Scope parallelism in coordination in Dependent Type Semantics

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Dynamic Semantics: Modern Type Theoretic and Category Theoretic Approaches

Outline

- The Geach RNR problem: overview
- Problems with prior accounts of Geach
  - A quick review of Hybrid TLCG
  - The Geach problem in Hybrid TLCG
- Analysis in Dependent Type Semantics

The Geach data

- [Geach, 1972]

(1) Every boy admires, and every girl detests, some saxophonist.
($\forall > \exists \wedge \forall > \exists$; $\exists > \forall \wedge \exists > \forall$)

- **NB:** (13) lacks readings in which the RNR'ed existential scopes above the universal in one conjunct but below it in the other conjunct.

The Canadian flag data

- The scope parallelism problem in Geach sentences is not restricted to RNR,
- since cases such as (2), first noted in [Hirshbühler, 1982], show that it holds in VP ellipsis as well.

(2) A Canadian flag was hanging in front of every window and an American flag was too.

- Two readings are available: $\forall > \exists \wedge \forall > \exists$ and $\exists > \forall \wedge \exists > \forall$
- but no mixed reading $\forall > \exists \wedge \exists > \forall$.
- Hence any fully general account of VP ellipsis needs to provide an account of this parallelism
- and, optimally, show how it falls out from the same source as the Geach parallelism effect.

Rules in Hybrid TLCG

Connective	Introduction	Elimination
$/$	$\dfrac{\dfrac{\vdots \quad \vdots \quad \dfrac{[\varphi; x; A]^1}{\vdots \quad \vdots} \quad \vdots \quad \vdots}{b \bullet \varphi;\ \mathcal{F};\ B}}{b;\ \lambda x.\mathcal{F};\ B/A}\ /\mathrm{I}^n$	$\dfrac{a;\ \mathcal{F};\ A/B \quad b;\ \mathcal{G};\ B}{a \bullet b;\ \mathcal{F}(\mathcal{G});\ A}\ /\mathrm{E}$
$\backslash$	$\dfrac{\dfrac{\vdots \quad \vdots \quad \dfrac{[\varphi; x; A]^1}{\vdots \quad \vdots} \quad \vdots \quad \vdots}{\varphi \bullet b;\ \mathcal{F};\ B}}{b;\ \lambda x.\mathcal{F};\ A\backslash B}\ \backslash\mathrm{I}^n$	$\dfrac{b;\ \mathcal{G};\ B \quad a;\ \mathcal{F};\ B\backslash A}{b \bullet a;\ \mathcal{F}(\mathcal{G});\ A}\ \backslash\mathrm{E}$
$\upharpoonright$	$\dfrac{\dfrac{\vdots \quad \vdots \quad \dfrac{[\varphi; x; A]^1}{\vdots \quad \vdots} \quad \vdots \quad \vdots}{b;\ \mathcal{F};\ B}}{\lambda \varphi.b;\ \lambda x.\mathcal{F};\ B\upharpoonright A}\ \upharpoonright\mathrm{I}^n$	$\dfrac{a;\ \mathcal{F};\ A\upharpoonright B \quad b;\ \mathcal{G};\ B}{a(b);\ \mathcal{F}(\mathcal{G});\ A}\ \upharpoonright\mathrm{E}$

Quantifiers and Slanting

- We follow [Oehrle, 1994] and much subsequent work in his framework [Muskens, 2003], [de Groote, 2001] in taking generalized quantifiers to have the form displayed in (3):

(3) $\lambda\varphi\lambda\sigma.\sigma(\texttt{some} \bullet \varphi)$; $\lambda Q.\mathbf{\exists}_{\mathbf{Q}}$; $\mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})$

- But it follows as an Hybrid TLCG theorem that from this form, by hypothetical reasoning, we can infer a variety of directional versions, e.g. (S/NP)\S:

(4)
$$\dfrac{\begin{array}{l}\lambda\sigma_1.\sigma_1(\texttt{some} \bullet \texttt{saxophonist});\\ \mathbf{\exists}_{\mathbf{sax}};\\ \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})\end{array} \qquad \dfrac{\dfrac{\varphi_1;\ P;\ \mathsf{S/NP} \quad \varphi_2;\ x;\ \mathsf{NP}}{\varphi_1 \bullet \varphi_2;\ P(x);\ \mathsf{S}}}{\lambda\varphi_2.\varphi_1 \bullet \varphi_2;\ \lambda x.P(x);\ \mathsf{S}{\upharpoonright}\mathsf{NP}}}{\dfrac{\varphi_1 \bullet \texttt{some} \bullet \texttt{saxophonist};\ \mathbf{\exists}_{\mathbf{sax}}(\lambda x.P(x));\ \mathsf{S}}{\texttt{some} \bullet \texttt{saxophonist};\ \lambda P.\mathbf{\exists}_{\mathbf{sax}}(\lambda x.P(x));\ (\mathsf{S/NP})\backslash\mathsf{S}}}$$

