LF and quantifier scope

Simon Charlow (simon.charlow@rutgers.edu)

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1 Semantics for quantified DPs and determiners

- As we saw on Monday, it makes sense to think of quantified DPs as mapping **properties** to 1 or 0:

$$[\![\text{every linguist}]\!]^g = \lambda P.\, \forall x.\, \textsc{ling}\, x \Rightarrow P\, x$$
$$[\![\text{more than three linguists}]\!]^g = \lambda P.\, |\{x : \textsc{ling}\, x\} \cap \{x : P\, x\}| > 3$$

- To get a semantics for quantified *determiners*, we need only abstract away from the restrictor NP's denotation:

$$[\![\text{every}]\!]^g = \lambda P.\, \lambda Q.\, \forall x.\, P\, x \Rightarrow Q\, x$$
$$[\![\text{more than three}]\!]^g = \lambda P.\, \lambda Q.\, |\{x : P\, x\} \cap \{x : Q\, x\}| > 3$$

- On this perspective, determiners express Curry'd **relations** between two properties.

2 Review: some things quantifiers can do

- Quantifiers as internal arguments of verbs:

(1) John $\text{knows}_{\langle e,\langle e,t\rangle\rangle}$ $[\text{many linguists}]_{\langle\langle e,t\rangle,t\rangle}$

(2) Uni $\text{showed}_{\langle e,\langle e,\langle e,t\rangle\rangle\rangle}$ $[\text{no cat}]_{\langle\langle e,t\rangle,t\rangle}$ Porky

- Ambiguity in cases of two quantifiers:

(3) A doctor examined every patient.

(4) A sentry guards every building.

- Binding:

(5) Every boy_i likes his_i mother.

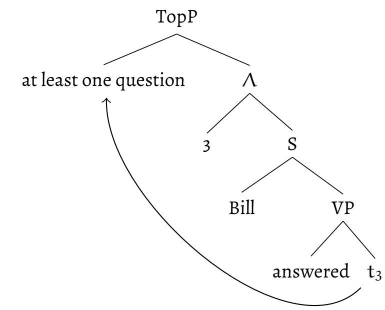
(6) We will sell no wine_i before its_i time.

3 Semantics for topicalization

- Before we see how to build our theory of quantification at the interface, let's consider a simpler example, with topicalization of a quantified object DP:

(7) At least one question, Bill answered _.

- To analyze this case, we'll assume that the relationship between a topicalized expression and an extraction gap is essentially the same as the relationship between a relative pronoun like who and an extraction gap. In other words, topicalization movement leaves a trace and a co-indexed, c-commanding abstraction operator. See Figure 1.



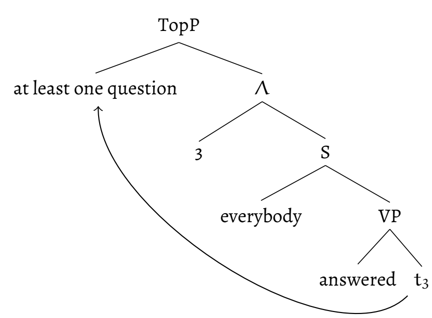
$$
\begin{array}{rll}
[\![\text{TopP}]\!]^g & = [\![\text{at least one question}]\!]^g([\![\Lambda]\!]^g) & \textbf{FA} \\
& = \textsc{aloq}\,([\![\Lambda]\!]^g) & \text{Lexicon} \\
& = \textsc{aloq}\,(\lambda x.\, [\![\text{S}]\!]^{g[3\to x]}) & \textbf{PA} \\
& = \textsc{aloq}\,(\lambda x.\, [\![\text{Bill}]\!]^{g[3\to x]}\, [\![\text{VP}]\!]^{g[3\to x]}) & \textbf{FA} \\
& = \textsc{aloq}\,(\lambda x.\, [\![\text{VP}]\!]^{g[3\to x]})\, \textsc{b} & \text{Lexicon} \\
& = \textsc{aloq}\,(\lambda x.\, [\![\text{answered}]\!]^{g[3\to x]}\, [\![t_3]\!]^{g[3\to x]}\, \textsc{b}) & \textbf{FA} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{answered}\, [\![t_3]\!]^{g[3\to x]}\, \textsc{b}) & \text{Lexicon} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{answered}\, x\, \textsc{b}) & \text{Lexicon}
\end{array}
$$

Figure 1: *at least one question, Bill answered*

- If $\textsc{aloq} = \lambda P.\, \{x : \textsc{question}\, x\} \cap \{x : P\, x\} \neq \varnothing$, then the result β-reduces to the following:

$$\{x : \textsc{question}\, x\} \cap \{x : \textsc{answered}\, x\, \textsc{b}\} \neq \varnothing$$

- Now for an example with two quantifiers. This works the same as the first case. The only difference is the presence of an additional quantifier. But since that extra quantifier is in subject position, interpretation proceeds seamlessly.



