Crossover i[1]

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[1] 24.979: Topics in semantics

Getting high: Scope, projection, and evaluation order

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General notice

- This will, as far as we're aware, be our final meeting in-person for the remainder of the semester. We plan to hold subsequent meetings via `zoom`. Details will follow.
- Next week's class, is *canceled*, and the following week is spring break. The next class will therefore be on **Thursday April 2**.
- We're going to do everything we can to make sure that this class continues to run as smoothly as possible.
- We're available for remote meetings during normal working hours. Take advantage of this!

Homework

- Registered students: please send us a *project proposal* (less than two pages long) by Thursday March 26. This should ideally include a brief summary of what you plan to present in class (either a paper, or your own work).
- Everyone:
  - Read Gennaro Chierchia's 2019 paper "Origins of weak crossover: when dynamic semantics meets event semantics" (*Natural Language Semantics*). Send me at least one question by the end of Spring break.
  - There will be a third problem set, posted on Friday.

1 *Setting the stage*

- Last time Martin gave an overview of the movement approach to quantifier scope, and some of the other analytical approaches available to us (e.g., the ϵ-calculus).
- Given the extensive and rich literature, quantifier raising is a powerful tool

for analyzing phenomena such as Antecedent Contained Deletion (ACD).

- *Continuation semantics* is a much less mature framework. There haven't yet been serious attempts to model, e.g., ACD, but this should at least be attempted.[4].

- There are some conceptual advantages to continuation semantics, however – it sidesteps non-compositional complications involving, e.g., *trace conversion*[5], allowing for expressions to take scope via a generalization of Partee's LIFT.

- Furthermore Scopal Function Application (SFA) – the composition rule essential for composing continuized values – has a *built in left-to-right bias*.

- So far we've only applied this to the (poorly understood) surface scope bias for sentences with multiple QPs.

- This week we'll be getting round to (arguably) the jewel in the crown of the continuations literature – a semantic account of *crossover phenomena*.

- I'll begin by giving a brief overview of the phenomenon, before discussing pronominal binding in Variable Free Semantics (VFS).

- I'll show how the Barker & Shan account of crossover leverages distinctive properties of continuation semantics, in a *variable free* setting.

- In the next section, I'll show how we can translate Barker & Shan's account into the "standard" setting, where pronouns denote variables.

[4] There are also over-generation issues. Much like Quantifier Raising (QR), *scope islands* seriously constrain scope-taking possiblities (and unlike QR, continuations allow for a purely *denotational* theory of scope islands). On other hand, our toy account of split scope demonstrated that continuations are so powerful, that unattested readings can be difficult to block.

[5] Sauerland 2004, Fox & Johnson 2016, etc.

2 The phenomenon

2.1 Weak crossover and overt movement

The simplest form of the Weak Crossover (WCO) paradigm[6] is illustrated below:

(1) a. Who^{x} t_x likes his$_x$ mother?
 b. *Who^{x} does his mother like t_x?

[6] The term "crossover" was originally coined by Paul Postal.

At first blush, it looks like the *wh*-quantifier can only bind a pronominal if the base-position of the *wh* c-commands the pronoun.

Why is this a problem? It is fairly standard to assume that scope feeds binding; in fact, according in semantics 101, it's often assumed that scope is *necessary* for binding – moving the *wh* creates an abstraction index.

The following LF should be perfectly legitimate from the perspective of the semantics:

(2) who 1 [his$_1$ mother likes t_1]?

Since both traces and pronouns are interpreted as variables, there is no reason why the representation above shouldn't result in a sensible reading.

This constraint on variable binding extends beyond configurations involving overt *wh*-movement to those involving quantificational scope.[7]

[7] This was first observed by Chomsky (1976)

(3) a. Everyone^x loves his$_x$ mother.
    b. *His$_x$ mother loves everyone^x.

A special case of WCO is *strong crossover* – in a strong crossover configuration, the bound pronoun c-commands the base position of the binder.

(4) a. *Who^x did he$_x$ say Mary saw t_x?
    b. Who^x said Mary saw him$_x$.

(5) a. *He$_x$ wants to see everyone^x?
    b. Everyone^x wants to see him$_x$.

2.2 *A- vs. A'-dependencies*

Unlike A'-movement, A-movement *bleeds* WCO.

This is illustrated for A-movement (raising) of a QP...

(6) Everyone^x seems to his$_x$ mother to be a genius.

...and for A-movement, followed by A'-movement, of a *wh*-expression. Crucially, the dependency spanning the bound variable is an A-dependency:

(7) Who^x seems to his$_x$ mother to be a genius.

We'll have something to say about this later on.

2.3 wco is about scope, not c-command

It has been known for some time that variable binding *doesn't* require c-command (contra received wisdom):

In the following examples, the base-position of the binder doesn't c-command the bound variable, but binding is still possible (Ruys 1992 calls this the *transitivity property* of variable binding).

(8) [Every boy^x's mother] loves him$_x$.

(9) [[Every boy^x's mother]'s husband] loves him$_x$.

(10) [Which boy^x's mother] loves him$_x$.

(11) [[Which boy^x's mother]'s husband] loves him$_x$.

Note that this paradigm could in itself be tricky for quantifier raising theories of scope (the *wh* pied-piping cases fare even worse), especially if DP is a phase.

Continuation semantics, on the other hand, straightforwardly predicts scope and hence binding out of DP, as we'll see later.

Binding out of DP correlates with inverse linking readings:

(12) [Someone in [every city]^x] hates it$_x$. ✓ $\forall > \exists$; ✗$\exists > \forall$

Scope is harder to distinguish between two *wh*-expressions:[8]

(13) [Which picture of [which boy]^x] pleased him$_x$.

Note that wco effects obtain if the the pronoun precedes the base-position of the DP containing the binder:

(14) *His$_x$ father loves [every boy^x's mother].

(15) *[Whose^x father] does his$_x$ mother hate?

It seems that crossover obtains if a pronoun occurs to the *left* of the base-position of its binder (modulo A-movement).

[8] In fact, if the *wh*-expressions are just existential quantifiers, they should be scopally commutative.

One might imagine that the binder must be the *sort key* (in Kuno's 1982 sense) under a pair-list reading of the question. I've argued however in other work (see Elliott 2019a) that what I call *nested wh-questions* following Heim 1994, lack a pair-list reading.

These kinds of examples deserve more careful consideration.

3 *Weakest crossover*

Lasnik & Stowell observe that crossover is obviated in configurations such as the following:

(16) Who did you stay with [Op_{PG} before his wife had spoken to __]?