Getting the Geach readings in Hybrid TLCG

$\forall > \exists\wedge$

(5)

$$\dfrac{\dfrac{\dfrac{\begin{matrix}\vdots & \vdots \\ \varphi_2 \bullet \mathtt{admires}; & \\ \lambda w.\mathbf{admire}(w)(v); \mathsf{S/NP} & [\varphi_1; \mathscr{V}; (\mathsf{S/NP})\backslash\mathsf{S}]^1\end{matrix}}{\varphi_2 \bullet \mathtt{admires} \bullet \varphi_1;\ \mathscr{V}(\lambda w.\mathbf{admire}(w)(v));\ \mathsf{S}}}{\begin{matrix}\lambda\varphi_2.\varphi_2 \bullet \mathtt{admires} \bullet \varphi_1; & \lambda\sigma_1.\sigma_1(\mathtt{every} \bullet \mathtt{boy}); \\ \lambda v.\mathscr{V}(\lambda w.\mathbf{admire}(w)(v)); \mathsf{S}{\upharpoonright}\mathsf{NP} & \mathbf{V}_{\mathbf{boy}}; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})\end{matrix}}}{\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires} \bullet \varphi_1;\ \mathbf{V}_{\mathbf{boy}}(\lambda v.\mathscr{V}(\lambda w.\mathbf{admire}(w)(v)));\ \mathsf{S}}}{\begin{matrix}\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires}; \\ \lambda\mathscr{V}.\mathbf{V}_{\mathbf{boy}}(\lambda v.\mathscr{V}(\lambda w.\mathbf{admire}(w)(v))); \mathsf{S}/((\mathsf{S/NP})\backslash\mathsf{S})\end{matrix}}$$

- In parallel fashion we obtain

(6) $\mathtt{every} \bullet \mathtt{girl} \bullet \mathtt{detests};\ \lambda\mathscr{U}.\mathbf{V}_{\mathbf{girl}}(\lambda z.\mathscr{U}(\lambda u.\mathbf{detest}(w)(z)));$
$\mathsf{S}/((\mathsf{S/NP})\backslash\mathsf{S})$

- As usual, we take coordination to correspond in general to Partee and Rooth's generalized conjunction and disjunction operators $\sqcap, \sqcup$

...

- . . . which yields

(7) $\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires} \bullet \mathtt{and} \bullet \mathtt{every} \bullet \mathtt{girl} \bullet \mathtt{detests}$;
$\mathbf{\forall_{boy}}(\lambda z.\mathscr{W}(\lambda x.\mathbf{admire}(x)(z))) \wedge \mathbf{\forall_{girl}}(\lambda z.\mathscr{W}(\lambda x.\mathbf{detest}(x)(z)))$;
S/((S/NP)\S)

- When (7) combines as argument with the 'slanted' version of *some saxophonist* derived in (4), we get the reading in which the latter's denotation is distributed over the conjunction.

- We can derive the wide-scope interpretation for the 'raised' term in a similar way, obtaining

(8) $\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires} \bullet \mathtt{and} \bullet \mathtt{every} \bullet \mathtt{girl} \bullet \mathtt{detests}$;
$\lambda\mathscr{U}.\mathscr{U}(\lambda w.\mathbf{\exists_{boy(}}\lambda y.\mathbf{admire}(w)(y)) \wedge \mathbf{\exists_{girl}}(\lambda z.\mathbf{detest}(w)(z)))$;
S/((S/NP)\S)

- which, when applied to slanted *some saxophonist*, yields the wide scope reading for the existential.

