

## Evaluation order, crossover, and reconstruction

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This paper explores an approach to reconstruction that falls into the general category of semantic reconstruction: the syntax and the semantics collaborate in order to account for a number of reconstruction effects, but without any syntactic movement.

The analysis developed here builds on Shan and Barker 2006, Barker and Shan 2008, and Barker 2009. It serves in turn as the basis for chapter 6 of Barker and Shan 2014, which, although published earlier, was written later. The briefer discussion in Barker and Shan 2014 relies on the current paper for a number of elaborations and more detailed discussions.

My starting point is the observation in Shan and Barker 2006:123 that at least some reconstruction effects fall out from the interaction of their particular analyses of scope-taking, binding, and *wh*-interrogatives. In Barker 2009, I discuss that account of reconstruction, developing especially some of the details of the treatment of questions and higher-order pronoun meanings. These previous discussions, however, considered only a very small range of example types. One of the main goals of the current paper is to see how well the approach scales up to a wider range of reconstruction effects and example types, including quantificational binding, binding of anaphors, idiom licensing, and especially crossover phenomena, in the context of *wh*-interrogatives, relative clauses, and *wh*-relatives.

Although the analyses just mentioned differ small ways, they all share core assumptions and goals with the account presented here. I will call the general strategy they develop the *evaluation order* approach. The central goal is to explain crossover effects as following from imposing a default left-to-right evaluation order:

- (1) a. Everyone<sub>i</sub> loves his<sub>i</sub> mother.  
b.\*His<sub>i</sub> mother loves everyone<sub>i</sub>.

If a quantifier such as *everyone* must be evaluated (in a sense to be discussed below) before any pronoun that it binds, and if evaluation proceeds from left to right, then we have an explanation for the contrast in (1): in (1b), the quantifier will not be evaluated until after we have already encountered the pronoun.

Reconstruction appears at first glance to pose a sharp challenge to the evaluation-order account of crossover:

- (2) a. Which of his<sub>i</sub> relatives does everyone<sub>i</sub> love \_\_? (Answer: his mother)  
 b. the relative of his<sub>i</sub> that everyone<sub>i</sub> loves \_\_ (completion: ...is his mother)

In the wh-question in (2a), the pronoun precedes the quantifier, yet there is a salient interpretation of (2a) on which the pronoun varies with the person selected by the quantifier; likewise for the relative clause in (2b). We shall see that this sort of quantificational binding, as well as other types of reconstruction effects, are in fact perfectly compatible with an evaluation-order explanation for crossover.

Crucially, the possibility of backwards quantificational binding in (2) does not mean that evaluation order restrictions have been suspended. In particular, crossover effects re-emerge when the wh-trace precedes the quantifier:

- (3) a. \*Which of her<sub>i</sub> relatives \_\_ loves everyone<sub>i</sub>?  
 b. \*the relative of hers<sub>i</sub> who \_\_ loves everyone<sub>i</sub>

These expressions are ungrammatical on the indicated binding relationships. The difference between the examples in (2) and the examples in (3) is that in (3), the reconstructed position of the pronoun (marked with ‘\_\_’) still precedes the quantifier. The rough descriptive generalization, then, is that a quantifier can bind a pronoun just in case the quantifier is evaluated before the *reconstructed* pronoun. Given a default evaluation order of left to right, the facts above follow.

On syntactic reconstruction approaches, material including the pronoun would syntactically reconstruct (move) into the reconstruction position, or, as in some versions (e.g., Munn 1994) there would be an unpronounced copy of the syntactic material within the gap site. Instead, on the approach here, the meaning of the constituent containing the pronoun will be packaged semantically in such a way that its evaluation will be delayed. The net result will be that the evaluation of the pronoun will be timed as if the pronoun had appeared in its reconstructed position.

After explaining how the evaluation-order strategy works in detail, and how delayed evaluation works, both for wh-questions and relative clauses, I will go on to consider other kinds of reconstruction effects, including idioms, reflexive pronouns, and *each other* anaphors:

- (4) a. Which strings did John pull?  
 b. the strings that John pulled
- (5) a. Which picture of herself does Mary like?  
 b. the picture of herself that Mary likes
- (6) a. Which pictures of each other did they like?  
 b. the pictures of each other that they liked

Although some empirical issues will remain unresolved, the conclusion I will come to is that the evaluation order strategy is a viable explanation for crossover, at the same time that it accounts for a substantial range of reconstruction effects.

### 1.1. Three key ideas

The approach here will rely heavily on three central ideas about meaning. The first idea is that natural language pronouns denote identity functions. This view of pronoun meaning has been advocated most prominently in a series of papers by Jacobson, e.g., Jacobson 1994, 1999.<sup>1</sup> Likewise, and not coincidentally, on the Shan/Barker fragment, not only pronouns, but wh-phrases and gaps will also denote identity functions.

The second idea is that we can think of pronouns and other bindable elements as taking scope, as suggested by Dowty 2007. On this view, a bound pronoun chooses its binder by taking scope just narrower than the quantifier that binds it. This is important here because it predicts that pronouns interact in certain ways with other scope-taking elements such as quantifiers, all within a unified system for scope-taking.

The third key idea is the notion of semantic reconstruction, as first articulated by von Stechow (in unpublished work I do not have access to), Cresti 1995, Rullmann 1995, and Sternefeld 1998, 2001. They suggest that allowing pronouns and gaps to denote higher-order functions can delay evaluation (in my terms) in a way that models reconstruction effects. The fragment here is just one specific implementation of this strategy. One point of interest is that the higher-order functions proposed by, e.g., Sternefeld, follow here without stipulation from independently motivated aspects of the semantic analysis of scope-taking, wh-question formation, and relative clause formation.

The key innovation here is to combine Jacobson's notion of pronouns as identity functions with Dowty's notion of pronouns as scope-takers in order to provide a delayed evaluation implementation of semantic reconstruction.

## 2. Fragment

The fragment as presented here takes the form of a combinatory categorial grammar in the style of Jacobson 1999 or Steedman 2000, in which a small number of type-shifters ("combinators") apply freely and without constraint. It is faithful both to the spirit and to many of the details of the Shan and Barker 2006 analysis, though it uses the 'tower' notation introduced in Barker and Shan 2008, rather than strings of combinators as in Shan and Barker 2006. The presentation here will provide just enough detail to understand the derivations below. A similar tower presentation, as well as additional technical details and some relevant discussion concerning reconstruction, can be found in Barker 2009. See especially Barker and Shan 2014 for a more complete development of the fragment in the context of a treatment of scope, binding, and a wide range of other phenomena.

