Anaphora and Indefinites in Type Logical Grammar

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Outline of talk

- Anaphora in Type Logical Grammar
- Extrapolation to indefinites
- Linguistic consequences:
  - Indefinites and scope
  - Sluicing

Anaphora in TLG

Jacobson's proposal (Jacobson 1992, 1994)

- Semantics: pronouns denote identity functions
- Syntax: next to forward and backward looking categories, there are categories that look for an antecedent ($A|B$)
- Pronouns: category $np|np$

Adaption to TLG (Jäger 2001)

$$\mathcal{F} := \mathcal{A} \| \mathcal{F} \backslash \mathcal{F} \| \mathcal{F} \bullet \mathcal{F} \| \mathcal{F} / \mathcal{F} \| \mathcal{F} | \mathcal{F}$$

- Associative Lambek Calculus **L** is extended to $\mathbf{L}_{|}$ by rule of use and rule of proof for $|$

Rule of use

$$\frac{Y \Rightarrow M : B \qquad X, x : B, Z, y : A, W \Rightarrow N : C}{X, Y, Z, z : A|B, W \Rightarrow N[M/x][(zM)/y] : C} |L$$

- In presence of Cut equivalent to

$$\frac{}{x : A, y : B|A \Rightarrow \langle x, (yx) \rangle : A \bullet B}$$

plus

$$\frac{}{x : A, z : C, y : B|A \Rightarrow \langle x, z, (yx) \rangle : A \bullet C \bullet B}$$

Rule of proof

$$\frac{X, x : A, Y \Rightarrow M : B}{X, y : A|C, Y \Rightarrow \lambda z.M[yz/x] : B|C} \, [|R]$$

Theorem 1 *Cut is admissible in* $\mathbf{L}_|$.

- Proof: standard

Corollary 1 $\mathbf{L}_|$ *is decidable and has the finite reading property.*

Natural Deduction format

$$\dfrac{\begin{array}{ccc} \vdots & \dfrac{M : A|B}{Mx : A}\, i & \vdots \\ \vdots & \vdots & \vdots \end{array}}{\dfrac{N : C}{\lambda x N : C|B}\, |I, i} \qquad [M : A]_i \quad \cdots \quad \dfrac{N : B|A}{[NM : B]_i}\, |E, i$$

- Only constraint on anaphora resolution: The antecedent must precede the pronoun

Simple cases

(1) a. John said he walked

b.

$$\dfrac{\dfrac{\textit{John}}{[\text{J'} : np]_i}\,lex \qquad \dfrac{\dfrac{\textit{said}}{\text{SAY'} : np\backslash s/s}\,lex \qquad \dfrac{\dfrac{\dfrac{\textit{he}}{[\lambda x.x : np|np]_i}\,lex}{\text{J'} : np}\,|E \qquad \dfrac{\textit{walked}}{\text{WALK'} : np\backslash s}\,lex}{\text{WALK' J'} : s}\,\backslash E}{\text{SAY'(WALK' J')} : np\backslash s}\,/E}{\text{SAY'(WALK' J')J'} : s}\,\backslash E$$

Pronoun binding

(2) a. Everybody loves his mother

b.

$$\dfrac{\dfrac{\dfrac{\dfrac{\textit{everybody}}{\begin{matrix}q(np,s,s)\\ \textsc{every'}\end{matrix}}\,lex}{\begin{matrix}[np]_i\\ x\end{matrix}}\,1 \qquad \dfrac{\dfrac{\textit{loves}}{\begin{matrix}(np\backslash s)/np\\ \textsc{love'}\end{matrix}}\,lex \quad \dfrac{\dfrac{\textit{his mother}}{\begin{matrix}[np|np]_i\\ \textsc{mother'}\end{matrix}}}{\begin{matrix}np\\ \textsc{mother'}x\end{matrix}}\,|E}{\begin{matrix}np\backslash s\\ \textsc{love'}(\textsc{mother'}x)\end{matrix}}\,/E}{\begin{matrix}s\\ \textsc{love'}(\textsc{mother'}x)x\end{matrix}}\,\backslash E}{\begin{matrix}s\\ \textsc{every'}(\lambda x.\textsc{love'}(\textsc{mother'}x)x)\end{matrix}}\,qE,1$$