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\begin{array}{rll}
[\![\text{TopP}]\!]^g & = [\![\text{at least one question}]\!]^g([\![\Lambda]\!]^g) & \textbf{FA} \\
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& = \textsc{aloq}\,(\lambda x.\, [\![\text{S}]\!]^{g[3\to x]}) & \textbf{PA} \\
& = \textsc{aloq}\,(\lambda x.\, [\![\text{everybody}]\!]^{g[3\to x]}([\![\text{VP}]\!]^{g[3\to x]})) & \textbf{FA} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{eb}\, [\![\text{VP}]\!]^{g[3\to x]}) & \text{Lexicon} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{eb}\,([\![\text{answered}]\!]^{g[3\to x]}\, [\![t_3]\!]^{g[3\to x]})) & \textbf{FA} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{eb}\,(\textsc{answered}\, [\![t_3]\!]^{g[3\to x]})) & \text{Lexicon} \\
& = \textsc{aloq}\,(\lambda x.\, \textsc{eb}\,(\textsc{answered}\, x)) & \text{Lexicon}
\end{array}
$$

Figure 2: *at least one question, everybody answered*

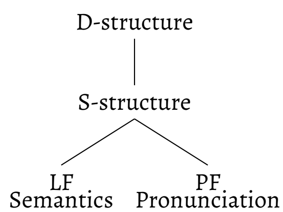
- We end up requiring the set of questions and the set of things everybody answered have a nonempty intersection:

$$\{x : \textsc{question}\, x\} \cap \{x : \textsc{ppl} \subseteq \{y : \textsc{answered}\, x\, y\}\} \neq \varnothing$$

- Specifically, the property that characterizes things everybody answered is asserted to be a member of $[\![\text{at least one question}]\!]^g$. This holds iff the set of things everybody answered and the set of questions have a non-empty intersection.
- The overall theme: movement creates a structure such that the sister of the moved quantifier denotes a property (type $\langle e, t\rangle$), exactly the right sort of thing to combine with the moved quantifier (type $\langle\langle e, t\rangle, t\rangle$) by functional application.
- It is important that the trace is type e. What happens if the trace is type $\langle\langle e, t\rangle, t\rangle$ and the type of Λ is $\langle\langle\langle e, t\rangle, t\rangle, t\rangle$?

4 LF

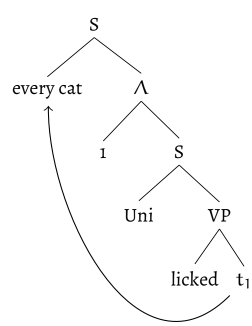
- Our account of these phenomena will closely parallel the account of topicalization we began with. It'll require two substantial shifts in our theory:
  1. **LF** (mnemonic for "logical form", but really means something distinct from what is usually meant by that term): an abstract level of representation which serves as the input to $[\![\cdot]\!]^g$.
  2. **QR** (abbreviation for "quantifier raising"): a movement operation that may occur between surface structures and LF. Results when an XP is covertly moved, leaving behind a trace and inserting an abstraction index co-indexed with the trace.
- "Y-model" of syntax (we have not talked so much about D-structure or PF):



- So the relationship between overt structure and meaning is less direct than we had been assuming (hoping?). As we will see, the interpreted structure can be a good deal more abstract than what we see on the surface.
- What we will assume is that the interpreted structures with quantifiers in them can look a lot like topicalized cases.
- Like topicalization, QR inserts a trace and a co-indexed, c-commanding abstraction operator. The sister of the moved quantifier will have type $\langle e, t\rangle$, the right sort of thing to combine with the quantifier by functional application.

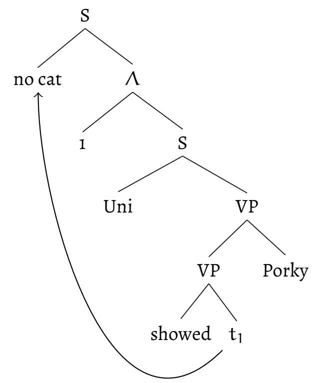
5 Examples (take notes!)

