Recursion in Semantics?
The Case of Binding

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Interfaces + Recursion = Language
The View from Syntax and Semantics
March 24, 2005

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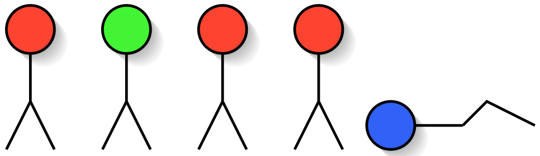
Binding: The Phenomenon

His in (1) doesn't pick out a single boy-representation.

(1) Every red boy is standing on his feet.



Three semantic accounts:

- Index-Binding (Frege, Tarski)
- Combinatorial Logic (Schönfinkel, Curry)
- Flat Binding (new today)

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Index-Binding (Frege, Tarski)

Basic assumptions of one popular version:

- bound elements bear abstract indices
- the semantic model contains a *assignment sequence*
- indexed λ-operators can modify the assignment sequence

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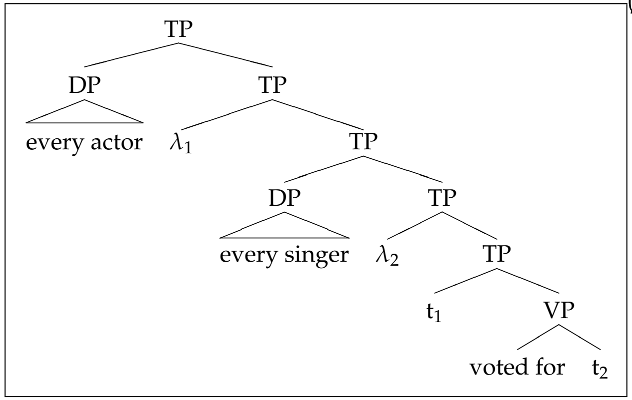
Index-Binding: Example, Step 1

(2) Every actor voted for every singer.



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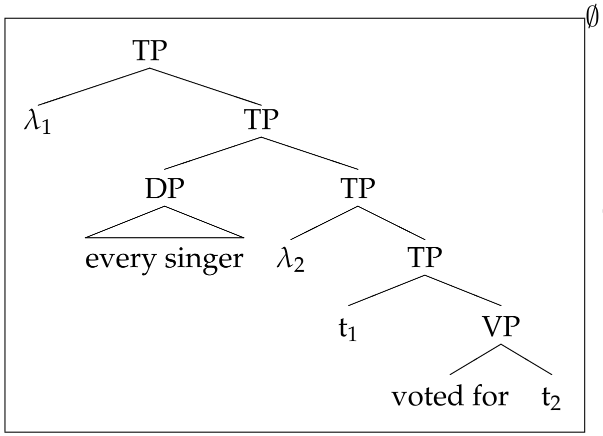
Index-Binding: Example, Step 2

(3) Every actor voted for every singer.

For every actor A, evaluate:



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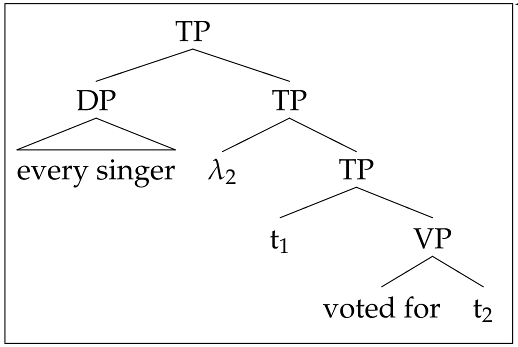
Index-Binding: Example, Step 3

(3) Every actor voted for every singer.

For every actor A, evaluate:



$\{1 \to A\}$

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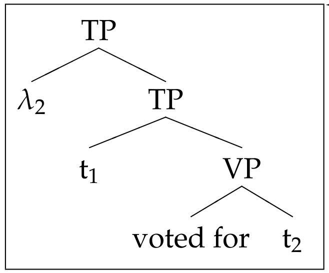
Index-Binding: Example, Step 4

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:



$\{1 \rightarrow A\}$

(S)

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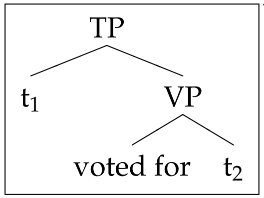
Index-Binding: Example, Step 5

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:



$$\left\{ \begin{array}{l} 1 \rightarrow A \\ 2 \rightarrow S \end{array} \right\}$$