Mixed readings

- But note that the following two are of the same syntactic type:

$\texttt{every} \bullet \texttt{boy} \bullet \texttt{admires}; \lambda \mathscr{V}.\mathbf{\forall}_{\mathbf{boy}}(\lambda v.\mathscr{V}(\lambda w.\mathbf{admire}(w)(v))); \mathsf{S}/((\mathsf{S}/\mathsf{NP})\backslash\mathsf{S})$

$\texttt{every} \bullet \texttt{girl} \bullet \texttt{detests}; \lambda \mathscr{U}.\mathscr{U}(\mathbf{\exists}_{\mathbf{girl}}(\lambda z.\mathbf{detest}(w)(z))); \mathsf{S}/((\mathsf{S}/\mathsf{NP})\backslash\mathsf{S})$

- Conjoining them yields:

(9) $\texttt{every} \bullet \texttt{boy} \bullet \texttt{admires} \bullet \texttt{and} \bullet \texttt{every} \bullet \texttt{girl} \bullet \texttt{detests};$
$\lambda \mathscr{W}.\mathbf{\forall}_{\mathbf{boy}}(\lambda v.\mathscr{W}(\lambda w.\mathbf{admire}(w)(v))) \wedge \mathscr{W}(\lambda u \mathbf{\forall}_{\mathbf{girl}}(\lambda z.\mathbf{detest}(u)(z));$
$\mathsf{S}/((\mathsf{S}/\mathsf{NP})\backslash\mathsf{S}))$

- Applied to the slanted form of *some saxophonist*, we will obtain

(10) $\texttt{every} \bullet \texttt{boy} \bullet \texttt{admires} \bullet \texttt{and} \bullet \texttt{every} \bullet \texttt{girl} \bullet \texttt{detests} \bullet$
$\texttt{some} \bullet \texttt{saxophonist};$
$\mathbf{\forall}_{\mathbf{boy}}(\lambda v.\mathbf{\exists}_{\mathbf{sax}}(\lambda w.\mathbf{admire}(w)(v)))\wedge$
$\mathbf{\exists}_{\mathbf{sax}(}\lambda u \mathbf{\forall}_{\mathbf{girl}}(\lambda z.\mathbf{detest}(u)(z)); \mathsf{S}$

- which is the unavailable mixed reading.

Steedman's solution: Skolem terms

- Steedman proposes a CCG solution for the Geach problem
- reinterpretating existentials not as generalized quantifiers but rather generalized Skolem terms corresponding either to
  - constants (with wide scope) when unbound, or
  - functional terms containing variables which become bound when in the scope of a universal.

RNR revisited

- Steedman's solution for the Geach sentence facts hinges on the fact that a given Skolem term must correspond either a constant or a function on the value of the variable bound by some universal.
- In (11), the determination of which of these possibilities is realized (Skolem specification) is made only AFTER the RNRed element combines with the S/NP conjunction and is distributed under the scope of the universal in conjunct at the point ♠.

(11)

$$\dfrac{\dfrac{\dfrac{\text{Every boy admires and every girl detests}}{S/NP : \lambda x.\forall y[\textit{boy}'(y) \supset \textit{admire}'(x)(y)] \wedge \forall z[\textit{girl}'(z) \supset \textit{detest}'(x)(z)]} \quad \dfrac{\text{some saxophonist}}{(S/NP)\backslash S : \lambda q.q(\textit{skolem}'(\textit{sax}'))}}{S : \forall y[\textit{boy}'(y) \supset \textit{admire}'(\textit{skolem}'(\textit{sax}'))(y)] \wedge \forall z[\textit{girl}'(z) \supset \textit{detest}'(\textit{skolem}'(\textit{sax}'))(z)]}}{S : \forall y[\textit{boy}'(y) \supset \textit{admire}'(\textit{sk}^{(y)}_{\textit{sax}'})(y)]} \spadesuit$$

- Hence both Skolem terms are interpreted as varying functions, corresponding to narrow scope under each universal.
- But if the original Skolem term's status is specified BEFORE λ-conversion distributes it among the conjuncts, it will not be under any quantifier's scope, and hence will be a constant, scoping wide.

Empirical problems with Steedman's account

- While Steedman's analysis blocks the mixed reading...
- the means by which it does so rule out in advance any possibility of an existential scoping narrowly with respect to the RNR coordination but widely with respect to a universal in either or both conjuncts...
- because if it's a constant, it outscopes everything, and if it's not, it must be under the scope of some universal.
- But examples of just this sort, ruled by the Skolem term analysis, are readily available.

(12) Every American respects, and every Japanese admires, some novelist—namely, their respective most recent Nobel Prize winner.

- The crucial part of the interpretation can be paraphrased as ‘There is some American novelist such that very American respects that novelist and there is some Japanese novelist such that every Japanese person respects that novelist’...
- ...so that the existential interpretation distributes over the conjunction (like a Skolem function), but within each conjunct takes widest scope (like a constant).
- Hybrid TLCG however can license (12) unproblematically, so that...