- In situ quantification:



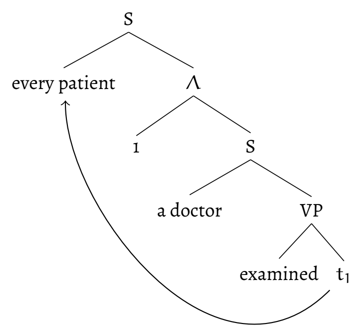
$\textsc{every-cat}\ (\lambda x.\ \textsc{licked}\ x\ \textsc{u})$

- In situ quantification with ditransitives:



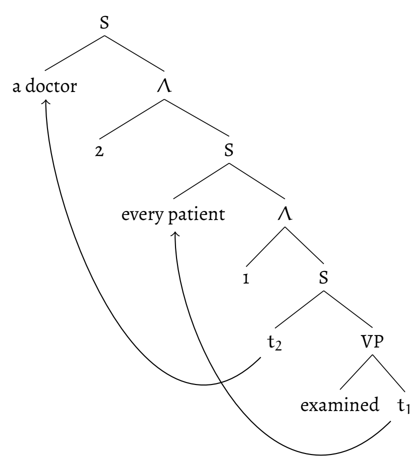
NO-CAT $(\lambda x.$ SHOWED x P U$)$

- Inverse scope:



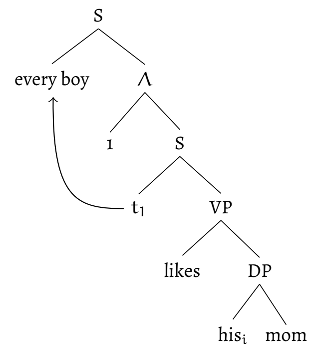
EVERY-PATIENT $(\lambda x.$ A-DOCTOR (EXAMINED $x$$))$

- Restoring surface scope:



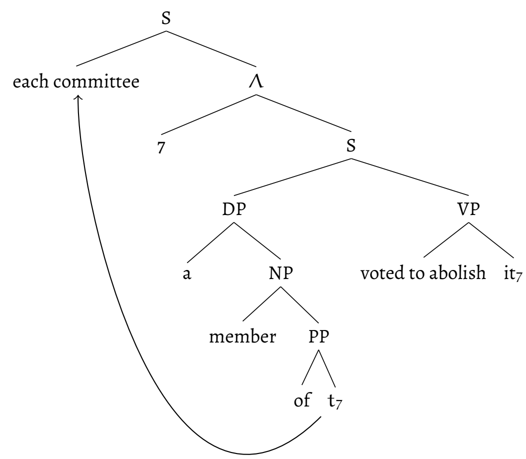
A-DOCTOR $(\lambda y.$ EVERY-PATIENT $(\lambda x.$ EXAMINED $x\ y))$

- Binding:



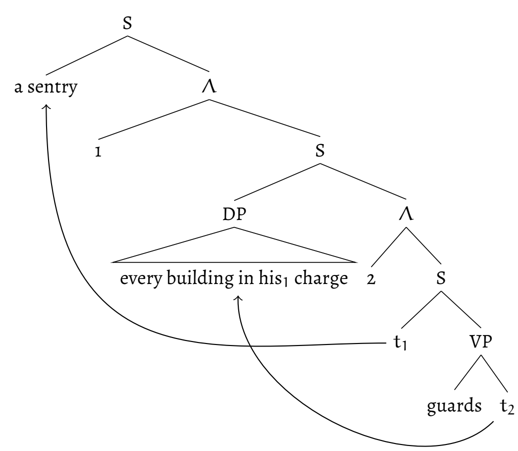
$$\textsc{every-boy}\,(\lambda x.\ \textsc{likes}\,(\textsc{mom}\ x)\ x)$$

- Inverse linking:



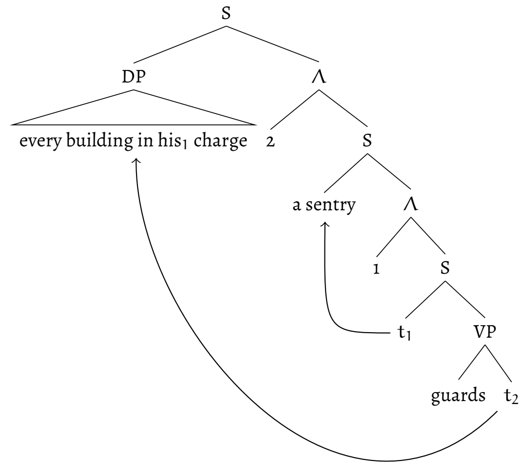
$$\textsc{each-committee}\,(\lambda x.\ [\![\text{a member of } t_7]\!]^{g[7\to x]}\ (\textsc{voted-to-abolish}\ x))$$