4 *Crossover phenomena in continuation semantics*

A refresher

(17) Tower notation (def.)

$$\frac{f\,[]}{x} \coloneqq \lambda k \,.\, f\,(k\,x)$$

(18) Tower types (def.)

$$\frac{\mathsf{b}}{\mathsf{a}} \coloneqq (\mathsf{a} \to \mathsf{b}) \to \mathsf{b}$$

(19) Type constructor $\mathsf{K_t}$ (def.)

$$\mathsf{K_t}\ \mathsf{a} \coloneqq \frac{\mathsf{t}}{\mathsf{a}}$$

(20) *lift* (def.)

$$a^{\uparrow} \coloneqq \frac{[]}{a} \qquad (\uparrow) : \mathsf{a} \to \mathsf{K_t}\ \mathsf{a}$$

(21) *Internal lift* (tower ver.)

$$\left(\frac{f\,[]}{x}\right)^{\Uparrow} \coloneqq \cfrac{f\,[]}{\cfrac{[]}{x}}$$

(22) *lower* (def.)

$$\left(\frac{f\,[]}{p}\right)^{\downarrow} = f\ p \qquad (\downarrow) : \mathsf{K_t}\ \mathsf{t} \to \mathsf{t}$$

(23) *Internal lower* (def.)

$$\left(\cfrac{f\,[]}{\cfrac{g\,[]}{p}}\right)^{\Downarrow} \coloneqq \cfrac{f\,[]}{\left(\cfrac{g\,[]}{p}\right)^{\downarrow}}$$

(24) Scopal Function Application (SFA) (def.)

$$\frac{f\,[]}{x}\ \mathsf{S}\ \frac{g\,[]}{y} \coloneqq \frac{f\,(g\,[])}{x\ \mathsf{A}\ y} \qquad \mathsf{S} : \mathsf{K_t}\ (\mathsf{a} \to \mathsf{b}) \to \mathsf{K_t}\ \mathsf{a} \to \mathsf{K_t}\ \mathsf{b}$$

Remember: the default in continuation semantics is *left-to-right sequencing of scopal effects*.

Lower accounts for scopal ambiguities with scopally immobile expressions, such as intensional verbs etc.

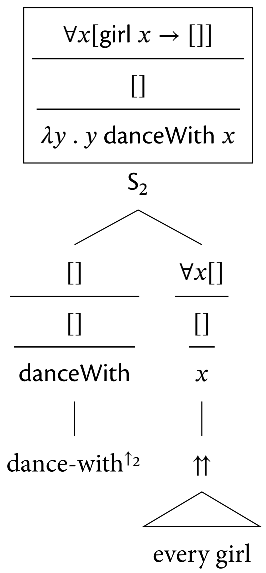
We need *internal lift* and *n-story towers* in order to obviate the *left-to-right bias*, and account for inverse scope (in non scopally-rigid languages).[9]

[9] See Barker 2002 for a different approach couched in continuation semantics, which posits both a rightwards version of SFA and a leftwards version.

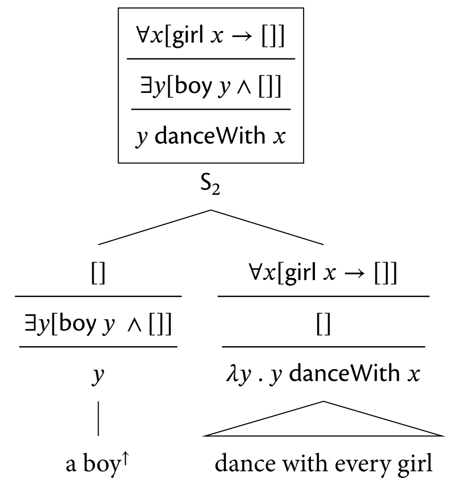
For a reminder of how this works, let's derive an inverse scope reading:

(25) A boy danced with every girl. $\forall > \exists$

(26) Step 1: internally lift *every girl*

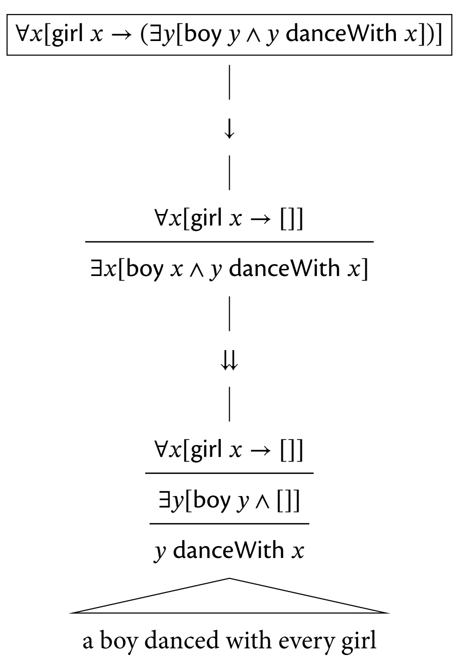


(27) Step 2: externally lift *a boy*



Now we can collapse the tower by doing *internal lower*, followed by *lower*:

(28)



4.1 Variable free foundations

Before we develop a story for crossover phenomena in continuation semantics, we need a story about pronominal binding.

Barker & Shan adopt a version of Polly Jacobson's Variable Free Semantics (VFS) – in this section, we'll lay out the foundations.

The fundamental idea is that a sentence with a free pronoun denotes an open proposition.

(29) $[\![\text{Jo likes him}]\!] \coloneqq \lambda x \,.\, \mathsf{j\ likes}\ x$

How do we derive this compositionally?

Jacobson (1999) develops a theory of pronominals according to which they denote the identity function on individuals – this theory is known as VFS:[10]

[10] Pronouns also come with phi features, which must be interpeted – we'll mostly abstract away from this complication in what follows, but the most straightforward implementation is to treat pronouns with phi features as denoting partial (i.e., presuppositional) identity functions.

(30) $[\![\text{her}]\!] \coloneqq \lambda x : \mathsf{identifies\text{-}fem}\ x \,.\, x$

(31) $\mathsf{pro}_{Polly} \coloneqq \lambda x \,.\, x$ $\qquad \mathsf{e} \to \mathsf{e}$

Pronominal meanings can compose with ordinary meanings via a type-shifter (analogous to *lift*) and a composition rule (analagous to SFA).[11]

[11] This presentation of VFS departs significantly from Jacobson and is based on Charlow 2018, 2019.

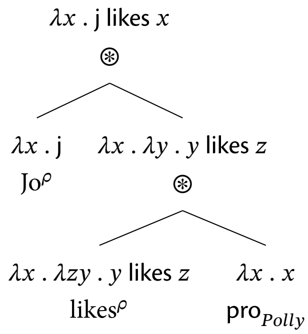
(32) Pure (def.)
$a^{\rho} \coloneqq \lambda x \,.\, a$ $\qquad \rho : \mathsf{a} \to \mathsf{e} \to \mathsf{a}$

(33) Ap (def.)[12]
$m \circledast n \coloneqq \lambda x \,.\, (m\ x)\ \mathsf{A}\ (n\ x)$ $\qquad \circledast : (\mathsf{e} \to (\mathsf{a} \to \mathsf{b})) \to (\mathsf{e} \to \mathsf{a}) \to \mathsf{e} \to \mathsf{b}$
$\circledast : (\mathsf{e} \to \mathsf{a}) \to (\mathsf{e} \to (\mathsf{a} \to \mathsf{b})) \to \mathsf{e} \to \mathsf{b}$

[12] Since *ap* is defined in terms of bidirectional function application (A), we have a forwards ap and a backwards ap, depending on whether the function argument is on the left or the right. I give the type signatures of both functions here.