- …we are left in the unsatisfactory situation of either blocking mixed readings for Geach sentences but undergenerating (12) (via the CCG analysis), or licensing (12) and while overgenerating the mixed Geach reading (via Hybrid TLCG).

Solution for the Geach puzzle in words

(13) Every boy admires, and every girl detests, some saxophonist.
($\forall > \exists \wedge \forall > \exists$; $\exists > \forall \wedge \exists > \forall$)

(14) Every boy$_i$ is such that there is a saxophonist$_j$ such that he$_i$ admires him$_j$, and every girl$_k$ is such that there is a saxophonist$_l$ such that she$_k$ admires him$_l$.

Solution for the Geach puzzle in words

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Note that the same interpretive parallelism holds in binding:

(15) Every Englishman respects, and every American loves, his mother.

(15) doesn't mean: 'Every Englishman respects his own mother and every American respects x, where x is some contextually salient person's mother'

Anaphora in DTS

(16) A man entered. He sat down.

(17)

$$\lambda c. \begin{bmatrix} v : \begin{bmatrix} u : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{Man}(x) \end{bmatrix} \\ \mathbf{Enter}(\pi_1 u) \end{bmatrix} \\ \mathbf{SitDown}(@_1(c, v)) \end{bmatrix}$$

Anaphora in DTS

(16) A man entered. He sat down.

(17)

$$\lambda c. \left[\begin{array}{l} v : \left[\begin{array}{l} u : \left[\begin{array}{l} x : \mathbf{Ent} \\ \mathbf{Man}(x) \end{array} \right] \\ \mathbf{Enter}(\pi_1 u) \end{array} \right] \\ \mathbf{SitDown}(@_1(c, v)) \end{array} \right]$$

- $@_1 = \lambda c.\pi_1\pi_1\pi_2 c$
- $@_1(c, v) = \pi_1\pi_1 v$

Anaphora in DTS

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(17)

$$\lambda c. \begin{bmatrix} v : \begin{bmatrix} u : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{Man}(x) \end{bmatrix} \\ \mathbf{Enter}(\pi_1 u) \end{bmatrix} \\ \mathbf{SitDown}(@_1(c, v)) \end{bmatrix}$$

- $@_1 = \lambda c.\pi_1\pi_1\pi_2 c$
- $@_1(c, v) = \pi_1\pi_1 v$

Note:

- The analysis of anaphora resolution is from [Bekki, 2014]; it doesn't reflect the update in the version of the theory assumed in Bekki's and Tanaka's talks.
- We sometimes write $[(x : \mathbf{Ent}) \times \mathbf{Man}(x)]$ for $\begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{Man}(x) \end{bmatrix}$

Mixed binding problem isn't a problem [Bekki, 2014]

(18) Each of John and Bill loves his father.

Reading 1: 'John loves his own father and Bill loves his own father.'
Reading 2: 'Both John and Bill love the same person's father.'
Unavailable reading: 'John loves his own father and Bill loves somebody else's father.'

Mixed binding problem isn't a problem [Bekki, 2014]

(18) Each of John and Bill loves his father.

Reading 1: 'John loves his own father and Bill loves his own father.'
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Unavailable reading: 'John loves his own father and Bill loves somebody else's father.'

(19)

$$\lambda c.\mathbf{L}(\mathbf{j}, \pi_1((@_1 : \gamma_1 \rightarrow \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{FatherOf}(x, (@_0 : \gamma_0 \rightarrow e)(c, \mathbf{j})) \end{bmatrix})(c, \mathbf{j})))$$

$$\wedge \mathbf{L}(\mathbf{b}, \pi_1((@_1 : \gamma_1 \rightarrow \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{FatherOf}(x, (@_0 : \gamma_0 \rightarrow e)(c, \mathbf{b})) \end{bmatrix})(c, \mathbf{b})))$$