Covering indefinites

Basic idea

- Consider the minimal pair

(3) a. It moved
    b. Something moved

- Denotation of (3a):

$$\lambda x.\textsc{move'}x$$

- Proposal: (a) and (b) have the same denotation
- Difference in truth conditions and semantic contribution in larger structures is due to different syntactic categories

Type Logical implementation

- yet another substructural implication, "$\leadsto$"
- Intuition: $A \leadsto B$ is category of a B-sign containing an indefinite A
  (in practice, $A = np$)
- Curry-Howard correspondence is preserved, thus:

$$Dom(A \leadsto B) = Dom(B|A) = Dom(A\backslash B) = Dom(B/A) = Dom(B)^{Dom(A)}$$

- category of indefinite NPs: $np \leadsto np$
- *it* and *something* are synonymous; both denote the identity function on individuals

- The function corresponding to an indefinite function composes with its environment in semantic composition:

$$\frac{X, x : A, Y \Rightarrow M : B}{X, y : C \leadsto A, Y \Rightarrow \lambda z.M[yz/x] : C \leadsto B}\,[\leadsto]$$

- Natural deduction format:

$$\dfrac{\begin{array}{ccc} & \dfrac{M : A \leadsto B}{Mx : B}\,i & \\ \vdots & & \vdots \\ \vdots & \vdots & \vdots \end{array}}{\dfrac{N : C}{\lambda x N : A \leadsto C}\leadsto, i}$$

(4) a. John saw something

b.

$$
\dfrac{
\dfrac{John}{\begin{array}{c}\text{JOHN'}\\ np\end{array}}\,lex
\qquad
\dfrac{
\dfrac{saw}{\begin{array}{c}\text{SEE'}\\ (np\backslash s)/np\end{array}}\,lex
\quad
\dfrac{\dfrac{something}{\begin{array}{c}\lambda x x\\ np \rightsquigarrow np\end{array}}\,lex}{\begin{array}{c}y\\ np\end{array}}\,i
}{\begin{array}{c}\text{SEE'}y\\ np\backslash s\end{array}}\,/E
}{
\dfrac{\begin{array}{c}\text{SEE'}y\text{JOHN'}\\ s\end{array}}{\begin{array}{c}\lambda y.\text{SEE'}y\text{JOHN'}\\ np \rightsquigarrow s\end{array}}\,\rightsquigarrow, i
}\,\backslash E
$$

The descriptive content of indefinites

- Idea: descriptive content is interpreted as domain restriction
- $\|$a cup$\|$ = the identity function on the set of cups
- $\|$a cup moved$\|$ = partial function f from individuals to truth values:
  - $f(x) = 1$ iff x is a cup that moved
  - $f(x) = 0$ iff x is a cup that did not move
  - $f(x)$ is undefined iff x is not a cup

Definition 1

- If M and φ are terms of types σ and t respectively and v is a variable of type τ, then $\lambda v_\varphi M$ is a term of type $\langle \tau, \sigma \rangle$.
- $\| \lambda v_\varphi M \|_g = \{ \langle a, \| M \|_{g[v \to a]} \rangle : \| \varphi \|_{g[v \to a]} = 1 \}$

A cup moved	$\mapsto$	$\lambda x_{\text{CUP'}x}.\text{MOVE'}x$
a cup	$\mapsto$	$\lambda x_{\text{CUP'}x} x$
a	$\mapsto$	$\lambda P x_{Px} x$

Truth and negation

- Inspired by Dekker 2000: Truth is relativized to sequences of individuals $\vec{e}$
- Truth furthermore relativized to category of a sentence (implicit in Dekker's approach)