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Index-Binding: Example, Step 6

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:

$$\boxed{\text{voted for}}^{\left\{\begin{array}{l}1 \rightarrow \mathsf{A}\\ 2 \rightarrow \mathsf{S}\end{array}\right\}}\left(\boxed{t_2}^{\left\{\begin{array}{l}1 \rightarrow \mathsf{A}\\ 2 \rightarrow \mathsf{S}\end{array}\right\}}\right)\left(\boxed{t_1}^{\left\{\begin{array}{l}1 \rightarrow \mathsf{A}\\ 2 \rightarrow \mathsf{S}\end{array}\right\}}\right)$$

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Index-Binding: Example, Step 7

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:

$$\boxed{\text{voted for}}\text{(S)(A)}$$

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Index-Binding: Cons

- indices in syntactic structures
- sequences in semantic models

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Combinatorial Logic

Basic assumptions:

- argument positions may remain open
- new semantic rules ('combinators') percolate open argument positions up

Cons:

- requires recursive type system: a constituent with *n* bound pronouns may be an *n*-place predicate
- empirical problems with some agreement cases

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My: Proposal: Flat Binding

Basic assumptions of my approach:

- bound elements are definite descriptions
- the semantic model contains a *assignment set*
- unindexed λ-operators extend the assignment set

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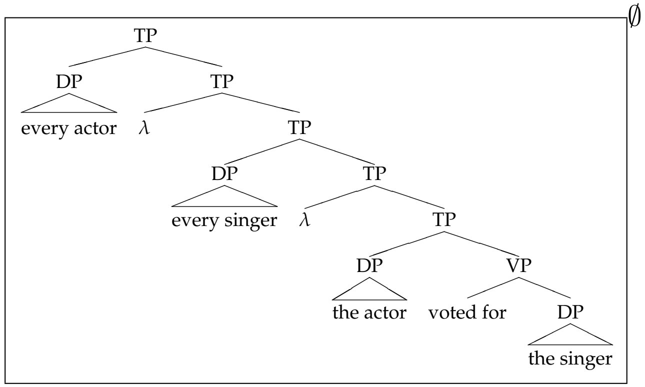
Flat Binding: Example, Step 1

(3) Every actor voted for every singer.



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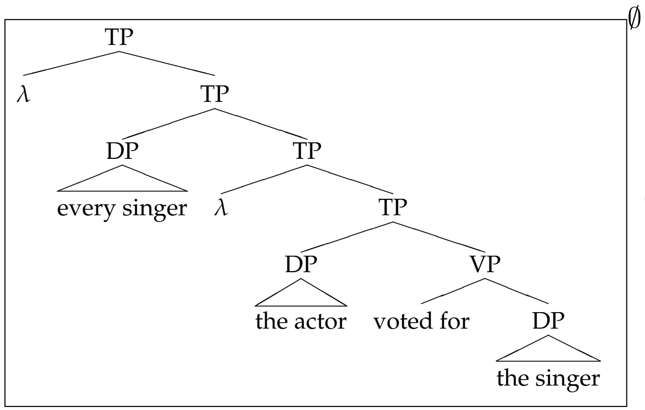
Flat Binding: Example, Step 2

(3) Every actor voted for every singer.

For every actor A, evaluate:



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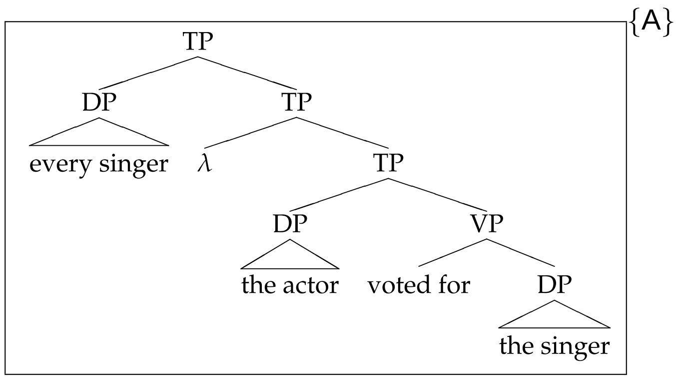
Flat Binding: Example, Step 3

(3) Every actor voted for every singer.