Hybrid TLCG + DTS

(20) a. $\lambda\varphi\lambda\sigma.\sigma(\texttt{every} \bullet \varphi)$;
$\lambda P \lambda Q \lambda c.(u : [(x : \mathbf{Ent}) \times Pxc]) \to Q(\pi_1 u)(c, u)$;
$\mathsf{S}{\restriction}(\mathsf{S}{\restriction}\mathsf{NP}){\restriction}\mathsf{N}$

b. $\lambda\varphi\lambda\sigma.\sigma(\texttt{some} \bullet \varphi)$; $\lambda P \lambda Q \lambda c.\begin{bmatrix} u : [(x : \mathbf{Ent}) \times Pxc] \\ Q(\pi_1 u)(c, u) \end{bmatrix}$;
$\mathsf{S}{\restriction}(\mathsf{S}{\restriction}\mathsf{NP}){\restriction}\mathsf{N}$

c. $\lambda\sigma.\sigma(\texttt{it})$; $\lambda P \lambda c.P(@_1 c)(c, @_1 c)$; $\mathsf{S}{\restriction}(\mathsf{S}{\restriction}\mathsf{NP})$

Donkey anaphora

(21)

$$\begin{bmatrix} \varphi_1; \\ x; \\ \mathsf{NP} \end{bmatrix}^1 \qquad \begin{bmatrix} \varphi_2; \\ y; \\ \mathsf{NP} \end{bmatrix}^2$$

$$\vdots \quad \vdots$$

$$\dfrac{\lambda\sigma.\sigma(\texttt{a} \bullet \texttt{donkey}); \; \lambda Q \lambda c. \begin{bmatrix} u : \begin{bmatrix} y : \mathbf{Ent} \\ \mathbf{D}y \end{bmatrix} \\ Q(\pi_1 u)(c, u) \end{bmatrix}; \; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}) \qquad \dfrac{\vdots \; \vdots \qquad \vdots \; \vdots}{\lambda\varphi_2.\varphi_1 \bullet \texttt{owns} \bullet \varphi_2; \; \lambda y \lambda c.\mathbf{O}(x, y); \; \mathsf{S}{\upharpoonright}\mathsf{NP}}}{\varphi_1 \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda c. \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{S}}$$

$$\dfrac{\varphi_1 \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda c. \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{S}}{\lambda\varphi_1.\varphi_1 \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda x \lambda c. \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{S}{\upharpoonright}\mathsf{NP}}$$

$$\dfrac{\lambda\sigma.\texttt{who} \bullet \sigma(\varepsilon); \; \lambda P \lambda Q \lambda x \lambda c. \; Qxc \times Pxc; \; (\mathsf{N}\backslash\mathsf{N}){\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}) \qquad \lambda\varphi_1.\varphi_1 \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda x \lambda c. \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{S}{\upharpoonright}\mathsf{NP}}{\texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda Q \lambda x \lambda c. Qxc \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{N}\backslash\mathsf{N}}$$

$$\dfrac{\texttt{farmer}; \; \lambda x \lambda c. \; \mathbf{F}x; \; \mathsf{N} \qquad \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda Q \lambda x \lambda c. Qxc \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{N}\backslash\mathsf{N}}{\texttt{farmer} \bullet \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda x \lambda c.\mathbf{F}x \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{N}}$$

$$\dfrac{\lambda\varphi\lambda\sigma. \; \sigma(\texttt{every} \bullet \varphi); \; \lambda P \lambda Q \lambda c. \; \left(v : \begin{bmatrix} x : \mathbf{Ent} \\ Pxc \end{bmatrix}\right) \to Q(\pi_1 v)(c, v); \; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}){\upharpoonright}\mathsf{N} \qquad \texttt{farmer} \bullet \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}; \; \lambda x \lambda c.\mathbf{F}x \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix}; \mathsf{N}}{\lambda\sigma.\sigma(\texttt{every} \bullet \texttt{farmer} \bullet \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}); \; \lambda Q \lambda c. \left(v : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{F}x \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix} \end{bmatrix}\right) \to Q(\pi_1 v)(c, v); \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})}$$

Donkey anaphora (cont.)

(22)

$$\begin{bmatrix} \varphi_3; \\ z; \mathsf{NP} \end{bmatrix}^3 \quad \begin{bmatrix} \varphi_4; \\ w; \mathsf{NP} \end{bmatrix}^4$$

$$\vdots \quad \vdots$$

$$\lambda\sigma.\sigma(\texttt{every} \bullet \texttt{farmer} \bullet \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey}); \ \lambda Q \lambda c.(v : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{F}x \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix} \end{bmatrix}) \to Q(\pi_1 v)(c, v); \mathsf{S}\restriction(\mathsf{S}\restriction\mathsf{NP})$$