Definition 2 (Truth)

$$\begin{aligned}
\vec{e} \models \alpha : s \quad & \text{iff} \quad \alpha = 1 \\
c\vec{e} \models \alpha : S|np \quad & \text{iff} \quad \vec{e} \models (\alpha c) : S \\
\vec{e} \models \alpha : np \rightsquigarrow S \quad & \text{iff} \quad \vec{e} \models (\bigcup_{\alpha c \text{ is defined}} (\alpha c)) : S
\end{aligned}$$

$$
\begin{aligned}
&\vec{e} \models \|\lambda x_{\text{CUP'}_x}.\text{MOVE'}x\|_g : np \rightsquigarrow s && \iff \\
&\vec{e} \models \bigcup_{a \in \|\text{CUP'}\|_g} \|\text{MOVE'}\|_g(a) : s && \iff \\
&\bigcup_{a \in \|\text{CUP'}\|_g} \|\text{MOVE'}\|_g(a) = 1 && \iff \\
&\exists a.a \in \|\text{CUP'}\|_g \cap \|\text{MOVE'}\|_g
\end{aligned}
$$

Negation

- Negation is polymorphic
- all indefinites in it scope are existentially closed
- anaphora slots are passed through unchanged

Definition 3 (Negation)

$$
\begin{aligned}
\sim \alpha : s &= 1 - \alpha \\
\sim \alpha : S|A &= \lambda c. \sim (\alpha c) \\
\sim \alpha : A \rightsquigarrow S &= \sim \Big(\bigcup_{c \in Dom(\alpha)} \alpha c \Big)
\end{aligned}
$$

Linguistic consequences

Indefinites and scope

(5) If a cup moved, the ghost is present

- $\varphi \vee \psi \doteq \neg(\neg\varphi \wedge \neg\psi)$
- $\varphi \longrightarrow \psi \doteq \neg\varphi \vee \psi$

$$\dfrac{\dfrac{\dfrac{\dfrac{\dfrac{a}{\lambda P x_{Px} x \quad (np \leadsto np)/n}\,lex \qquad \dfrac{cup}{\text{CUP'} \quad n}\,lex}{\lambda x_{\text{CUP'}x} x \quad np \leadsto np}\,/E}{(\lambda x_{\text{CUP'}x} x)y \quad np}\,i \qquad \dfrac{moved}{\text{MOVE'} \quad np\backslash s}\,lex}{\text{MOVE'}((\lambda x_{\text{CUP'}x} x)y) \quad s}\,\backslash E}{\lambda y_{\text{CUP'}y}.\text{MOVE'}y \quad np \leadsto s}\,\leadsto, i$$

$$\dfrac{\dfrac{if}{\lambda pq.p \to q \quad S_1/S_1/S_2}\,lex \qquad \lambda y_{\text{CUP'}y}.\text{MOVE'}y \quad np \leadsto s}{\lambda q.(\lambda y_{\text{CUP'}y}.\text{MOVE'}y) \to q \quad S_1/S_1}\,/E$$

$$\dfrac{\lambda q.(\lambda y_{\text{CUP'}y}.\text{MOVE'}y) \to q \quad S_1/S_1 \qquad \dfrac{the\_ghost\_is\_present}{\text{PRESENT(GHOST)'} \quad s}}{(\lambda y_{\text{CUP'}y}.\text{MOVE'}y) \to \text{PRESENT(GHOST)'} \quad s}\,/E$$

$$\exists y(\text{CUP'}y \wedge \text{MOVE'}y) \to \text{PRESENT(GHOST)'}$$

$$\frac{a}{\lambda P x_{Px} x \quad (np \rightsquigarrow np)/n}\,lex \qquad \frac{cup}{\text{CUP'} \quad n}\,lex$$

$$\frac{\lambda P x_{Px} x \;\; (np \rightsquigarrow np)/n \qquad \text{CUP'} \;\; n}{\lambda x_{\text{CUP'}x} x \quad np \rightsquigarrow np}\,/E$$

$$\frac{\lambda x_{\text{CUP'}x} x \quad np \rightsquigarrow np}{(\lambda x_{\text{CUP'}x} x) y \quad np}\,i \qquad \frac{moved}{\text{MOVE'} \quad np\backslash s}\,lex$$

$$\frac{(\lambda x_{\text{CUP'}x} x) y \;\; np \qquad \text{MOVE'} \;\; np\backslash s}{\text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \quad s}\,\backslash E$$