- A quantifier $\mathcal{Q}_1$ can only bind into a quantifier $\mathcal{Q}_2$ if $\mathcal{Q}_1$ has scope over $\mathcal{Q}_2$, where $\mathcal{Q}_1$ has scope over $\mathcal{Q}_2$ iff $\mathcal{Q}_1$ c-commands $\mathcal{Q}_2$ at LF:



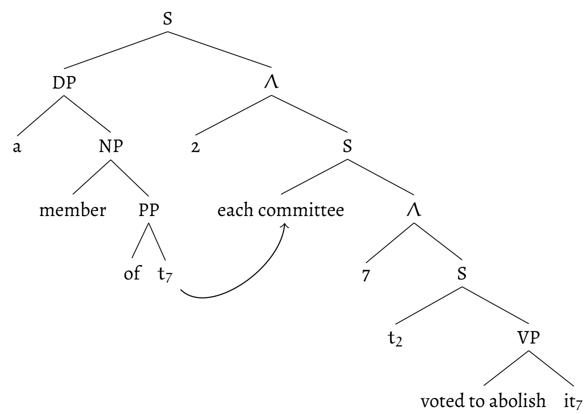
$$\textsc{a-sentry}\,(\lambda x.\ [\![\text{every building in his}_1 \text{ charge}]\!]^{g[1\to x]}\ (\lambda y.\ \textsc{guards}\ y\ x))$$

- If we try to assign the object quantifier scope over the subject, we inevitably end up unbinding the pronoun his_1:



$$[\![\text{every building in his}_1\text{ charge}]\!]^g\ (\lambda y.\ \textsc{a-sentry}\ (\lambda x.\ \textsc{guards}\ y\ x))$$

- Over-generation concern: QR should never be able to un-bind traces. That is, the following LF shouldn't be allowed, on pain of assigning a free-pronoun-like interpretation to the trace:



$$[\![\text{a member of } t_7]\!]^g\ (\lambda x.\ \textsc{each-committee}\ (\lambda y.\ \textsc{voted-to-abolish}\ y\ x))$$

- The truth conditions derived in this case are truly bizarre. Given an assignment g, they require there to be a member of $g\ 7$ such that, for each committee x, s/he voted to abolish x.
- Obviously, this isn't a possible reading of the sentence, and so the rule that relates S-structure with LFs will have to be carefully formulated so avoid this sort of outcome.

6 Getting by without QR?

- There exist other ways to interpret object quantifiers in situ. For example, we might imagine that there is a silent morpheme that either applies to transitive verbs or quantifiers and allows them to compose directly:

$$[\![\text{sat}_\varnothing]\!]^g = \lambda R_{\langle e,\langle e,t\rangle\rangle}.\lambda \mathcal{Q}_{\langle\langle e,t\rangle,t\rangle}.\lambda x_e.\mathcal{Q}(\lambda y.R(y)(x))$$

$$[\![\text{sat}_\varnothing]\!]^g = \lambda \mathcal{Q}_{\langle\langle e,t\rangle,t\rangle}.\lambda R_{\langle e,\langle e,t\rangle\rangle}.\lambda x_e.\mathcal{Q}(\lambda y.R(y)(x))$$

- Alternatively, it could be that everything is type $\langle\langle e,t\rangle,t\rangle$ and transitive verbs are born with a higher type:

$$[\![\text{John}]\!]^g = \lambda P_{\langle e,t\rangle}.P(j) \qquad [\![\text{met}]\!]^g = \lambda \mathcal{Q}_{\langle\langle e,t\rangle,t\rangle}.\lambda x.\mathcal{Q}(\lambda y.\text{met}'(y)(x))$$

- Yet another possibility is that some expressions are born as type e but shift into type-$\langle\langle e,t\rangle,t\rangle$ expressions via the following silent morpheme:

$$[\![\text{lift}]\!]^g = \lambda x_e.\lambda P_{\langle e,t\rangle}.P(x)$$

- And we haven't even come close to exploring the entire logical space of possibilities. For example, it might be the case that functional application is not the sole saturative mode of combination(!).