$$\lambda\sigma.\sigma(\texttt{it}); \ \lambda P \lambda c.P(@_1 c)(c, @_1 c); \ \mathsf{S}\restriction(\mathsf{S}\restriction\mathsf{NP})$$

$$\lambda\varphi_4.\varphi_3 \bullet \texttt{beats} \bullet \varphi_4; \ \lambda w \lambda c.\mathbf{B}(z, w); \ \mathsf{S}\restriction\mathsf{NP}$$

$$\varphi_3 \bullet \texttt{beats} \bullet \texttt{it}; \ \lambda c.\mathbf{B}(z, @_1 c); \ \mathsf{S}$$

$$\lambda\varphi_3.\varphi_3 \bullet \texttt{beats} \bullet \texttt{it}; \ \lambda z \lambda c.\mathbf{B}(z, @_1 c); \ \mathsf{S}\restriction\mathsf{NP}$$

$$\texttt{every} \bullet \texttt{farmer} \bullet \texttt{who} \bullet \texttt{owns} \bullet \texttt{a} \bullet \texttt{donkey} \bullet \texttt{beats} \bullet \texttt{it}; \ \lambda c.(v : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{F}x \times \begin{bmatrix} u : [(y : \mathbf{Ent}) \times \mathbf{D}y] \\ \mathbf{O}(x, \pi_1 u) \end{bmatrix} \end{bmatrix}) \to \mathbf{B}(\pi_1 v, @_1(c, v)); \mathsf{S}$$

Binding parallelism

(23) Every Englishman respects, and every American loves, his mother.

(24)

$$\lambda c.(u : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{E}(x) \end{bmatrix}) \to \mathbf{R}(\pi_1 u, \pi_1((@_1 : \gamma_1 \to \begin{bmatrix} y : \mathbf{Ent} \\ \mathbf{M}(y, (@_0 : \gamma_0 \to e)(c, u)) \end{bmatrix})(c, u)))$$

$$\wedge (u : \begin{bmatrix} x : \mathbf{Ent} \\ \mathbf{A}(x) \end{bmatrix}) \to \mathbf{L}(\pi_1 u, \pi_1((@_1 : \gamma_1 \to \begin{bmatrix} y : \mathbf{Ent} \\ \mathbf{M}(y, (@_0 : \gamma_0 \to e)(c, u)) \end{bmatrix})(c, u)))$$

Revised entry for the existential quantifier

(25) a. $\texttt{it}$; $\lambda c.@_i c$; NP_p

b. $\texttt{admires}$; $\lambda f \lambda x \lambda c.\mathbf{A}(x, fc)$; $(\mathsf{NP}\backslash\mathsf{S})/\mathsf{NP}_p$

(26) $\lambda\varphi\lambda\sigma.\sigma(\texttt{some} \bullet \varphi)$; $\lambda P \lambda Q \lambda c.\left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times Pxc] \\ Q(\lambda d.@_i^{\pi_1 u} d)(c, u) \end{array}\right]$;
$\mathsf{S}{\restriction}(\mathsf{S}{\restriction}\mathsf{NP}_p){\restriction}\mathsf{N}$

where, for all contexts c, $@_i^{\pi_1 u} c = \begin{cases} @_i c & \text{if } @_i c = \pi_1 u \\ \text{undefined} & \text{otherwise} \end{cases}$

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(25) a. it; $\lambda c.@_i c$; NP_p

b. admires; $\lambda f \lambda x \lambda c.\mathbf{A}(x, fc)$; $(\mathsf{NP}\backslash\mathsf{S})/\mathsf{NP}_p$

(26) $\lambda\varphi\lambda\sigma.\sigma(\mathtt{some} \bullet \varphi)$; $\lambda P \lambda Q \lambda c. \left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times Pxc] \\ Q(\lambda d.@_i^{\pi_1 u} d)(c, u) \end{array}\right]$;
$\mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}_p){\upharpoonright}\mathsf{N}$

where, for all contexts c, $@_i^{\pi_1 u} c = \begin{cases} @_i c & \text{if } @_i c = \pi_1 u \\ \text{undefined} & \text{otherwise} \end{cases}$

Cf. older entry:

(27) $\lambda\varphi\lambda\sigma.\sigma(\mathtt{some} \bullet \varphi)$; $\lambda P \lambda Q \lambda c. \left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times Pxc] \\ Q(\pi_1 u)(c, u) \end{array}\right]$;
$\mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}){\upharpoonright}\mathsf{N}$

All quantifier entries will be revised accordingly, but for expository ease, below we replace the entries of the relevant quantifiers only.