Composition of a sentence with a pronoun may now proceed via ap and pure – non-pronominal meanings get pure-shifted, and composition proceeds via ap.

(34)



An aside on **applicative functors**

As we've alluded to, there's a family resemblance between:

- The *lift* of continuation semantics, and the *pure* of VFS
- SFA from continuation semantics and the *ap* of VFS.

This is because both continuation semantics and VFS implicitly use *applicative functors* (Mcbride & Paterson 2008) – a notion from functional programming and category theory for characterizing composition in an enriched semantic domain.
An applicative functor simply consists of a type-constructor, characterizing the enriched value-space, and two operations.

[13] Charlow (2019) provides a different way of incorporating VFS and continuation semantics by composing applicative functors.

4.2 *Going Scopal*

How do we get pronouns to interact with scope-takers in our current setting? Barker & Shan's solution is to treat pronouns *themselves* as scope-takers:[13]

(35) Pronouns in continuation semantics
$\text{pro}_{BS} \coloneqq \lambda k\,.\,\lambda x\,.\,k\;x$

(36) Pronouns (tower version)
$$\text{pro} \coloneqq \frac{\lambda x\,.\,[\,]}{x}$$

The pro_{BS} denotation preserves the intuition of VFS that pronouns should be treated as identity functions, but the λx part *takes scope*.[14]

Our current definition of SFA is too rigidly typed to handle pronominal scope takers, however. To see why, consider the type of pro_{BS}:

[14] How do we derive the *BS* pronoun denotation from the *Polly* pronoun denotation? Explaining how requires borrowing a useful notion from functional programming/category theory.

First, note that $((\to)\;\mathsf{e})$ characterizes an *enriched value space* – essentially, the value space assumed in VFS. Informally, meanings with an extra outer λx argument. $((\to)\;\mathsf{e})$ is a *functor*, which means that we can characterize a general way of applying ordinary functions of type $\mathsf{a} \to \mathsf{b}$ to values of type $\mathsf{e} \to \mathsf{a}$. We'll call this mapping map.

(37) $\text{map}\;m \coloneqq \lambda k\,.\,\lambda x\,.\,k\;(m\;x)$
$\text{map} : (\mathsf{e} \to \mathsf{a}) \to (\mathsf{a} \to \mathsf{b}) \to \mathsf{e} \to \mathsf{b}$

Applying map to pro_{Polly} gives back...pro_{BS}!

(38) $\text{pro}_{BS} : (\texttt{e} \rightarrow \texttt{t}) \rightarrow \texttt{e} \rightarrow \texttt{t}$

SFA is designed to handle scope-takers of type $(\texttt{a} \rightarrow \texttt{b}) \rightarrow \texttt{b}$, whereas a pronoun is a scope-taker of type $(\texttt{a} \rightarrow \texttt{b}) \rightarrow \texttt{c}$:

- It *expects* at a constituent of type $\texttt{t}$...
- ...and returns something of type $\texttt{e} \rightarrow \texttt{t}$.

It turns out, however, that we can give our existing definition of SFA a more general type in order to accommodate pronominal scope-takers:[15]

[15] If you had a go at the second problem set, and read the extra material from the second handout of the semester, then this idea should be familiar. In fact, generalizing our existing machinery to scope-takers of type $(\texttt{a} \rightarrow \texttt{b}) \rightarrow \texttt{c}$ receives independent motivation from DP-internal composition. We'll come back to this when we discuss scope out of DP and inverse linking later on.

(39) $m \, \mathsf{S} \, n \coloneqq \lambda k \, . \, m \, (\lambda x \, . \, n \, (\lambda y \, . \, k \, (x \, \mathsf{A} \, y)))$

(40) $\mathsf{S} : (((\texttt{a} \rightarrow \texttt{b}) \rightarrow \texttt{r}_1) \rightarrow \texttt{r}_2) \rightarrow ((\texttt{a} \rightarrow \texttt{r}_3) \rightarrow \texttt{r}_1) \rightarrow (\texttt{b} \rightarrow \texttt{r}_3) \rightarrow \texttt{r}_2$

Just so long as the scope type of the left input and the return type of the right input match, they cancel out.

We can model this idea of a generalized scope-taker using the type constructor $\mathsf{K}_\texttt{r}^\texttt{i}$.[16]

[16] This ultimately goes back to Wadler 1994.

(41) $\mathsf{K}_\texttt{r}^\texttt{i} \, \texttt{a} \coloneqq (\texttt{a} \rightarrow \texttt{i}) \rightarrow \texttt{r}$

Barker & Shan (2014) further generalize tower-type notation in order to accommodate scope takers in which the expected and return types differ.[17]

[17] See also Shan 2002.

(42) Tripartite tower types (def.)

$$\frac{\texttt{r} \mid \texttt{i}}{\texttt{a}} \coloneqq (\texttt{a} \rightarrow \texttt{i}) \rightarrow \texttt{r}$$

We can think of our existing tower notation as an abbreviation for a tripartite tower type, where the intermediate and final result types happen to be the same:

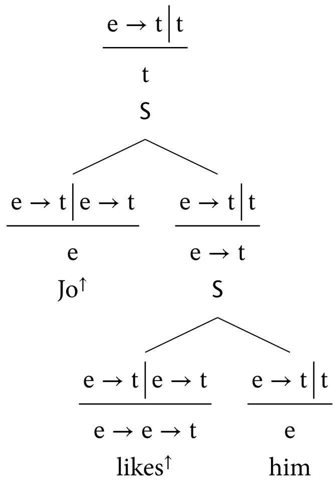
(43) Bipartite towers as abbreviations for tripartite towers

$$\frac{\texttt{r}}{\texttt{a}} \coloneqq \frac{\texttt{r} \mid \texttt{r}}{\texttt{a}}$$

We now have everything we need to accommodate pronominal scope-takers into our compositional regime:

(44) Jo likes him.

(45)



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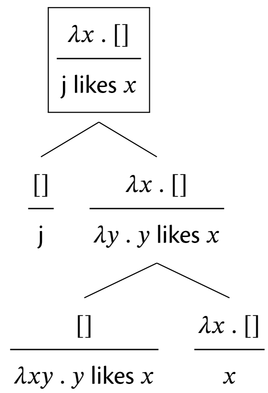


Now that we have tripartite towers, we can also adopt a more general typing for *lower*, which simply requires that the inner type and the scope type are both t.

(47) Lower (revised type)

$$\downarrow : \frac{a \,|\, t}{t} \rightarrow a$$

The definition remains the same – namely, when we *lower* a continuized value, we saturate the continuation argument with the identity function.

Observe that *lowering* the result of scoping out pro_{BS} gives back a VFS-style sentential meaning.