For every actor A, evaluate:



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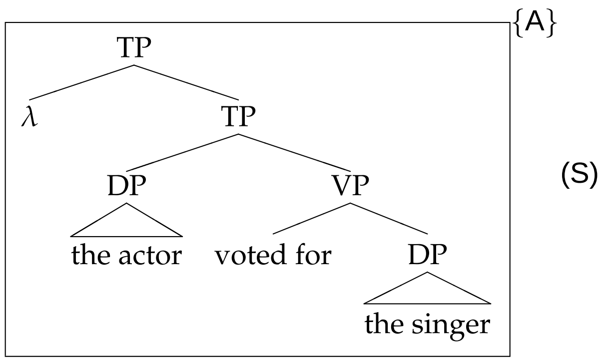
Flat Binding: Example, Step 4

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:



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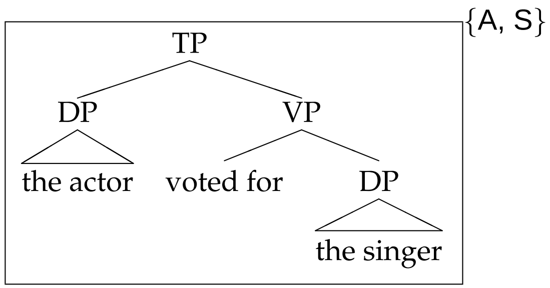
Flat Binding: Example, Step 5

(3) Every actor voted for every singer.

For every actor A and every singer S, evaluate:



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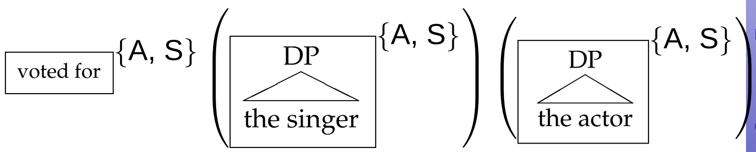
Flat Binding: Example, Step 6

(3) Every actor voted for every singer.

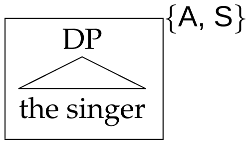
For every actor A and every singer S, evaluate:



The Overlap Problem

(3) Every actor voted for every singer.

The definite description only uniquely denotes an element of the set {A, S} if A is not also a singer.



But the sentence can be used when there is overlap:

(4) Every actor voted for every singer.
can entail: Every singing actor voted for himself.

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Concepts in Semantic Models

Our knowledge of object properties is always incomplete. Therefore: Represent objects as concepts; functions from possible worlds to individuals:

(5) Sean, actor:
$$f : \{w \colon \text{Sean is an actor in } w\} \longrightarrow D_e$$
$$w \longrightarrow \text{Sean}$$

(6) Sean, actor and singer:
$$f : \{w \colon \text{Sean is an actor and singer in } w\} \longrightarrow D_e$$
$$w \longrightarrow \text{Sean}$$

A concept x has property P, if x selects an individuals with property P whereever x is defined.

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Maximal Concepts

The smaller its domain, the more properties or a concept are known. On the other hand, a maximal P-concept has only property P and properties.

(7) Definition: A concept x is maximal for property P, if it has property P and:

$$\text{domain}(x) = \{w \mid \exists y : P(y(w))\}$$

Example: A maximal girl-concept P can never have the property 'under 20 years old': We can imagine a possible world where humans first live as genderless caterpillars underground before they hatch. A maximal girl-concept must select a 20-year old individual in this world.

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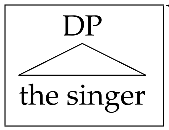
Overlap Resolved

Proposal: Quantifiers range of maximal concepts only.

(3) Every actor voted for every singer.

Since A is a maximal actor concept and S a maximal singer concept, the definite denotes uniquely:



$^{\{A, S\}} = S$

Now, the concepts are first applied to the actual world, and then the verb.

$\boxed{\text{voted for}}(S(w_0))(A(w_0))$

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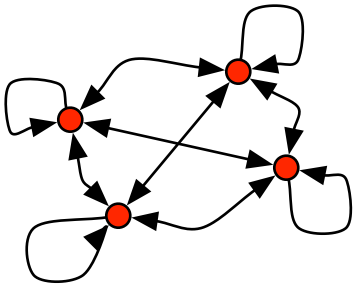
Identical Quantifiers I

Identical quantifiers should range over the same maximal concepts:

(8) Every dot is connected to every dot.