Atomic categories include DP, S, and N. Complex categories include  $B \setminus A$  and  $A/B$ , where A and B are any categories. These slashes are the normal slashes from categorial

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<sup>1</sup>Analogously in formal languages, variables translate as identity functions in the standard elimination of variables in combinatory logic, e.g., Barendregt 1984:152.

grammar. Syntactically, they correspond to the ordinary merge operation, and semantically, they correspond to function application, as usual:

$$(7) \quad \left( \begin{array}{cc} \text{DP} & \text{DP}\backslash\text{S} \\ \textit{John} & \textit{left} \\ \mathbf{j} & \mathbf{left} \end{array} \right) = \begin{array}{c} \text{S} \\ \textit{John left} \\ \mathbf{left(j)} \end{array}$$

For instance, an expression in the category  $\text{DP}\backslash\text{S}$  can merge with a DP to its left in order to form a complex expression of category S, with the semantics of function application.

The set of complex categories also includes  $A\backslash B$  and  $B//A$ . Syntactically, these hollow slashes correspond to in-situ scope-taking.

$$(8) \quad \left( \begin{array}{cc} \frac{\text{S} | \text{S}}{\text{DP}} & \frac{\text{S} | \text{S}}{\text{DP}\backslash\text{S}} \\ \textit{everyone} & \textit{left} \\ \frac{\forall y. []}{y} & \frac{[]}{\mathbf{left}} \end{array} \right) = \begin{array}{c} \frac{\text{S} | \text{S}}{\text{S}} \\ \textit{everyone left} \\ \frac{\forall y. []}{\mathbf{left}(y)} \end{array}$$

There are several elements in this derivation that need to be explained. First, as a purely notational convenience, syntactic categories of the form  $C//(\text{A}\backslash\text{B})$  can be written as  $\frac{C | B}{A}$

(this is the ‘tower’ convention). So, in particular, the syntactic category given here for *everyone* is  $\frac{\text{S} | \text{S}}{\text{DP}} \equiv \text{S}//(\text{DP}\backslash\text{S})$ : something that functions locally as a DP, takes scope over an S, and returns as a result an expression of category S. Likewise, in the corresponding semantics,  $\lambda\kappa.g[\kappa f]$  can by convention be written equivalently as  $\frac{g[]}{f}$ , so the

denotation of *everyone* is  $\frac{\forall y. []}{y} \equiv \lambda\kappa.\forall y.\kappa y$ .

Syntactic and semantic combination proceeds according to the following general schema:<sup>2</sup>

$$(9) \quad \left( \begin{array}{cc} \frac{C | D}{A/B} & \frac{D | E}{B} \\ \textit{left} & \textit{right} \\ \frac{g[]}{f} & \frac{h[]}{x} \end{array} \right) = \begin{array}{c} \frac{C | E}{A} \\ \textit{left right} \\ \frac{g[h[]]}{f(x)} \end{array}$$

<sup>2</sup>There is a variant of this schema in which the functor category ( $B\backslash A$  beneath the line) is on the right and the argument category (B) is on the left, with the function/argument roles in the semantics reversed. In linear notation, the variant is  $C//(\text{B}\backslash\text{D}) + \text{D}//(\text{B}\backslash\text{A})\backslash\text{E} = \text{D}//(\text{A}\backslash\text{E})$ . The combination in (8) is an instance of this second schema. The need for two variants of the combination schema can be eliminated in favor of a single schema, as in Shan and Barker 2006, but doing this here would complicate exposition.

Translating from the tower notation back into linear notation, on the syntactic level we have  $C//((A/B)\backslash D) + D//(\backslash B/E) = C//(\backslash A/E)$ . On the semantic level, below the horizontal line is normal function application:  $f + x = f(x)$ . Above the line is something resembling function composition:  $g[] + h[] = g[h[]]$ . Translating from tower notation back to linear notation, we have:  $(\lambda\kappa.g[\kappa f]) + (\lambda\gamma.h[\gamma(x)]) = (\lambda\delta.g[h[\delta(fx)]])$ .

Another element that needs comment in the derivation in (8) given above is that the syntax and semantics for *left* does not match that given in (7) above. The reason is that non-scope-taking elements such as *left* must be adjusted in order to combine with scope-takers, in the same way that Montague recognized that the denotations of proper names (fundamentally of type  $e$ ) must be adjusted in order to match quantificational DPs (type  $\langle\langle e, t \rangle, t\rangle$ ). In both cases, the adjustment mechanism is the same: Partee's 1987 LIFT type-shifter. In general, for all categories A and B:

$$(10) \quad \begin{array}{ccc} & & \frac{B \mid B}{A} \\ A & \text{LIFT} & \frac{A}{\text{phrase}} \\ \text{phrase} & \Rightarrow & \frac{[]}{x} \end{array}$$

$$(11) \quad \begin{array}{ccc} & & \frac{S \mid S}{DP} \\ DP & \text{LIFT} & \frac{DP}{\text{John}} \\ \text{John} & \Rightarrow & \frac{[]}{\mathbf{j}} \end{array} \quad \begin{array}{ccc} & & \frac{S \mid S}{DP \backslash S} \\ DP \backslash S & \text{LIFT} & \frac{DP \backslash S}{\text{left}} \\ \text{left} & \Rightarrow & \frac{[]}{\mathbf{left}} \end{array}$$

If  $x$  is the semantic value of A, then  $\frac{[]}{x} \equiv \lambda\kappa.\kappa x$  is the value of  $\text{LIFT}(A)$ . For instance, in (11a), LIFTing the proper name *John* into the quantifier category yields the usual generalized quantifier semantics,  $\frac{[]}{\mathbf{j}} \equiv \lambda\kappa.\kappa(\mathbf{j})$ . Likewise, when *left* undergoes the LIFT typeshifter, the result in (11b) is the verb phrase that appears above in the derivation of *everyone left*.