$$\frac{if}{\lambda pq.p \rightarrow q \quad S_1/S_1/S_2}\,lex$$

$$\frac{\lambda pq.p \rightarrow q \;\; S_1/S_1/S_2 \qquad \text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \;\; s}{\lambda q.\text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \rightarrow q \quad S_1/S_1}\,/E \qquad \frac{the\_ghost\_is\_present}{\text{PRESENT(GHOST)'} \quad s}$$

$$\frac{\lambda q.\text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \rightarrow q \;\; S_1/S_1 \qquad \text{PRESENT(GHOST)'} \;\; s}{\text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \rightarrow \text{PRESENT(GHOST)'} \quad s}\,/E$$

$$\frac{\text{MOVE'}((\lambda x_{\text{CUP'}x} x) y) \rightarrow \text{PRESENT(GHOST)'} \quad s}{\lambda y_{\text{CUP'}y}.\text{MOVE'}y \rightarrow \text{PRESENT(GHOST)'} \quad s}\,\rightsquigarrow, i$$

$$\exists y.\text{CUP'}y \wedge (\text{MOVE'}y \rightarrow \text{PRESENT(GHOST)'})$$

Properties of the analysis

No island effects

- An indefinite can take scope over each clause it is contained in
- Indefinites scopally interact with operators like negation, but:
  - No movement involved $\rightsquigarrow$ not constrained by constraints on movement
  - scoping mechanism is independent from quantifier scoping $\rightsquigarrow$ not constrained by constraints on quantifier scope

Comparison to other *in situ* theories of wide scope indefinites

Unselective binding

- Analysis of wide scope indefinites by means of unselective binding (in the sense of Kamp 1981) leads to wrong truth conditions:

(6) a. If we invite some philosopher, Max will be offended
    b. $\exists x(\text{PHILOSOPHER'}x \wedge \text{INVITE'}x\text{WE'} \longrightarrow \text{OFFENDED'MAX'})$

- Known as "Donald Duck Problem" (because the existence of the non-philosopher Donald Duck is sufficient to make the sentence true)

Choice function approach

- Donald Duck problem is avoided in choice function approach (Reinhart 1995; Winter 1996)
- However, existential scope and scope of descriptive content are still too independent from each other (as noted among others by Reniers 1997a,b; Geurts 1999; Endriss and Haida 2000):

(7) a. At most three girls$_i$ visited a boy that they$_i$ fancied

b. $\exists f.CH(f) \wedge$
$|\lambda x.\text{GIRL'}x \wedge \text{VISIT'}(f(\lambda y.\text{BOY'}y \wedge \text{FANCY'}yx))x| \leq 3$

c. $|\lambda x.\text{GIRL'}x \wedge \forall y(\text{BOY'}y \wedge \text{FANCY'}yx \rightarrow \text{VISIT'}yx)| \leq 3$

Present approach

- descriptive part is interpreted as domain restriction of partial function
- is inherited by superconstituents in semantic composition:

$$Dom(f) \subseteq Dom(f \circ g)$$

- Existential closure entails non-emptiness of domain
- Thus existential and descriptive scope are always identical

Sluicing

(8) a. A cup moved, and Bill wonders which cup
 b. A cup moved, and Bill wonders which cup moved

- Syntax:
  - Sluicing involves a bare *wh*-phrase
  - needs a declarative clause containing an indefinite as antecedent
- Semantics:
  - "missing" material is identical to antecedent except that indefinite is replaced by *wh*-trace

- Proposal: *which cup* has two types (but only one meaning):

(9) a. $q|(np \leadsto s) : \lambda P.?x\text{CUP'}x \wedge Px$
    b. $q/(s \uparrow np) : \lambda P.?x\text{CUP'}x \wedge Px$

- Antecedent clause has exactly the denotation that is needed to complete the elliptical question

Conclusion

- Indefinites and pronouns are interpreted as (partial) identity functions
- Pronoun binding via syntactic deduction
- existential impact of indefinites is buried in truth definition/semantics of negation etc.
- descriptive content of indefinites is interpreted as domain restriction
- empirical coverage: specificity and sluicing

Further issues

- Donkey anaphora: Paul's Predicate Logic with Anaphora (Dekker 2000) can straightforwardly be accommodated (cf. Jäger 2001, chap 7)
- Open problem: double scope behavior of specific plural indefinites

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