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Identical Quantifiers II

Quantifier can always have additional, silent restrictors (Westerståhl, 1985; Stanley and Szabo, 2000): (9) can mean that the sailors on board wave to the sailors on shore.

(9) Every sailor waved to every sailor. (Stanley and Williamson, 1995)

The silent restrictors can be extensionally equivalent:

(10) Every (red) dot is connected to every (round) dot.

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Relevant Empirical Evidence

Conceptual: no more indices in syntax, no more sequences in semantics
Further sources of evidence:

- lexical content (see below)
- types of bound elements (Landman, 2004)
- available quantifiers (in progress)
- pronoun agreement (in progress)

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Evidence for Lexical Content

Representation of traces and pronouns on the two theories:

Index-binding	Flat binding
i	DP the *P*

Traces: Lexical content (= obligatory reconstruction): (Chomsky, 1993; Fox, 1999; Sauerland, 1998, 2004a)
Pronouns: Lexical content, specifically bound ones: Sauerland (2000, 2001, 2004b).

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Pronouns and Focus

Contrastive focus marks meaning differences (see Schwarzschild 1999):

(11) On Monday, Mary praised Bill, and . . .

a. . . . on [Tuesday]$_F$, Mary praised [JOHN]$_F$.

b. #on [Tuesday]$_F$, [MARY]$_F$ praised [JOHN]$_F$.

Two bound pronouns can be contrasted, if and only if their lexical content is different (Sauerland, 1998, 2000, 2004b).

(12) On Monday, every boy called his mother, and . . .

a. . . . on [Tuesday]$_F$, every [TEAcher]$_F$ called [HIS]$_F$ mother.

b. #. . . on [Tuesday]$_F$, every boy called [HIS]$_F$ mother (again).

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Explanation

Flat binding explains this contrast:

(13) every boy λ the boy called the boy's mother, and . . .

a. every t. λ the t. called [the teacher]$_F$'s mother

b. #every boy λ the boy called [the boy]$_F$'s mother

Index-binding has no explanation for the contrast:

(14) every boy λ_1 1 called 1's mother, and . . .

a. . . . every teacher λ_1 1 called [1]$_F$'s mother

b. #. . . every boy λ_1 1 called [1]$_F$'s mother

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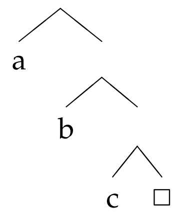
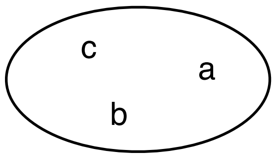
Where is Recursion?

- no indices in syntax
- no sequences in semantic models

Sequence: $\langle a, b, c \rangle$ Set: $\{a, b, c\}$





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Modeltheoretic Semantics

syntactic structure $\longleftrightarrow$ semantic model

The current semantic model is generated in the mind and affected by several factors:

- ontological principles (innate)
- sensory stimulation
- memory
- the prior semantic model
- prior language input
- effects of other cognitive domains

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Limiting Structural Complexity

Model-theoretic semantics has not sought to constrain the complexity of semantic models.

Hypothesis:

The processes generating the current semantic model are not recursive (except for reference to the prior semantic model).

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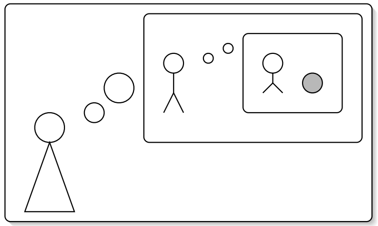
Recursion Outside Syntax

- purely semantic recursion: recursive structure introduced solely to make compositional interpretation possible
- natural numbers:

  1, successor(1), successor(successor(1)), . . .
- social cognition/theory of mind:



Mary thinks that Bill knows that John is playing football.

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Numbers/Theory of Mind

Numbers and language (Bloom, 1994; Gelman and Butterworth, 2005):

- number vs. approximate numerosity (Dehaene, 1999)
- acquisition of exact numbers follows that of number words (Feigenson et al., 2004)
- exact numbers not perceived by speakers of languages lacking number words (Gordon, 2004)

Theory of mind and language:

- acquisition of theory of mind follows that of *think* and similar verbs: (de Villiers and de Villiers, 2000)
- training of *think* accelerates acquisition of theory of mind: (Lohmann and Tomasello, 2003; Hale and Tager-Flusberg, 2003)

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Conclusions

- no indices in syntax
- no sequences in semantic models
- semantic models may not involve recursion

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