The final element in the derivation of *everyone left* that requires explanation is the fact that the derivation as given above ends with a multi-level syntactic category. That is, the final syntactic category is  $\frac{S \mid S}{S}$  instead of a plain S. This would be appropriate if we imagined that the sentence might be embedded in a larger expression over which the quantifier might need to take scope; but since this is the complete utterance, we need a

way to close off the scope domain of the quantifier. We accomplish this with the following type-shifter:

(12) For all categories A, and for all  $B \neq DP \triangleright C$ :

$$\boxed{\begin{array}{ccc} \frac{A \mid B}{B} & \text{LOWER} & A \\ \textit{phrase} & \Rightarrow & \textit{phrase} \\ \frac{f[\ ]}{x} & & f[x] \end{array}}$$

$$(13) \quad \frac{\frac{\frac{S \mid S}{S}}{\textit{everyone left}}}{\forall y. [\ ]}}{\textit{left } y} \quad \text{LOWER} \quad \frac{S}{\textit{everyone left}} \forall y. \textit{left } y$$

If F is the semantic value of the original expression, then  $F(\lambda\kappa.\kappa)$  is the value of the shifted expression. This combinator lowers the category of the sentence *everyone left* back to S. If the semantic value of *everyone* is  $\lambda P\forall x.Px$ , and the semantic value of *left* is **left**, then the semantic value of  $\text{LOWER}(\textit{everyone LIFT}(\textit{left}))$  is  $\forall x.\mathbf{left}(x)$ . The LOWER type-shifter plays a role closely similar to Groenendijk and Stokhof's 1989 ' $\downarrow$ ' operator. We will see in the next subsection that it is important to add the restriction that  $B \neq DP \triangleright C$  to account for weak crossover. (This concludes the explanation for the derivation of *everyone left* in (8).)

To see how the combination schema enforces left-to-right evaluation order, note that when a sentence contains two quantifiers, by default, the quantifier on the left takes scope over the one on the right:

$$(14) \quad \frac{\frac{S \mid S}{DP}}{\textit{someone}} \frac{\exists x. [\ ]}{x} \left( \frac{\frac{S \mid S}{(DP \setminus S)/DP}}{\textit{loves}} \frac{[\ ]}{\textit{loves}} \quad \frac{\frac{S \mid S}{DP}}{\textit{everyone}} \frac{\forall y. [\ ]}{y} \right)$$

$$= \frac{\frac{S \mid S}{S}}{\textit{Someone loves everyone}} \frac{\exists x. \forall y. [\ ]}{\textit{loves } y \ x} \quad \text{LOWER} \quad \frac{S}{\textit{Someone loves everyone}} \frac{\exists x. \forall y. \textit{loves } y \ x}{\textit{loves } y \ x}$$

As a result of the left-to-right bias built into the combination schema, this evaluates to  $\exists x \forall y. \text{loves } y \ x$ .

## 2.1. Pronouns and binding

As in Jacobson 1999, the presence of an unbound pronoun will be recorded on the category of each larger expression that contains it. In particular, a clause containing an unbound pronoun will have category  $DP \triangleright S$  rather than plain  $S$ . In order to accomplish this, a pronoun functions locally as a  $DP$ , takes scope over an  $S$ , and turns that  $S$  into an open proposition:

$$(15) \quad \left( \begin{array}{c|c} \frac{DP \triangleright S \mid S}{DP} & \frac{S \mid S}{DP \setminus S} \\ \hline he & left \\ \frac{\lambda y. []}{y} & [] \\ \hline & \mathbf{left} \end{array} \right) = \frac{DP \triangleright S \mid S}{S} \quad \text{LOWER} \quad \frac{DP \triangleright S}{DP \triangleright S} \\ \Rightarrow \frac{he \ left}{\lambda y. []} \quad \Rightarrow \quad \frac{he \ left}{\lambda y. \mathbf{left} \ y}$$

Note that the lexical denotation of the pronoun is  $\frac{\lambda y. []}{y} \equiv \lambda \kappa y. \kappa y$ , a (two-place) identity function.

If the category of a complete utterance is  $DP \triangleright S$ , the value of the embedded pronoun must be supplied by the pragmatic context. In order to demonstrate how an element within the utterance can bind a pronoun, we can give a variant of the quantifier *everyone* that is able to bind. It will have category  $\frac{S \mid DP \triangleright S}{DP}$  and semantics  $\lambda \kappa \forall x. \kappa \ x \ x$ : something that knows how to turn a sentence containing a pronoun ( $DP \triangleright S$ ) into a plain clause ( $S$ ) by semantically duplicating an individual and using the second copy to provide the value of the pronoun.<sup>3</sup>

<sup>3</sup>In general, a type-shifter will derive a binding version of an arbitrary  $DP$  (see Barker and Shan 2014:chapter 2):  $\lambda \kappa. g[\kappa x] : B // (DP \setminus A) \xrightarrow{\text{BIND}} \lambda \kappa. g[\kappa x x] : B // (DP \setminus (DP \triangleright A))$

We immediately have an account of quantificational binding:

$$\begin{aligned}
 (16) \quad & \frac{\frac{S \mid DP \triangleright S}{DP} \quad \frac{\forall x. [] x}{x}}{\text{everyone}} \left( \frac{\frac{DP \triangleright S \mid DP \triangleright S}{(DP \setminus S) / DP} \quad \frac{[]}{\text{loves}}}{\text{loves}} \left( \frac{\frac{DP \triangleright S \mid S}{DP} \quad \frac{S \mid S}{DP \setminus DP}}{\text{his mother}} \right) \right) \\
 & = \frac{\frac{S \mid S}{S} \quad \text{Everyone loves his mother}}{\forall x. (\lambda y. [] ) x} \quad \text{LOWER} \quad \frac{S}{\forall x. (\lambda y. \text{loves} (\mathbf{mom} y) x) x} \\
 & \quad \text{loves} (\mathbf{mom} y) x
 \end{aligned}$$

After beta reduction, the semantic value reduces to  $\forall x. \text{loves} (\mathbf{mom} x) x$ .

## 2.2. Crossover

Continuations are well suited to providing control over evaluation order. Shan & Barker 2006 propose explaining weak crossover as default left-to-right evaluation order: a quantifier must be evaluated before any pronoun that it binds. We've already seen how left to right evaluation gives default linear scope in (14), and also how a quantifier can bind a pronoun. Here is what happens when we try to allow a quantifier to bind a pronoun when the quantifier follows the pronoun in a classic weak crossover configuration:

$$\begin{aligned}
 (17) \quad & \left( \frac{\frac{DP \triangleright S \mid S}{DP} \quad \frac{S \mid S}{DP \setminus DP}}{\text{his mother}} \right) \left( \frac{\frac{S \mid S}{(DP \setminus S) / DP} \quad \frac{S \mid DP \triangleright S}{DP}}{\text{loves everyone}} \right) \\
 & = \frac{\frac{DP \triangleright S \mid DP \triangleright S}{S}}{\text{his mother loves everyone}}
 \end{aligned}$$

Combination proceeds smoothly, and the complete string is recognized as a syntactic (and semantic) constituent; but the result is not part of a complete derivation of a clause. In particular, it can't be lowered, since the category of the expression does not match the input to the LOWER type-shifter. This means that the pronoun continues to need a binder, and the quantifier continues to need something to bind. We'll see in section 3 how reconstruction can sometimes circumvent the need for a quantifier to precede a pronoun that it binds.

