hidden operators.
- Possible next step: A more systematic analysis of the various kinds of dot object nouns studied in the literature.
- Many further issues. Example:

  (10) Mary read the heavy book on magic. She read part of it on her ebook reader for convenience.

  Issue: Variability of the physical carrier while reading a single book (understood as an informational object).

  Possible solution: Describe the reading event as consisting of different subevents, each of which is bound to a certain physical information carrier.

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Merci pour votre attention!