(48)
$$\left(\frac{\lambda x \,.\, []}{\text{j likes } x}\right)^{\downarrow} = \lambda x \,.\, \text{j likes } x$$

5 *Achieving variable binding*

Barker & Shan (2014) achieve *binding* in their framework by type-shifting the binder.

(49) Bind (def.)
$m^B := \lambda k \,.\, m\, (\lambda x \,.\, k\, x\, x)$ $\quad B : ((\mathsf{a} \to \mathsf{b}) \to \mathsf{c}) \to (\mathsf{a} \to \mathsf{a} \to \mathsf{b}) \to \mathsf{c}$

Bind pulls out the inner value from a continuized meaning, returns a new continuation with an extra argument saturated by the inner value. The tower version is perhaps more intuitive:

(50) Bind (tower ver.)

$$\left(\frac{f\, []}{x}\right) = \frac{f\, ([]\, x)}{x} \qquad B : \frac{\mathsf{c} \,|\, \mathsf{b}}{\mathsf{a}} \to \frac{\mathsf{c} \,|\, \mathsf{a} \to \mathsf{b}}{\mathsf{a}}$$

We'll illustrate with a quantifier, such as *every boy*:

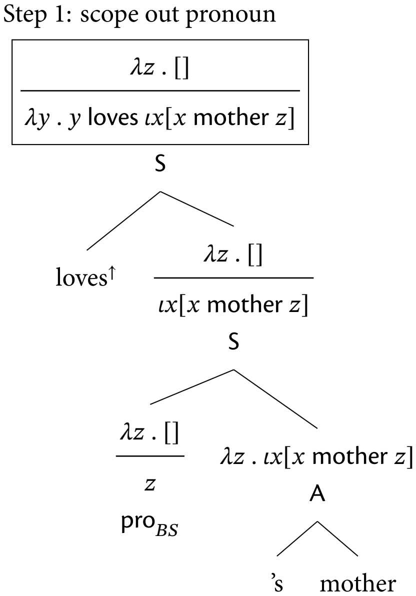
(51) $$\left(\frac{\forall x[\mathsf{boy}\ x \to []]}{x}\right)^B = \frac{\forall x[\mathsf{boy}\ x \to ([]\ x)]}{x}.$$

B-shifted *every boy* expects an *open proposition*; pronominals create open propositions.

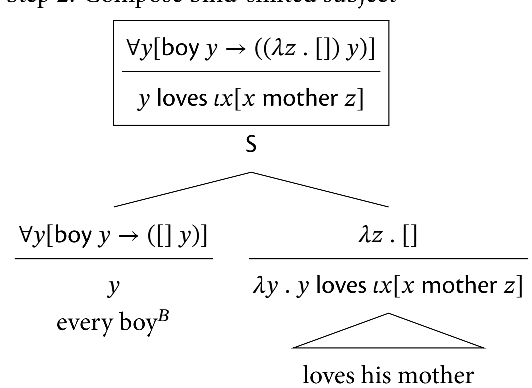
We now have everything we need in order to account for a simple case of variable binding.

(52) Every boy^x loves his$_x$ mother.

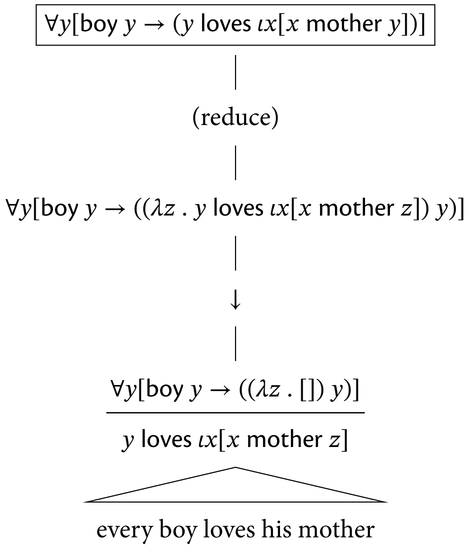
(53) Step 1: scope out pronoun



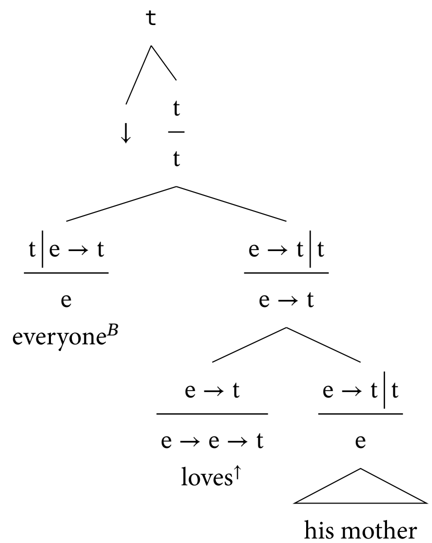
(54) Step 2: Compose bind-shifted subject



(55) Step 3: Lower the result



(56) Types:



> **Intuition**
>
> Pronouns *expect a proposition and return an open proposition*, whereas bind-shifted quantifiers *expect an open proposition and return a proposition*.

5.1 Getting the basic facts

Due to the *left-to-right bias* of SFA WCO-violating readings can never be fully lowered, assuming our basic inventory of combinators (we put higher-order combinators such as internal lift to one side for the time being).

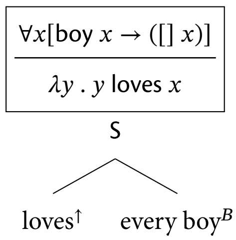
> **Assumption**
> A sentence is deemed felicitous only if computing its meaning results in a value of a lowerable type.

To illustrate, let's try to compute the meaning of a WCO violating sentence, and see how far we get:

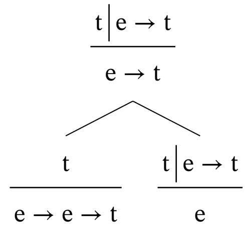
(57) *His$_x$ mother loves every boy^x.

First, we compute the value of the VP, first bind-shifting the quantifier:

(58) Composition

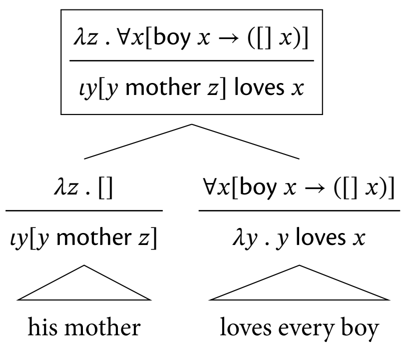


(59) Types:



Next, let's try to compose the pronoun. Since the effect of the pronoun (the λz) gets processed *before* the effect of the bind-shifted quantifier, binding is not and *can not* be achieved.

(60)



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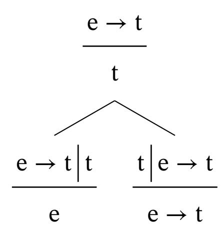


Furthermore, the resulting meaning is of an *unlowerable type* – it expects an open proposition, and returns an open proposition. This is the basic account of crossover in Barker & Shan (2014).