### 2.3. Scope ambiguity

The left-to-right bias built into the combination scheme guarantees linear scope for any derivation that has a single layer of scope-taking, as we have seen. But of course sentences containing two quantifiers typically are ambiguous, having both a linear scope reading and an inverse scope reading. Clearly, then, inverse scope must require more than a single layer of scope-taking. This requires, in turn, generalizing type-shifters so that they can apply to a multi-story tower. We will do this by requiring the following: if some type-shifter maps an expression of category  $A$  into category  $B$ , then the same type-shifter also maps any expression of category  $\frac{C \mid D}{A}$  into category  $\frac{C \mid D}{B}$ .<sup>4</sup> Then for any category  $\alpha$ , we have

$$(18) \quad \frac{\frac{S \mid S}{DP} \quad \text{everyone}}{\forall x. []} \quad \text{LIFT} \quad \Rightarrow \quad \frac{\frac{S \mid S}{\alpha \mid \alpha} \quad \text{everyone}}{\forall x. []} \quad \frac{[]}{x}$$

The semantics of the generalized LIFT interacts with the combination schema in such a way that within a layer, quantifiers on the left still outscope quantifiers on the right, but any quantifier in a higher layer outscores any quantifier on a lower layer. Because the LIFTed version of *everyone* given in (18) allows the quantification introduced to take place on the top level, it will outscope the existential introduced by *someone*, which occupies the middle layer.

I will not dwell on scope ambiguities in this paper; see, e.g., Barker and Shan 2014:chapter 4 for additional discussion. What is most relevant for present purposes is that even when the lifted *everyone* is at a different layer from the pronoun, crossover is still correctly ruled

<sup>4</sup>In more detail, if some combinator  $\mathbf{X}$  is such that  $\mathbf{X}(x:A) \Rightarrow (y:B)$ , then  $\mathbf{X}(\lambda\kappa.f[\kappa x]):(C \parallel (A \parallel D)) \Rightarrow (\lambda\kappa.f[\kappa y]):(C \parallel (B \parallel D))$ .

out:

$$\begin{aligned}
 (19) \quad & \frac{\begin{array}{c|c} S & S \\ \hline DP \triangleright S & S \end{array}}{DP} \\
 & \quad \textit{he} \\
 & \left( \begin{array}{c|c} S & S \\ \hline S & S \end{array} \quad \frac{\begin{array}{c|c} S & DP \triangleright S \\ \hline S & S \end{array}}{DP} \right) \\
 & \quad \textit{loves} \quad \quad \textit{everyone} \\
 & = \frac{\begin{array}{c|c} S & DP \triangleright S \\ \hline DP \triangleright S & S \end{array}}{S} \xrightarrow{\text{LOWER}} \frac{\begin{array}{c|c} S & DP \triangleright S \\ \hline DP \triangleright S & S \end{array}}{DP \triangleright S} \\
 & \quad \textit{He loves everyone} \quad \quad \textit{He loves everyone}
 \end{aligned}$$

Because the LOWER type-shifter given in (13) is forbidden to match categories containing  $DP \triangleright S$  in the key positions (namely, the ‘B’ position in the schema in (12)), this final category still cannot be lowered to a plain S. Since LOWERing is the way that the scope of quantifier is closed, one way to gloss this restriction on lowering would be to say ‘Pronouns cannot have their value resolved by lowering’. As a result, quantifiers can only bind pronouns when they occupy the same layers of their towers; given the left-to-right bias of the combination scheme, this means that (at least, in the absence of reconstruction) a quantifier must precede any pronoun that it binds.

## 2.4. Gaps

In order to discuss reconstruction in wh-questions, we must provide an account of basic wh-questions such as *Who did John see ...?*. The first step towards that goal is to provide an account of gapped clauses, such as *did John see ...*.

A gap will be an identity function with category  $X//X$  for some choice of X. In arithmetic, it is always legitimate to multiply by  $X/X$ , since multiplication by 1 does not change the result; likewise, in the current context it is ok to merge with a gap, since gaps are the identity category. Furthermore, since there are many possible choices for X in the category schema  $X//X$ , there are many flavors of gap. For instance, if we choose  $X = DP//S$ , we can prove that  $\text{LOWER}(\textit{did John see ...})$  has category  $DP//S$  (i.e., a clause missing a DP),

with denotation  $\lambda x.\mathbf{say} \ x \ \mathbf{j}$ :

$$(20) \quad \frac{\frac{\alpha \mid \alpha}{S/S} \quad \frac{\lambda p.p}{\lambda p.p}}{\left( \frac{\frac{\alpha \mid \alpha}{DP} \quad \frac{\mathbf{j}}{\mathbf{j}}}{\left( \frac{\frac{\alpha \mid \alpha}{(DP \setminus S)/DP} \quad \frac{DP \setminus S \mid S}{DP} \right)} \right)} \quad \frac{\frac{see}{\lambda x.[]} \quad \frac{--}{\lambda x.[]}}{\frac{see}{x}}}$$

$$= \frac{\frac{DP \setminus S \mid S}{S} \quad \frac{see \ x \ \mathbf{j}}{\lambda x.[]}}{\frac{see \ x \ \mathbf{j}}{\lambda x.[]}} \quad \text{LOWER} \quad \frac{DP \setminus S}{\lambda x.\mathbf{say} \ x \ \mathbf{j}} \Rightarrow \frac{does \ John \ see \ --}{\lambda x.\mathbf{say} \ x \ \mathbf{j}}$$

In this derivation, choose  $\alpha = DP \setminus S$  when lifting.