Simple sentence involving a quantifier

(28)

$$\left[\begin{array}{l}\varphi_1;\\ z;\mathsf{NP}\end{array}\right]^1 \quad \left[\begin{array}{l}\varphi_2;\\ f;\mathsf{NP}_p\end{array}\right]^2$$

$$\vdots \quad \vdots \qquad\qquad \vdots \quad \vdots$$

$$\lambda\varphi_2.\varphi_1 \bullet \mathtt{admires} \bullet \varphi_2;\ \lambda f\lambda c.\mathbf{A}(z, fc); \mathsf{S}{\upharpoonright}\mathsf{NP}_p$$

$$\vdots \quad \vdots$$

$$\lambda\sigma.\sigma(\mathtt{some} \bullet \mathtt{saxophonist});\ \lambda Q\lambda c.\left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ Q(\lambda d.@_1^{\pi_1 u} d)(c, u)\end{array}\right]; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}_p)$$

$$\varphi_1 \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist};\ \lambda c.\left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(z, @_1^{\pi_1 u}(c, u))\end{array}\right]; \mathsf{S}$$

$$\lambda\varphi_1.\varphi_1 \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist};\ \lambda z\lambda c.\left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(z, @_1^{\pi_1 u}(c, u))\end{array}\right]; \mathsf{S}{\upharpoonright}\mathsf{NP}$$

$$\vdots \quad \vdots$$

$$\lambda\varphi\lambda\sigma.\sigma(\mathtt{every} \bullet \mathtt{boy});\ \lambda Q\lambda c.(v : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to Q(\pi_1 v)(c, v);\ \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})$$

$$\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist};\ \lambda c.(v : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \left[\begin{array}{l} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(\pi_1 v, @_1^{\pi_1 u}((c, v), u))\end{array}\right]; \mathsf{S}$$

Simple sentence involving a quantifier

(28)

$$\begin{bmatrix} \varphi_1; \\ z; \mathsf{NP} \end{bmatrix}^1 \quad \begin{bmatrix} \varphi_2; \\ f; \mathsf{NP}_p \end{bmatrix}^2$$

$$\vdots \quad \vdots \qquad\qquad \vdots \quad \vdots$$

$$\frac{}{\lambda \varphi_2 . \varphi_1 \bullet \mathtt{admires} \bullet \varphi_2; \; \lambda f \lambda c. \mathbf{A}(z, fc); \mathsf{S}{\upharpoonright}\mathsf{NP}_p}$$

$$\vdots \quad \vdots$$

$$\lambda \sigma . \sigma(\mathtt{some} \bullet \mathtt{saxophonist}); \; \lambda Q \lambda c. \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ Q(\lambda d. @_1^{\pi_1 u} d)(c, u) \end{bmatrix}; \; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP}_p)$$

$$\frac{}{\varphi_1 \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist}; \; \lambda c. \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(z, @_1^{\pi_1 u}(c, u)) \end{bmatrix}; \mathsf{S}}$$

$$\frac{}{\lambda \varphi_1 . \varphi_1 \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist}; \; \lambda z \lambda c. \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(z, @_1^{\pi_1 u}(c, u)) \end{bmatrix}; \mathsf{S}{\upharpoonright}\mathsf{NP}}$$

$$\vdots \quad \vdots$$

$$\lambda \varphi \lambda \sigma . \sigma(\mathtt{every} \bullet \mathtt{boy}); \; \lambda Q \lambda c. (v : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to Q(\pi_1 v)(c, v); \; \mathsf{S}{\upharpoonright}(\mathsf{S}{\upharpoonright}\mathsf{NP})$$

$$\frac{}{\mathtt{every} \bullet \mathtt{boy} \bullet \mathtt{admires} \bullet \mathtt{some} \bullet \mathtt{saxophonist}; \; \lambda c. (v : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(\pi_1 v, @_1^{\pi_1 u}((c, v), u)) \end{bmatrix}; \mathsf{S}}$$

(29) $$\lambda c. (v : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(\pi_1 v, \pi_1 u) \end{bmatrix}$$

Geach sentences

Subject wide scope:

(30) $\texttt{every} \bullet \texttt{boy} \bullet \texttt{admires}$;
$\lambda \mathscr{P} \lambda c.(w : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \mathscr{P}(\lambda f \lambda c.\mathbf{A}(\pi_1 w, fc))(c, w)$;
$\mathsf{S}/((\mathsf{S}/\mathsf{NP}_p)\backslash\mathsf{S})$