5.2 *Binding out of DP*

It's worth noting that, since continuation semantics can straightforwardly account for scope out of DP, it can account for binding out of DP.

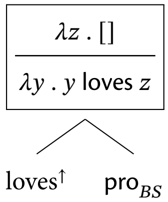
Bona fide scope out of DP is independently motivated in any case:

(62) [[No boy]^x's mother] gave him$_x$ anything to read.

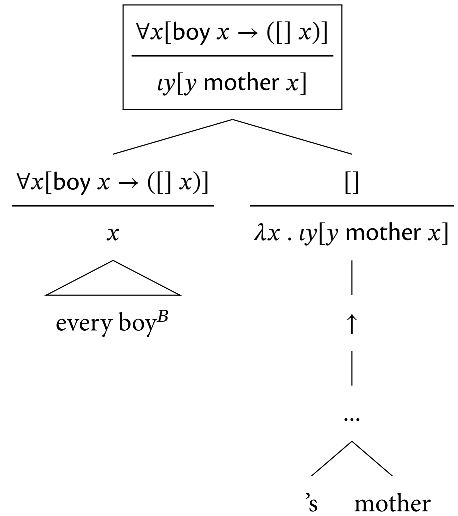
Consider a simple example of binding out of DP:

(63) Every boy^x's mother loves him$_x$.

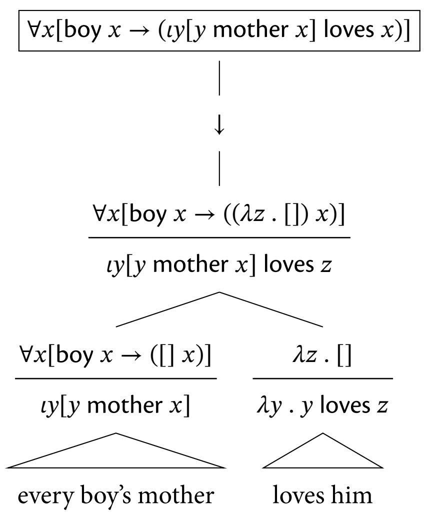
(64) Step 1: VP composition:



(65) Step 2: Subject composition:



(66) Step 3: compose and lower result



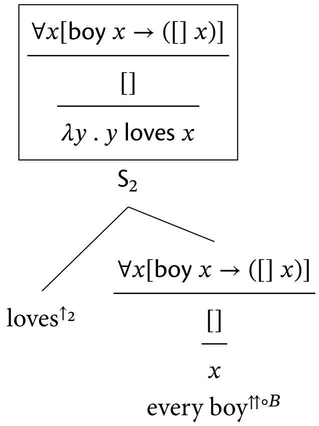
5.3 *Can inverse scope obviate crossover?*

Since continuation semantics has a mechanism for obviating the left-to-right bias – namely, *internal lift*, which allows QPs to take inverse scope – we have to ensure that internal lift doesn’t accidentally allow us to obviate crossover.

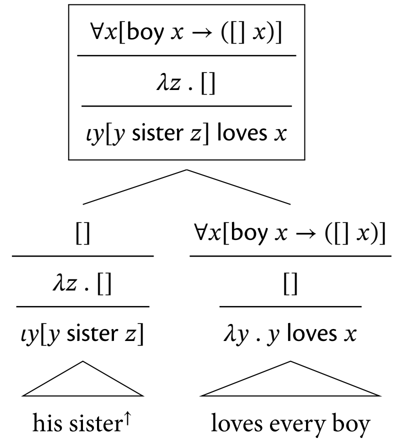
Let’s therefore try to bind-shift a crossover, and then internally lift it, to try to derive the unattested bound reading for *his sister loves every boy*:

(67) *His$_x$ sister loves every boy^x.

(68) Step 1: compose the VP meaning



(69) Step 2: compose the subject



The meaning we've computed looks fairly reasonable. Let's consider its type:

(70)
$$\left(\frac{\forall x[\mathsf{boy}\ x \to ([]\ x)]}{\dfrac{\lambda z\ .\ []}{\iota y[y\ \mathsf{sister}\ z]\ \mathsf{loves}\ x}}\right) : \frac{\mathsf{t} \mid \mathsf{e} \to \mathsf{t}}{\dfrac{\mathsf{e} \to \mathsf{t} \mid \mathsf{t}}{\mathsf{t}}}$$

We can internally lower once, since on the bottom two stories, the expected type matches the inner type, and we get:

(71)
$$\frac{\mathsf{t} \mid \mathsf{e} \to \mathsf{t}}{\mathsf{e} \to \mathsf{t}}$$

There *is* actually a sensible way to lower the result *again*, in such a way as to achieve binding, but in order to do this we'd need minimally a lower of type $(\mathtt{e} \to \mathtt{t}) \to \mathtt{e} \to \mathtt{t}$.

At the cost of being unable to treat lower simply as a polymorphic identity function, Barker & Shan conjecture that the grammar simply doesn't make a lower of the relevant type available – lower is rigidly typed, such that it only applies to propositions.

This is at the core of Barker & Shan's account of WCO – the payoff is a quantifier can only bind a pronoun on the same tower story.

It's worth noting at this point that Barker & Shan's makes an accurate prediction – WCO is about *scope*, not c-command – in continuation semantics, a quantifier can bind a pronoun just in case it's processed first.

This captures the fact that possessors can bind out of the DP:

A problem with continuation semantics and VFS: no obvious account of inverse linking.

6 *Variables strike back*

Does an explanation of crossover using continuations require a commitment to VFS?

Here I'll show that it doesn't. Their account is fully compatible with the "standard picture".

6.1 *The "standard" picture*

VFS has been argued to have some conceptual advantages, but it's far more common to treat pronouns as *variables*.

According to the standard picture (e.g., Heim & Kratzer 1998), pronouns are indexed and acquire their value relative to the evaluation assignment (the interpretation function is parameterized to an assignment).

(72) $[\![\text{her}_1]\!]^g \coloneqq g_1$

In the following I'll try to see if we can retain the essence of the Barker & Shan account of crossover in this more standard picture.

The first move I'll main is to extensionalize the standard picture, i.e., for us, pronouns will be *functions from assignments to individuals*:

(73) Pronouns (first ver.)

$\mathsf{pro}_n \coloneqq \lambda g\,.\,g_n \qquad \mathsf{pro}_n : \mathsf{g} \to \mathsf{e}$

Now, we can lift pronouns into scope takers in the same way as Barker & Shan lift the VFS pronoun into a scope-taker:[18]

(74) Pronouns (second ver.)

$\mathsf{pro}_n \coloneqq \dfrac{\lambda g\,.\,[\,]}{g_n} \qquad \mathsf{pro}_n : \dfrac{\mathsf{g} \to \mathsf{t} \,|\, \mathsf{t}}{\mathsf{e}}$

[18] Implicitly, we're using the map of type $\mathsf{g\ a} \to (\mathsf{a} \to \mathsf{b}) \to \mathsf{g\ b}$.