To summarize, unsaturated predicates, clauses containing an unbound pronoun, and gapped clauses all denote functions from individuals to propositions, and differ only in their syntactic category:

	CATEGORY	TYPE	EXAMPLE
Predicate:	$DP \setminus S$	$e \rightarrow t$	<i>left</i>
Open proposition:	$DP \triangleright S$	$e \rightarrow t$	<i>He left.</i>
Gapped clause:	$DP \setminus S$	$e \rightarrow t$	<i>does John see --</i>

## 2.5. Wh-phrases

In English, in-situ WH phrases are limited to echo questions and multiple wh-questions, though they are common cross-linguistically. Semantically, they turn the sentences that contain them into questions. Therefore the in-situ *who* will have category  $\frac{Q \mid S}{DP}$ : something that takes scope over a clause  $S$  and turns it into an interrogative  $Q$ . This means that the echo question *John saw WHO??* will denote **who**( $\lambda x.\mathbf{say} \ x \ \mathbf{j}$ ), where **who** is a function that turns the property of being seen by John into a question meaning (for instance, on some theories of questions, a set of propositions).

In order to derive English-style wh-questions, in which (the first) wh-phrase occurs at the left edge of the interrogative clause, we need a simple type-shifter that adjusts the syntactic category of a wh-phrase:

$$(21) \quad \boxed{\text{FRONT} \quad C_F // (A \setminus B) \quad \Rightarrow \quad C / (A \setminus B)}$$

This type-shifter is purely syntactic, and does not affect the semantic value of the shifted expression in any way. Syntactically, the type-shifter replaces the hollow forward slash ( $\diagup$ ), which says that the nuclear scope of the wh-phrase must surround it (i.e., that the wh-phrase is in-situ) into a solid slash ( $/$ ), which says that the nuclear scope of the wh-phrase follows it (i.e., that the wh-phrase has been fronted). In addition, the type-shifter also removes the syntactic feature ‘F’, which controls the timing of the FRONT rule in order to manage pied-piping, as discussed shortly.

Recall that by the tower notational convention,  $\frac{(\text{DP?S})_F | S}{\text{DP}} \equiv (\text{DP?S})_F / (\text{DP} \backslash S)$ .

Then the FRONT type-shifter applies to the following lexical entry for the wh-phrase *who*:

$$\frac{\frac{(\text{DP?S})_F | S}{\text{DP}}}{\text{who}(\lambda x.[])} \xrightarrow{\text{FRONT}} \frac{(\text{DP?S}) / (\text{DP} \backslash S)}{\text{who}(m)} \\ \frac{\text{who}(\lambda x.[])}{x} \quad \lambda \kappa. \text{who}(\lambda x. \kappa x)$$

Making use of the derivation of the gapped clause *did John see ...* given above in (20), we now have a derivation of a complete wh-question:

$$(22) \quad \frac{(\text{DP?S}) / (\text{DP} \backslash S)}{\text{who}(\lambda x. \kappa x)} \quad \frac{\text{DP} \backslash S}{\text{does John see } \dots} = \frac{\text{DP?S}}{\text{Who does John see } \dots?} \\ \lambda \kappa. \text{who}(\lambda x. \kappa x) \quad \lambda x. \text{see } x \mathbf{j} \quad \text{who}(\lambda x. \text{see } x \mathbf{j})$$

Pied piping is handled by delaying the application of the FRONT type-shifter until the wh-phrase has combined with additional material. For example, in order to derive questions in which *to whom* or *which man* has been fronted, we reason as follows:

$$(23) \quad \frac{\frac{\alpha | \alpha}{\text{PP/DP}}}{\text{to}[\ ]} \quad \frac{(\text{DP?S})_F | S}{\text{whom}(\lambda x.[])} = \frac{(\text{DP?S})_F | S}{\text{to whom}(\lambda x.[])} \xrightarrow{\text{FRONT}} \frac{(\text{DP?S}) / (\text{PP} \backslash S)}{\text{to whom}(\lambda x. \kappa(\text{to}(x)))}$$

$$(24) \quad \frac{((\text{DP/N)?S})_F | S}{\text{which}(\lambda f.[])} \quad \frac{\alpha | \alpha}{\text{man}[\ ]} = \frac{((\text{DP/N)?S})_F | S}{\text{which man}(\lambda f.[])} \xrightarrow{\text{FRONT}} \frac{((\text{DP/N)?S}) / (\text{DP} \backslash S)}{\text{which man}(\lambda f. \kappa(f(\mathbf{man})))}$$

In each case of pied piping, the lexical entry for the wh-word introduces an F feature, which remains part of the category of each successively larger constituent until the FRONT rule is applied, at which point the result category produced by the FRONT rule no longer contains the F feature. The net result is that a larger constituent surrounding the wh-word can appear in the fronted position:

- (25) a. [Who] did John speak to?      **who**( $\lambda x.$ **speak** (**to**( $x$ )) **j**)  
 b. [To whom] did John speak?      **who**( $\lambda x.$ **speak** (**to**( $x$ )) **j**)  
 c. [Which man] did John speak to? **which**( $\lambda f.$ **speak** (**to**( $f$ (**man**))) **j**)  
 d. [To which man] did John speak? **which**( $\lambda f.$ **speak** (**to**( $f$ (**man**))) **j**)

In (25a), the preposition is stranded because we applied the FRONT type-shifter to the bare wh-word *who*. In (25b), the wh-word combines with the preposition *to* before the FRONT type-shifter applies, creating a syntactic PP gap.<sup>5</sup>

### 3. Reconstructing a bound pronoun in a wh-question

All of the details above in section 2, including the analyses of in-situ scope, binding, wh-fronting and pied-piping, were determined without any view towards handling reconstruction. Nevertheless, we are now in a position to derive at least some reconstruction effects without any additional assumptions.

The essential element in the analysis that gives rise to reconstruction effects is the FRONT type-shifter. This type-shifter captures the essential similarity of the semantic scope-taking behavior of in-situ wh-phrases with the syntactic scope-taking behavior of fronted wh-phrases. Because the type-shifter does not affect semantic interpretation, it guarantees that the semantic value of the fronted wh-question will be exactly the same as if it had occurred in-situ in the wh-gap position.

For instance:

- (26) Which of his<sub>i</sub> relatives does everyone<sub>i</sub> love \_\_ (the most)?

In order to derive this example, we will discuss its two main syntactic constituents in turn: the fronted wh-phrase *which of his relatives*, followed by a derivation of the question body *does everyone love* ...

<sup>5</sup>What, then, blocks \*Which did John see \_\_ man? The derivation of this violation of the Left Branch island constraint would involve postulating a gap with category  $\frac{(DP/N) \setminus S \mid S}{DP/N}$ . We can recognize this as a violation because the gap category is looking to combine with a nominal N to its right. This particular island constraint, then, can be implemented as a constraint on the syntactic form of permissible gap categories.

