1 Relative clauses

We know what every boy who Mary saw laughed means:

∀x.boy(x) ∧ saw(x)(m) → laughed(x)

So, every boy who Mary saw must denote

λQ∀x.boy(x) ∧ saw(x)(m) → Q(x)

We already decided that every denotes

λPλQ∀x.P(x) → Q(x)

So, boy who Mary saw must denote something that combines with every to return the meaning of every boy who Mary saw. This does the job nicely:

λx.boy(x) ∧ saw(x)(m)

This leaves us with some interesting syntactic and semantic puzzles.

- Syntactic: what is the internal structure of boy who Mary saw? In particular, how do we cope with the fact that an NP object is missing — extraordinarily in this construction, since Mary saw is not generally thought to be a legitimate phrase (constituent)?

- Semantic: how can we built up the meaning λx.boy(x) ∧ saw(x)(m) compositionally, noting in particular that the λ binds a variable corresponding to the object of saw — what is normally it’s first syntactic argument?

We’ll look at two analyses.

- The movement-and-traces analysis of Heim & Kratzer (1998) makes crucial use of transformations and variable binding, and requires that the interpretive procedure operate on a separate level of “Logical Form”, rather than on the surface form of the sentence.
Jacobson’s analysis interprets the surface string directly, with crucial use of type-shifting operations. It enforces super-strict **locality** constraints: no interpretive procedure can make reference to the internal structure of its immediate arguments. This is why J keeps repeating things like “Parse trees are an epiphenomenon, the grammar does not see them”. In J’s grammar you only ever see expressions — (phon, syn, sem) triples — inside denotation braces.

2 Movement-and-traces analysis

Heim & Kratzer (1998) give a more-or-less standard analysis from transformational grammar: *who* is moved from the object position of *saw*, leaving behind a *trace* (or, a copy that is interpreted in the way that H&K interpret traces: Fox 2002).

![CP diagram]

We have to require that *who, that, or both are rendered phonologically null in some fashion* (Heim & Kratzer 1998: 89).

- every boy who Mary saw
- every boy that Mary saw
- every boy Mary saw
- *every boy who that Mary saw

H&K also assume that *that* is semantically vacuous, as in our CG fragment.

Their basic rule is type-driven function application, similar to the DC fragment. But they crucially include traces and pronouns, interpreted as free variables by relativizing interpretation of all expressions to an assignment function.

**Definition 1. (Assignment function)** An assignment function is any function $g : \mathbb{N} \rightarrow D_e$.

We define $\llbracket \cdot \rrbracket$ basically as in FOL, except that traces and pronouns are our variables.

- If, for some $i \in \mathbb{N}$, $\alpha \in \{t_i, \text{he}_i, \text{she}_i, \text{they}_i, \ldots\}$, then $\llbracket \alpha \rrbracket = g(i)$.
- Otherwise, $\llbracket \alpha \rrbracket = \mathcal{I} (\alpha)$.
Suppose \( g = \{1 \rightarrow b, 2 \rightarrow f, 3 \rightarrow s\} \). Then this sentence is true iff \( \text{saw}(f)(m) \).

To interpret this we need a new composition rule.

**Definition 2. (Predicate abstraction)** If \( \alpha \) is a branching node whose daughters are \( \beta_i \) and \( \gamma \), where \( \beta \) is a relative pronoun or “such”, and \( i \in \mathbb{N} \), then for any variable assignment \( g \), 
\[
[\alpha]^g = \lambda x.[\gamma]^g[i \mapsto x].
\]

This gives us

(Heim & Kratzer 1998: 114)
Notice that the truth of Mary saw \( t_2 \) depends on the choice of \( g \), but this is discarded when we get to the higher level: the truth of every boy that Mary saw laughed does not on the choice of \( g \).

3 Direct-compositional analysis

3.1 Composition

A different way to get the same effect, without variable assignments, movement, or traces:

**Compose-Right:** If \( \alpha = ([\alpha], A_{/RB}, [\alpha]) \) and \( \beta = ([\beta], B_{/RC}, [\beta]) \), there is a \( \gamma = ([\alpha - \beta], A_{/RC}, \lambda x.\alpha([\beta](x))) \).

**Compose-Left:** If \( \alpha = ([\alpha], A_{/LB}, [\alpha]) \) and \( \beta = ([\beta], B_{/LC}, [\beta]) \), there is a \( \gamma = ([\alpha - \beta], A_{/LC}, \lambda x.\alpha([\beta](x))) \).