If we try to compute the meaning of a simple sentence such as *Jo loves him*, and lower the result, with this pronominal meaning, it should be obvious that what we get is the classical meaning extensionalized.

(75) $[\![\text{Jo loves him}_1]\!] = \lambda g \,.\, \mathsf{j} \text{ loves } g_1$

How do we shift a QP into a binder? Intuitively, this should involve taking something that expects (and returns) a proposition, and returns something that expects (and returns) an *assignment sensitive* proposition.[19]

(76) Abstract (def.)

$$\Lambda_n\ m \coloneqq \lambda k \,.\, \lambda g \,.\, m\ (\lambda x \,.\, k\ x\ \mathsf{g}^{[n \to x]}) \qquad \Lambda_n : \frac{\mathsf{t}}{\mathsf{e}} \to \frac{\mathsf{g} \to \mathsf{t}}{\mathsf{e}}$$

[19] One advantage of going extensional is therefore a fully categorematic treatment of abstraction; there is no need for a syncategorematic rule, such as Heim & Kratzer's Predicate Abstraction.

An extensional account of assignment sensitivity provides a semantic account of binding reconstruction, although I won't go into the details here. It also has been argued to be necessary to resolve issues in the theory of acd by, e.g., Kennedy (2014).

Abstract takes a QP, pulls out its inner value, and returns a scope-taker that (i) expects an *assignment-sensitive proposition*, feeds in a modified assignment, and then re-abstracts over it.

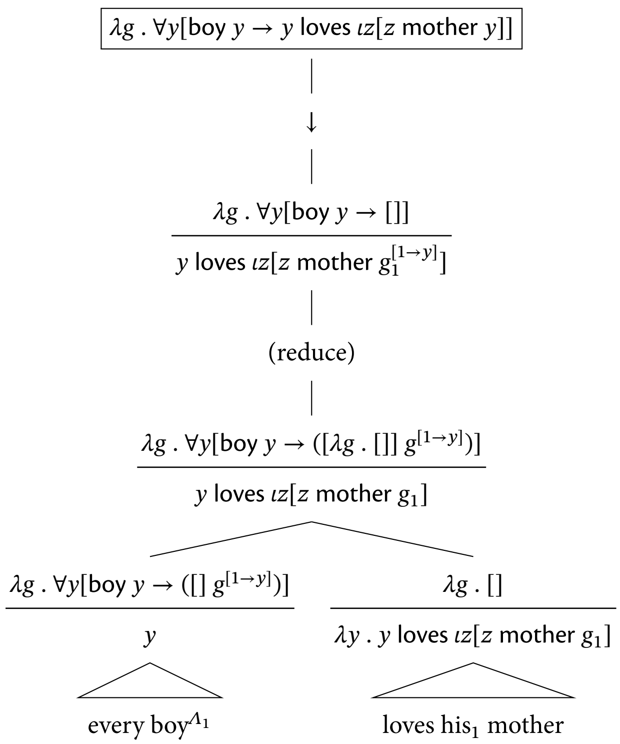
In tower form:

(77) $$\Lambda_n \left(\frac{f\ [\,]}{x} \right) = \frac{\lambda g \,.\, f\ ([\,]\ \mathsf{g}^{[n \to x]})}{x}$$

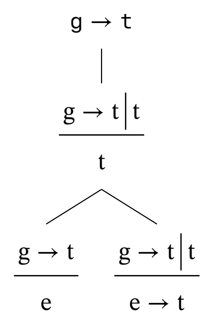
Now we have everything we need to achieve binding. The computation is pretty much isomorphic to what we had in vfs.

(78) Every boy loves his mother.

(79) Composition



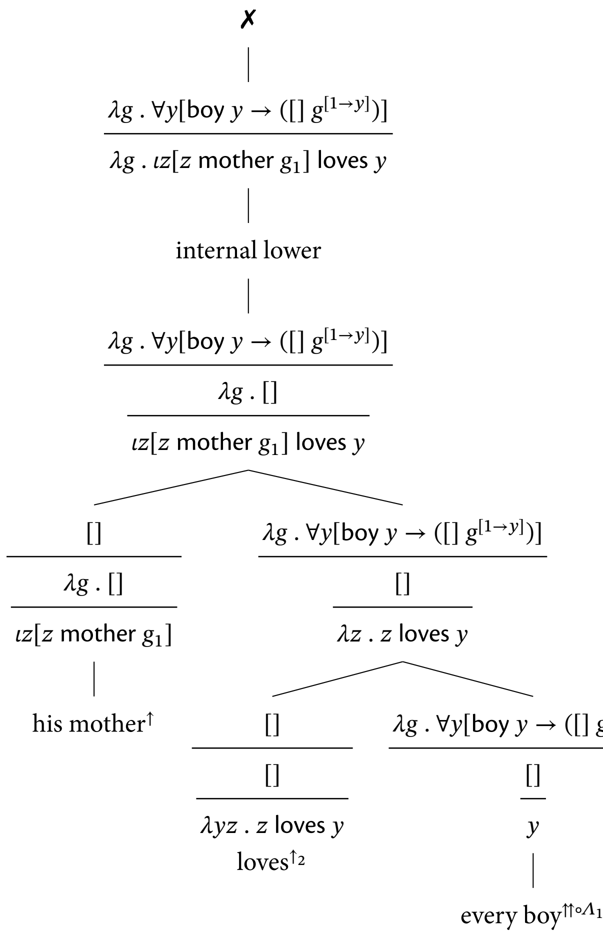
(80) Types



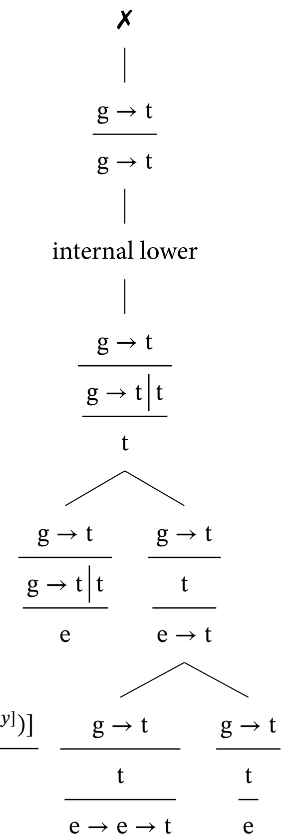
Let's also check that we don't accidentally feed binding via internal lift. Assuming that *lower* is rigidly typed to truth values, lowering the result of this is impossible.

(81) His$_x$ mother loves every boy^x.

(82) Composition



(83) Types



The primary intuition of Barker & Shan's account can therefore be maintained.

6.2 *A-movement*

As we've seen, overt A-movement *bleeds* WCO whereas overt A'-movement *feeds* WCO.

Concretely, overt A-movement bleeds WCO only when it feeds scope – (84) only has a reading on which *every boy* takes scope over the raising predicate *likely*.

(84) Every boy seems to his mother to be happy.