Recall that the category of a simple pronoun (as in (15)) is  $\text{pn} \equiv \frac{\text{DP} \triangleright \text{S} \mid \text{S}}{\text{DP}}$ .

(27)

$$\begin{array}{c}
 \frac{((\text{DP}/\text{N})?S)_F \mid \text{S}}{\alpha} \mid \alpha \\
 \hline
 \text{DP}/\text{N} \\
 \textit{which} \\
 \mathbf{which}(\lambda f.[]) \\
 \hline
 [] \\
 \hline
 f
 \end{array}
 \left(
 \begin{array}{c}
 \frac{\text{S} \mid \text{S}}{\alpha} \mid \alpha \\
 \hline
 \text{N}/\text{DP} \\
 \textit{relative-of} \\
 [] \\
 \hline
 [] \\
 \hline
 \mathbf{rel}
 \end{array}
 \quad
 \begin{array}{c}
 \frac{\text{S} \mid \text{S}}{\text{DP} \triangleright \text{S}} \mid \text{S} \\
 \hline
 \text{DP} \\
 \textit{his} \\
 [] \\
 \hline
 \lambda z.[] \\
 \hline
 z
 \end{array}
 \right)
 =
 \begin{array}{c}
 \frac{((\text{DP}/\text{N})?S)_F \mid \text{S}}{\text{DP} \triangleright \text{S}} \mid \text{S} \\
 \hline
 \text{DP} \\
 \textit{which rel of his} \\
 \mathbf{which}(\lambda f.[]) \\
 \hline
 \lambda z.[] \\
 \hline
 f(\mathbf{rel} z)
 \end{array}$$

$\equiv$ 
 $\frac{((\text{DP}/\text{N})?S)_F // (\text{pn} \backslash \text{S})}{\textit{which rel of his}}$ 
 $\xrightarrow{\text{FRONT}}$ 
 $\frac{((\text{DP}/\text{N})?S) / (\text{pn} \backslash \text{S})}{\textit{which rel of his}}$ 
  
 (no change)  $\Rightarrow$  (no change)

For lifting purposes in this derivation, choose  $\alpha = \text{DP} \triangleright \text{S}$ . Note that we have lifted in such a way that the main semantic effect of the wh-phrase occupies a higher layer than that of the pronoun. Translating the semantic tower back into linear notation, the semantic value of the fronted wh-phrase is  $\gamma.\mathbf{which}(\lambda f.\gamma(\lambda \kappa \lambda z.\kappa(f(\mathbf{rel} z))))$ .

We next derive the body of the question (ignoring the contribution of *does* for simplicity, see (20) for details):

(28)

$$\begin{array}{c}
 \frac{\alpha \mid \alpha}{\text{S} \mid \text{DP} \triangleright \text{S}} \\
 \hline
 \text{DP} \\
 \textit{everyone} \\
 [] \\
 \hline
 \forall x.[]x \\
 \hline
 x
 \end{array}
 \left(
 \begin{array}{c}
 \frac{\alpha \mid \alpha}{\beta} \mid \beta \\
 \hline
 (\text{DP} \backslash \text{S}) / \text{DP} \\
 \textit{love} \\
 [] \\
 \hline
 [] \\
 \hline
 \mathbf{love}
 \end{array}
 \quad
 \begin{array}{c}
 \frac{\text{pn} \backslash \text{S} \mid \text{S}}{\text{DP} \triangleright \text{S}} \mid \text{S} \\
 \hline
 \text{DP} \\
 \text{--} \\
 \lambda \mathcal{P}.[] \\
 \hline
 \mathcal{P}(\lambda y.[]) \\
 \hline
 y
 \end{array}
 \right)
 =
 \begin{array}{c}
 \frac{\text{pn} \backslash \text{S} \mid \text{S}}{\text{S} \mid \text{S}} \\
 \hline
 \text{S} \\
 \textit{does everyone love --} \\
 \lambda \mathcal{P}.[] \\
 \hline
 \forall x.(\mathcal{P}(\lambda y.[]))x \\
 \hline
 \mathbf{love} y x
 \end{array}$$

$\xrightarrow{\text{LOWER (twice)}}$ 
 $\Rightarrow$ 
 $\frac{\text{pn} \backslash \text{S}}{\lambda \mathcal{P}.\forall x.(\mathcal{P}(\lambda y.\mathbf{love} y x))x}$ 
  
 $\textit{does everyone love --}$

Here, choose  $\alpha = \text{pn} \backslash \text{S}$  and  $\beta = \text{DP} \triangleright \text{S}$ ;  $\mathcal{P}$  is a variable of type  $\text{pn}$ . The idea is that instead of having a simple gap in which an individual of category  $\text{DP}$  is missing, as in (20), we have a higher-order gap in which a pronoun is missing. Nevertheless, the pronoun denotation is still an identity function (see Barker 2009:20).

Putting the two halves of the question together, we have:

$$(29) \quad \begin{array}{ll} ((DP/N)?S)/(pn \setminus S) & pn \setminus S \\ \textit{which relative of his} & \textit{does everyone love \_} \\ \gamma.\mathbf{which}(\lambda f.\gamma(\lambda \kappa \lambda z.\kappa(f(\mathbf{rel} z)))) & \lambda \mathcal{P}.\forall y.\mathcal{P}(\lambda w(\mathbf{love} w y)) y \end{array}$$

This is a simple function/argument construction of the form  $A/B + B = A$ . The category of the entire question, then, will be  $(DP/N)?S$ : a question asking for a function from nominals to entities (as discussed below).

Although the derivation just given is complex, it makes use of nothing beyond what is needed for the simpler examples discussed in section 2, namely, the general combination schema, the four type-shifters (LIFT, LOWER, BIND, and FRONT), and the identity schema for gaps.