We can right-compose a GQ and a transitive verb to form a “nonstandard constituent”:

\[
\lambda z[\lambda Q \forall x.\text{dog}(x) \rightarrow Q(x)]([\lambda x \lambda y.\text{saw}(x)(y)](z))
\]

Top node reduces as follows:

\[\lambda z[\lambda Q \forall x.\text{dog}(x) \rightarrow Q(x)]([\lambda x \lambda y.\text{saw}(x)(y)](z)).\]
• \( \lambda z [\lambda Q \forall x. \text{dog}(x) \rightarrow Q(x)]([\lambda y. \text{saw}(z)(y)]) \)
• \( \lambda z \forall x. \text{dog}(x) \rightarrow [\lambda y. \text{saw}(z)(y)](x) \)
• \( \lambda z \forall x. \text{dog}(x) \rightarrow \text{saw}(z)(x) \quad \text{“the set of things that every dog saw”} \)

For names, we have to lift:

\[
\begin{array}{c}
\lambda z \forall x. \text{dog}(x) \rightarrow \text{saw}(z)(x) \\
\lambda P.P(\text{BO})([\lambda x \lambda y. \text{saw}(x)(y)](z)) \\
\end{array}
\]

where \( \text{BO} \) is a bound variable name.

Reduces to ... ?

Problematic?

- \textit{Barack saw} fails some syntactic constituency tests:
  1) (?) Michelle, Bill said that Barack saw
  2) *Barack saw, Bill said that Michelle

- So do other things that everyone agrees are constituents:
  3) *Man in the red hat, Bill said that Barack saw the

- Jacobson argues that whatever prevents ‘fronting’ in (3) may also account for (2).

### 3.2 Gapping

Two parses for \textit{Barack likes Michelle}:

\[
\begin{array}{c}
\begin{array}{c}
\text{S[V]} \\
\text{NP} \\
\text{Barack} \\
\end{array} \\
\begin{array}{c}
(\text{S[V]}/L\text{NP})/R\text{NP} \\
\text{likes} \\
\text{NP} \\
\text{Michelle} \\
\end{array} \\
\end{array}
\]

\[
\begin{array}{c}
\begin{array}{c}
\text{S[V]} \\
\text{NP} \\
\text{Barack} \\
\end{array} \\
\begin{array}{c}
(\text{S[V]}/L\text{NP})/R\text{NP} \\
\text{likes} \\
\text{NP} \\
\text{Michelle} \\
\end{array} \\
\end{array}
\]

5
“Nonstandard constituent” advantage: extremely simple account of gapping.

- Bill loves, and Mary hates, extremely long movies.
- Every dog saw, and Barack talked to, Michelle.

This is just ordinary coordination of nonstandard constituents!

3.3 Relative Clauses

The analysis of relative clauses like every boy who Mary likes now just requires us to add a new functional item to our lexicon:

$$\langle [\text{who}], (N/_{L}N)/R(S[V]/_{R}NP), \lambda P\lambda Q\lambda x. P(x) \land Q(x) \rangle$$

(Glossing over the animacy presupposition, of course.)

```
\begin{array}{c}
N \\
\lambda x.\text{saw}(x)(m) \land \text{boy}(x)
\end{array}
```

```
\begin{array}{c}
N/_{L}N \\
\text{boy} \\
\lambda Q\lambda x.\text{saw}(x)(m) \land Q(x)
\end{array}
```

```
\begin{array}{c}
(N/_{L}N)/R(S[V]/_{R}NP) \land P\lambda Q\lambda x. P(x) \land Q(x)
\end{array}
```

```
\begin{array}{c}
S[V]/_{R}NP \\
\lambda z.\text{saw}(z)(m)
\end{array}
```

```
\begin{array}{c}
(S[V])/_{R}(S[V]/_{L}NP) \land P.P(m)
\end{array}
```

```
\begin{array}{c}
\lambda x.y.\text{saw}(x)(y)
\end{array}
```

Jacobson achieves this effect in two steps, treating who as an identity function with result category RC, and generalizing the Mod type-shifter defined for attributive adjectives to apply to things of category RC as well, returning a $N/_{L}N$.

$$\langle [\text{who}], RC/_{R}(S[V]/_{R}NP), \lambda x.x \rangle$$
3.4 The Geach Rule

We can get the effect of function composition without introducing new composition principles by using the Geach type-shifter.

**Geach-Right:** If \( \alpha = ([\alpha], A/RB, [\alpha]) \), there is a \( \gamma = ([\alpha], (A/RC)/L(B/RC), \lambda P\alpha. [\alpha](P(x))) \).

**Geach-Left:** If \( \alpha = ([\alpha], A/LB, [\alpha]) \), there is a \( \gamma = ([\alpha], (A/LC)/L(B/LC), \lambda P\alpha. [\alpha](P(x))) \).

\[
\lambda y \forall x. \text{dog}(x) \rightarrow \text{saw}(y)(x) \land \text{boy}(y)
\]

References