Object wide scope:

(31) $\texttt{every} \bullet \texttt{girl} \bullet \texttt{detests}$;
$\lambda \mathscr{P}.\mathscr{P}(\lambda f \lambda c.(w : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \to \mathbf{D}(\pi_1 w, f(c, w)))$;
$\mathsf{S}/((\mathsf{S}/\mathsf{NP}_p)\backslash\mathsf{S})$

Parallel scope is predicted to be good

Using the object wide scope version for both conjuncts, we obtain:

(32)

$$\lambda c. \begin{bmatrix} t : \begin{bmatrix} w : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (u : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \rightarrow \mathbf{A}(@_1^{\pi_1 w}((c, w), u)) \end{bmatrix} \\ \begin{bmatrix} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \rightarrow \mathbf{D}(@_1^{\pi_1 s}(((c, t), s), v)) \end{bmatrix} \end{bmatrix}$$

Parallel scope is predicted to be good

Using the object wide scope version for both conjuncts, we obtain:

(32)

$$\lambda c.\left[\begin{array}{l} t : \left[\begin{array}{l} w : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (u : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \mathbf{A}(@_1^{\pi_1 w}((c, w), u)) \end{array}\right] \\ \left[\begin{array}{l} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \to \mathbf{D}(@_1^{\pi_1 s}(((c, t), s), v)) \end{array}\right] \end{array}\right]$$

With $@_1 = \lambda c.\pi_1\pi_2\pi_1 c$, we obtain the right interpretation.

Mixed scope is predicted to be bad

Using the subject wide scope version for the first conjunct and the object wide scope version for the second conjunct, we obtain:

(33)

$$\lambda c. \begin{bmatrix} t : \left((w : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \rightarrow \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(@_1^{\pi_1 u}((c, w), u)) \end{bmatrix} \right) \\ \begin{bmatrix} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \rightarrow \mathbf{D}(\pi_1 v, (@_1^{\pi_1 s}(((c, t), s), v)) \end{bmatrix} \end{bmatrix}$$

Mixed scope is predicted to be bad

Using the subject wide scope version for the first conjunct and the object wide scope version for the second conjunct, we obtain:

(33)

$$\lambda c. \begin{bmatrix} t : \left((w : [(x : \mathbf{Ent}) \times \mathbf{B}x]) \to \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(@_1^{\pi_1 u}((c, w), u)) \end{bmatrix} \right) \\ \begin{bmatrix} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \to \mathbf{D}(\pi_1 v, (@_1^{\pi_1 s}(((c, t), s), v)) \end{bmatrix} \end{bmatrix}$$

- first conjunct: $@_1 = \lambda c.\pi_1 \pi_2 c$
- second conjunct: $@_1 = \lambda c.\pi_1 \pi_2 \pi_1 c$

This time, there is no coherent way of resolving the $@_1$ operator.

Open questions

Our analysis predicts that the object existential quantifier cannot scope widely within the second conjunct in the following sentence:

(34) John admires, and every girl detests, some saxophonist.

(35)

$$\lambda c. \begin{bmatrix} t : \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(\mathbf{j}, @_1^{\pi_1 u}(c, t)) \end{bmatrix} \\ \begin{bmatrix} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \to \mathbf{D}(\pi_1 v, (@_1^{\pi_1 s}(((c, t), s), v)) \end{bmatrix} \end{bmatrix}$$

Open questions

Our analysis predicts that the object existential quantifier cannot scope widely within the second conjunct in the following sentence:

(34) John admires, and every girl detests, some saxophonist.

(35)

$$\lambda c. \begin{bmatrix} t : \begin{bmatrix} u : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ \mathbf{A}(\mathbf{j}, @_1^{\pi_1 u}(c, t)) \end{bmatrix} \\ \begin{bmatrix} s : [(x : \mathbf{Ent}) \times \mathbf{S}x] \\ (v : [(x : \mathbf{Ent}) \times \mathbf{G}x]) \to \mathbf{D}(\pi_1 v, (@_1^{\pi_1 s}(((c, t), s), v)) \end{bmatrix} \end{bmatrix}$$

More generally, when different numbers of quantifiers are present in the two conjuncts, a parallel in-conjunct wide scope reading is blocked. Is this a good prediction?

(36) Every American detests, and every Japanese has some serious reservations for, some Nobel Prize winner—namely, their respective most recent Literature Prize winners.

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