It will be instructive to consider the series of beta reductions that leads to a simplified representation of the semantic value of the question. As the reduction proceeds, the material to be reconstructed—the semantic contribution of the constituent *relative of his*—is underlined. The reconstructed material is destined to be the argument of the pronoun gap variable  $\mathcal{P}$ :

$$(30) \quad \begin{aligned} & (\lambda \gamma.\mathbf{which}(\lambda f.\gamma(\lambda \kappa \lambda z.\kappa(f(\mathbf{rel} z)))))(\lambda \mathcal{P}.\forall y.\mathcal{P}(\lambda w.\mathbf{love} w y)) y \\ & \rightsquigarrow \mathbf{which}(\lambda f.(\lambda \mathcal{P}.\forall y.\mathcal{P}(\lambda w.\mathbf{love} w y)) y)(\lambda \kappa \lambda z.\kappa(f(\mathbf{rel} z))) \\ & \rightsquigarrow \mathbf{which}(\lambda f.\forall y.(\lambda \kappa \lambda z.\kappa(f(\mathbf{rel} z))))(\lambda w.\mathbf{love} w y)) y \\ & \rightsquigarrow \mathbf{which}(\lambda f.\forall y.(\lambda z.(\lambda w.\mathbf{love} w y)(f(\mathbf{rel} z)))) y \\ & \rightsquigarrow \mathbf{which}(\lambda f.\forall y.(\lambda w.\mathbf{love} w y)(f(\mathbf{rel} y))) \\ & \rightsquigarrow \mathbf{which}(\lambda f.\forall y.\mathbf{love}(f(\mathbf{rel} y))) y \end{aligned}$$

Gloss: for what choice function  $f$  is it the case that every person  $y$  loves  $f(y$ 's relatives)? A possible answer for this question might be “the tallest”. (In order to arrive at the traditional answer, namely, *his mother*, we need yet higher types; that derivation is somewhat more complicated, but requires no additional assumptions. Full details are provided in Barker 2009.)

It is worth emphasizing that there is no syntactic movement, nor is there any sense in which the semantic beta reductions are actually moving semantic material from one place to another. That is, the lambda calculus is an equational theory: the series of reductions are a series of equivalences, not transformations. In other words, the analysis here is directly compositional in the sense of Jacobson 2002: every syntactic constituent has a well-formed semantic interpretation that does not depend on any material outside of the constituent.

### 3.1. Despite reconstruction, crossover effects remain in force

In the simplest examples, crossover occurs when a pronoun precedes the quantifier that binds it, as shown in (17). In reconstruction examples, a pronoun can precede the quantifier that binds it. But this does not mean that reconstruction suspends crossover effects:

(31) ?Which of his<sub>i</sub> relatives \_\_ loves everyone?

In the analysis of *Which of his relatives does everyone love \_\_?*, the binding analysis requires the quantifier *everyone* to bind the virtual pronoun inside the gap site, as illustrated above in (28). This is possible in part because the quantifier precedes the gap site, conforming to the left-to-right restrictions on binding imposed by the combination schema. In (31), in contrast, since the gap site precedes the quantifier, there is no way for the quantifier to bind into the gap, for exactly the same reason that the simple crossover binding attempts failed in (17) and (19).

In other words, even though semantic reconstruction can allow a quantifier to bind a pronoun that precedes it, crossover restrictions remain in effect even in reconstruction situations. In each reconstruction analysis below, we shall see that crossover effects remain in force.

### 3.2. Reconstructing binders instead of pronouns; strong versus weak crossover

In addition to reconstructing bound pronouns, we should observe reconstruction effects from reconstructing any scope-taking element. In particular, it should be possible for scope-taking quantifiers to behave as if they were evaluated in the reconstructed position. We can test this prediction by seeing which pronouns a reconstructed quantifier is able to bind:

- (32) a. John had to explain the lowest grade of each student<sub>i</sub> to her<sub>i</sub> mother.  
 b. Which grade of each student<sub>i</sub> did John have to explain to her<sub>i</sub> mother?

In (32a), the quantifier *each student* binds the pronoun *her*. Because the quantifier is to the left of the pronoun, the binding configuration conforms to left-to-right evaluation order. (The quantifier does not c-command the pronoun, but c-command is not required for binding on the account here; see Barker 2012 for arguments that c-command is irrelevant for quantificational binding.)

Likewise, if we replace *the lowest* in (32a) with the wh-determiner *which*, then, factoring in pied piping, we have the corresponding wh-question in (32b). Once again, because the FRONT type-shifter does not affect semantic value, the binding potential of the quantifier will be exactly similar to the corresponding quantifier in (32a). Thus the analysis here gives a bound reading as indicated in (32b).

The account here predicts that we should be able to observe crossover effects if the reconstruction position follows the pronoun to be bound. First, consider the following non-interrogative sentences:

- (33) a. \*She<sub>i</sub> called several friends of each student<sub>i</sub>. [STRONG XOVER]  
 b. ??Her<sub>i</sub> mother called several friends of each student<sub>i</sub>. [WEAK XOVER]
- (34) a. \*She completed some of each student's assignments. [STRONG XOVER]  
 b. ??Her<sub>i</sub> mother completed some of each student's<sub>i</sub> assignments. [WEAK XOVER]

In these examples, the contrast between weak and strong crossover effects is quite dramatic.

In order to create the corresponding reconstruction examples, we replace the expressions *several* and *some* with *wh*-expressions:

- (35) a. ?Which friends of each student<sub>i</sub> did she<sub>i</sub> call \_\_?  
 b. ?Which friends of each student<sub>i</sub> did her<sub>i</sub> mother call \_\_?
- (36) a. ?How many of each student<sub>i</sub>'s assignments did she<sub>i</sub> complete \_\_?  
 b. ?How many of each student<sub>i</sub>'s assignments did her<sub>i</sub> mother complete \_\_?

Because the reconstruction gap follows the pronoun, the account here correctly predicts that an attempt to derive a bound reading for the pronoun will give rise to a crossover violation.

Interestingly, after pied-piping, the contrast between the strong crossover in the (a) examples versus weak crossover in the (b) examples becomes attenuated in comparison with the strength of the effects observed above in (33) and (34). Nothing in the formal system distinguishes strong crossover from weak crossover. Presumably, strong crossover is due to some factor over and above whatever characterizes weak crossover, perhaps something along the lines of Safir's 2004 Independence Principle, which entails that if a pronoun is bound by a quantifier, that pronoun cannot c-command the quantifier. If so, it is telling that the pronouns in (35a) and in (36a) do not c-command the quantifier in question. If strong crossover follows from the Independence Principle, and the Independence Principle depends on syntactic c-command relations, then we have no reason to expect that examples like those in (35a) and (36a) will qualify as strong crossover, in agreement with the comparatively weak ungrammaticality of these examples.

In any case, the examples in (35) and (36) all give rise to the kind of processing difficulty expected from weak crossover, as predicted by the account here. Thus not only can reconstruction lead to situations in which a quantifier can bind a pronoun that precedes it, it can also lead to situations in which a quantifier does linearly precede a pronoun and yet still can't bind it. Left-to-right evaluation order accounts for both of these non-default patterns automatically for semantic reconstruction as provided by the FRONT type-shifter.