✓ ∀ > likely; ✗ likely > ∀

How do we account for the exceptionality of A-movement wrt crossover?[20]

What I'd like to suggest here is that A-traces are really a distinct lexical item, and denote, essentially, a VFS style pronoun.

(85) $\text{trace}_A := \dfrac{\lambda x\,.\,[]}{x} \qquad \dfrac{e \to t \,|\, t}{e}$

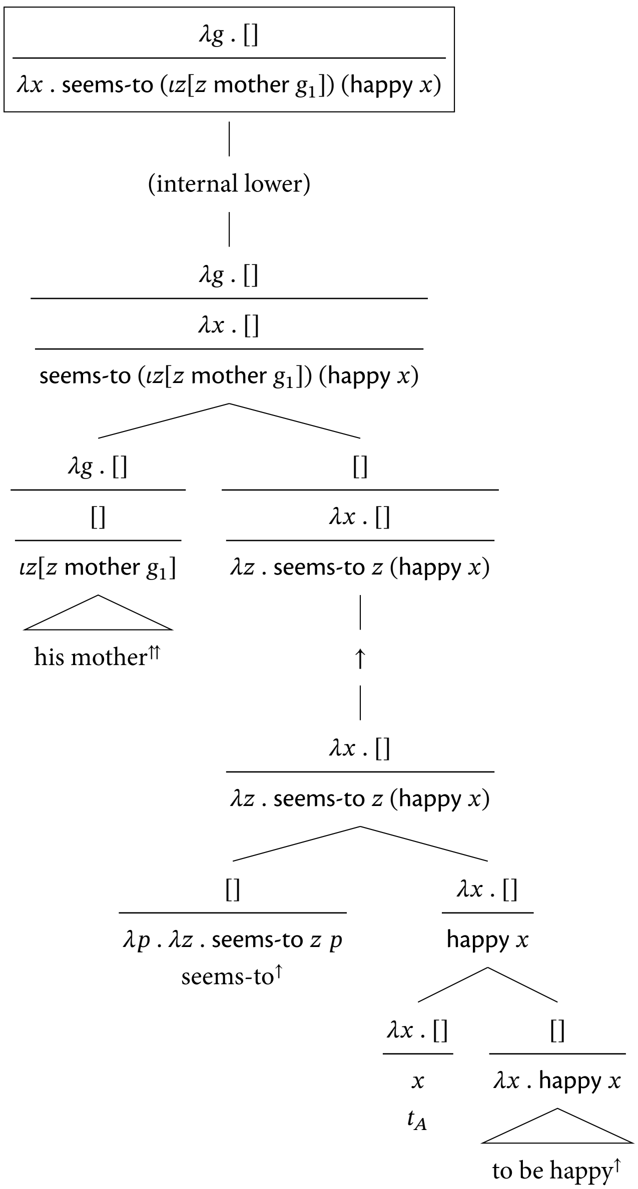
A-traces are scoped out, and lowered – A-raised DPs are base-generated in their surface position.

Let's see how this derives A-movement bleeding crossover for (84).

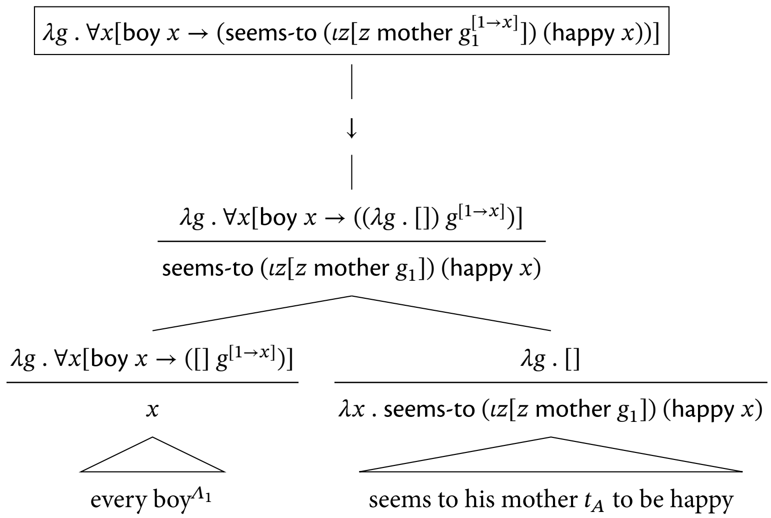
[20] As far as I can see, Barker & Shan (2014) don't have much to say about this.

(86) Every boy seems to his mother to be happy.

(87) Step 1: composition of matrix VP



(88) Step 2: Compose "A-moved" DP



This approach has a virtue – it explains why A-moved expressions can scope higher than their surface position (A-movement doesn't fix scope).

This is illustrated by the following example.

(89) Some boys wants every girl^{x} to seem to her$_{x}$ mother to be happy. $\forall > \exists$

How do we account for the fact that A'-movement *doesn't* bleed crossover? We can assume that A'-movers are genuinely interpreted as scope-takers, in their base position; on the syntactic side, the phonological features of the expression are displaced.[21] In general, we expect A-movement to feed A'-movement – if we think of A'-movement as scope-taking with a phonological reflex.

[21] See my manuscript Elliott 2019b for a theory of overt movement to this effect.

(90) Which boy seemed to be happy?

Interestingly, it also derives the ban on *improper movement* as a matter of the semantics (A-movement may not feed A'-movement). Why? This is because an t_A trace is a lexical item which must saturate an argument position.

(91) *John seems that is intelligent.

7 *Inverse linking in continuation semantics*

How can we get the inverse scope reading for the following, while maintaining the assumption that DP is a scope island?

(92) A boy from every city is attending.

Evidence that DP is (in some sense) a scope island, comes from Larson's generalization.[22]

[22] See Sauerland 2005 for critical discussion, and Charlow 2010 for a response.

(93) Two politicians spy on someone from every city.

✓$\forall > \exists > 2$
✓$2 > \forall > \textit{exists}$
✗$\forall > 2 > \textit{exists}$

We'll assume a completely standard semantics for determiners as Generalized Quantifiers. The semantics for *every* is given below.

It's a function from a predicate to a continuized individual.

(94) $[\![\text{every}]\!] = \lambda r \,.\, \lambda c \,.\, \forall x[r\; x \rightarrow c\; x]$ $\qquad (\mathtt{e} \rightarrow \mathtt{t}) \rightarrow \dfrac{\mathtt{t}}{\mathtt{e}}$

How does *every* compose with its restrictor? Well, since its restrictor is a syntactically simplex nominal, composition can proceed via function application.

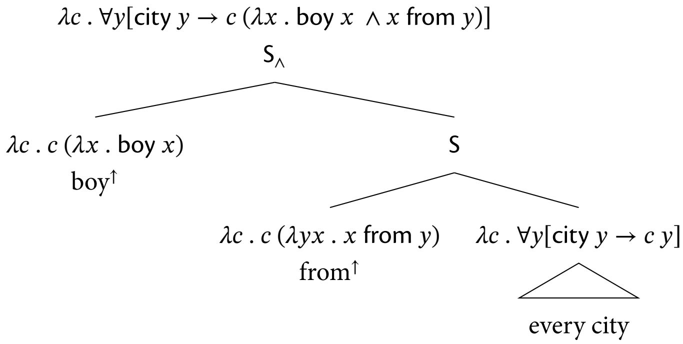
(95) Step 1: Compose *every* and its restrictor

$\lambda c \,.\, \forall x[\text{city}\; x \rightarrow c\; x]$
A
$\lambda r \,.\, \lambda c \,.\, \forall x[r\; x \rightarrow c\; x]$ $\quad$ $\lambda y \,.\, \text{city}\; y$

Since *every city* is a scope taker, composition of the PP and containing NP is mediated via *lift* and SFA.[23]

[23] As well as SFA, the derivation in (96) makes use of an additional composition rule: the scopal counterpart of *predicate modification*, written here as $\mathsf{S}_\wedge$.

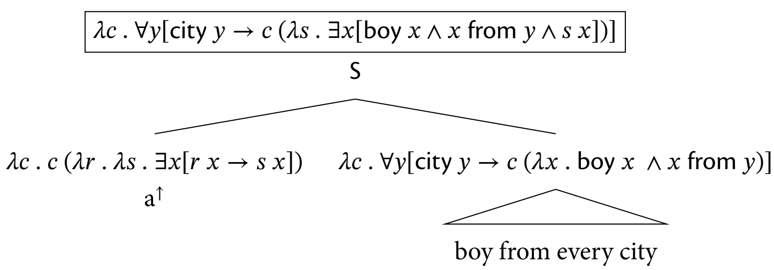
(96) Step 2: composition of NP



Finally, we need to compose the indefinite determiner with its restrictor. We assume that, much like *every*, *a* is a GQ. Its denotation is given below:

The restrictor of the indefinite is itself associated with a scopal *side-effect*, as reflected by its type. The indefinite is therefore unable to compose with its complement via A or S. In order to resolve the type mismatch, we must first lift the determiner, at which point composition can proceed via S.

(97)



At this stage in the derivation, the DP denotes an individual with two layers of scopal side-effects – the higher corresponding to the universal, and the lower corresponding the existential.

(98)
$$\frac{\forall y[\text{city } y \to [\,]]}{\frac{\exists x[\text{boy } x \wedge x \text{ from } y \wedge [\,]]}{x}}$$

Barker & Shan (2014) (see also Charlow 2014) typically use *internal lower* to collapse a three-story tower. There is, however, another way of collapsing a three-story tower *implicit* in our existing machinery.

We're now going to define a new operation for lowering a value of *m* of type

$\mathtt{K_t}\ (\mathtt{K_t}\ \mathtt{e})$, called *join* (written μ). Joining m is simply an instruction to *compose* m with lift:[24]

(100) Join (def.)
$m^{\mu} \coloneqq m \circ (\uparrow)$

We can now take the meaning we've computed for *a boy from every city* and lower it into an ordinary tower via *join* – as you can see, join takes a three-story tower, and sequences scopal side-effects from top-to-bottom:

(101)
$$\boxed{\lambda s\,.\,\forall y[\text{city}\ y \to (\exists x[\text{boy}\ x \wedge x\ \text{from}\ y \wedge s\ x])]}$$
$$\Big|\ \mu\ \Big|$$
$$\lambda c\,.\,\forall y[\text{city}\ y \to c\,(\lambda s\,.\,\exists x[\text{boy}\ x \wedge x\ \text{from}\ y \wedge s\ x])]$$

[24] Why does this work? Let's start by desugaring the type of m: $\mathtt{K_t}\ (\mathtt{K_t}\ \mathtt{e})$ – this is an abbreviation for the following type:

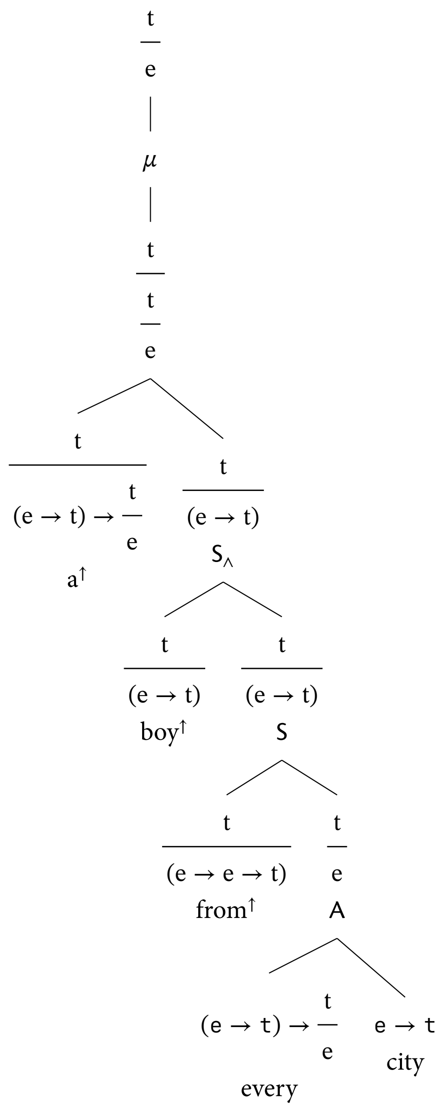
(99) $m : (((\mathtt{e} \to \mathtt{t}) \to \mathtt{t}) \to \mathtt{t}) \to \mathtt{t}$

This type is amenable to a distinct sugaring in terms of $\mathtt{K_t}$ – namely $m : \mathtt{K_t}\ (\mathtt{e} \to \mathtt{t}) \to \mathtt{t}$.

Now, consider the type of lift: $\mathtt{a} \to \mathtt{K_t}\ \mathtt{a}$. Since lift is polymorphic, a could be any type. Let's instantiate it as $\mathtt{e} \to \mathtt{t}$ – the corresponding lift function is of type $(\mathtt{e} \to \mathtt{t}) \to \mathtt{K_t}\ (\mathtt{e} \to \mathtt{t})$.

Note that the output of lift on $\mathtt{e} \to \mathtt{t}$ is the same as the input to our re-sugaring of $\mathtt{K_t}\ (\mathtt{K_t}\ \mathtt{e})$ into $\mathtt{K_t}\ (\mathtt{e} \to \mathtt{t}) \to \mathtt{t}$. This means we can do *function composition*. The result of composing m and lift should be a function of type $(\mathtt{e} \to \mathtt{t}) \to \mathtt{t}$ (i.e. $\mathtt{K_t}\ \mathtt{e}$).

(102)



In order to capture Larson's generalization, we conjecture that DPs are a kind of scope island, distinct to the *evaluation islands* discussed by Charlow (2014):

(103) DP type rigidity (def.)
A DP must denote a value of type K_t e before the derivation can proceed.

From this constraint, it follows straightforwardly that, if a quantificational determiner has a GQ in its complement, then the two must scope together.

I leave it as an exercise to combine our account of binding in the standard picture with the account of inverse linking outlined here.

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