### 3.3. Principle C

Under syntactic reconstruction, it is natural to expect Principle C effects.

- (37) \*Whose evaluation of John<sub>i</sub> did he<sub>i</sub> expect Mary to repudiate \_\_?

This example and its judgment is from Safir 1999:592. If *evaluation of John* syntactically reconstructs, then the name *John* will come to be c-commanded by the pronoun *he*. The ungrammaticality of (37) would then follow from Principle C, which says that referring expressions, including names, cannot corefer with a c-commanding expression. Note that the Independence Principle mentioned above also rules out (37), since (after syntactic reconstruction) the pronoun c-commands a coreferring expression.

The empirical status of Principle C violations in reconstruction contexts is both subtle and intricate (see Heycock 1995, Büring 2005, Sportiche 2006, Salzmann 2006, and others for comprehensive discussions). Certainly there are well-established classes of examples where reconstructed Principle C violations do not result in ungrammaticality. Safir 1999:609 discusses a range of such exceptions, including when the referring expression is within a possessor phrase, or, more generally, within an adjunct. Here are a few of Safir's examples, which I take it are generally accepted as grammatical:

- (38) a. Which of John<sub>i</sub>'s friends does he<sub>i</sub> like?  
 b. Which biography of Picasso<sub>i</sub>, do you think he<sub>i</sub> wants to read?  
 c. Which witness's attack on Lee<sub>i</sub> did he<sub>i</sub> try to get expunged from the trial records?  
 d. Whose criticism of Lee<sub>i</sub> did he<sub>i</sub> choose to ignore?

Any approach involving syntactic reconstruction must consider Principle C violations to be the default, and then explain how some examples escape through some separate mechanism. For instance, Safir suggests that reconstructed referring expressions sometimes function as if they were pronouns for the purposes of the binding constraints ('vehicle change').

In contrast, on the approach here, because reconstruction is entirely semantic, reconstruction does not have any effect on syntactic c-command relations. As a result, reconstruction is never expected to create Principle C effects. Thus it is ungrammatical cases such as (37) that must be explained through additional factors, such as Kuno's notions of discourse perspective and participant sympathy.<sup>6</sup>

## 4. Relative clauses and wh-relatives

As noted above in (2), it has long been observed that wh-questions bear a striking resemblance to some kinds of relative clauses:

- (39) a. [Which relative of his] does everyone love \_\_?  
 b. [the relative of his] that everyone loves \_\_

Just as there can be a quantificational binding relationship between *everyone* and *his* in (39a), there can be the same kind of binding relationship in (39b). On the account here,

<sup>6</sup>Kuno 1987 is relevant, and there is an unpublished 1997 Harvard manuscript cited in the literature called 'Binding Theory and the Minimalist Program' that I have not been able to get hold of.

this suggests that the definite determiner *the* may have a lexical entry that closely resembles the pied-piping lexical entry for the wh-determiner *which*:

$$(40) \quad \frac{\frac{((DP/N)?S)_F \mid S}{DP/N} \quad \frac{DP_F \mid S}{DP/N}}{\mathbf{which}(\lambda f.[])} \quad \frac{\quad}{\mathbf{the}(\lambda f.[])}$$

f f

If we have such a lexical entry among the analyses for *the*, we get the following analysis in parallel with the reconstruction derivation given above for wh-questions:

- (41) a. Which relative of his does everyone love ...? (answer: the tallest)  
 b.  $\mathbf{which}(\lambda f. \forall y. \mathbf{love}(f(\mathbf{rel} \ y)) \ y)$

- (42) a. the relative of his that everyone loves ... (completion: is always the tallest)  
 b.  $\mathbf{the}(\lambda f. \forall y. \mathbf{love}(f(\mathbf{rel} \ y)) \ y)$

This is an analysis on which the definite description receives (at least by default) a functional interpretation rather than a strictly referential one.

To see what this means, start with the denotation of the wh-question in (41b). This will be a question whose answers correspond to choice functions that pick an object out of a set of relatives. The answer will be referential (“Uncle Bob”) just in case the choice function returns the same individual for each set of relatives (assume that the quantificational domain for *everyone* is contextually restricted to the participants in a family reunion).

Analogously, the denotation of the definite description in (42a) will likewise be functional. To the extent that it refers, it describes an intensional object, similar to the definite description in *the most beloved person is the one who listens most carefully*. As for the wh interrogative, the functional description can be coerced into referring to an individual just in case the relevant function returns the same individual for every set of relatives (the “Uncle Bob” reading).

Anticipating the treatment of reflexive pronouns in the next section, we can make the referential interpretation highly salient:

- (43) a. the picture of herself that Mary likes  
 b.  $\mathbf{the}(\lambda f. \mathbf{likes}(f(\mathbf{pic} \ \mathbf{m})) \ \mathbf{m})$

In order to arrive at a bound interpretation of the reflexive pronoun, the analysis here requires the reconstruction definite determiner given above in (40). Although the description in (43a) might still have a functional interpretation, a referential interpretation is much more natural. To arrive at a referent, **the** must take a property of choice functions and return an individual.

$$\mathbf{the}_{\text{ref}} \equiv \lambda \kappa. \iota x. \forall f. (\forall P. P x \rightarrow (f P = x)) \rightarrow \kappa f$$

Gloss: given  $\kappa$ , a property of choice functions, return the unique object  $x$  such that any choice function that returns  $x$  whenever possible has property  $\kappa$ .

On the topic of functional (intensional) descriptions, Grosu and Krifka 2007 note that reconstruction is relevant for understanding what they call equational intensional reconstruction relatives:

(44) the gifted mathematician that John claims to be  
**the**( $\lambda f$ .**claim**(**be**( $f$ (**gifted-math'n**), **j**)))

As they note, one of the hallmarks of this construction is that the referent of the description is not entailed to be a gifted mathematician. This is exactly what we would expect by using the version of *the* from (40), since the semantic material contributed by *gifted mathematician* will be reconstructed into the gap position under the scope of *claim*. There are many special properties of this construction that I cannot explore in this paper; nevertheless, the general approach to reconstruction here may provide some hint into how the interaction of reconstruction and intensionality in this construction can be implemented in a framework that does not make use of syntactic movement.

#### 4.1. Combining wh with relative clauses: relative pronouns with pied piping

Of course, one place where wh-phrases and relative clause formation overlap is in relative pronouns:

$$(45) \quad \frac{\frac{(A \setminus S)_F \mid S}{A}}{\lambda x.[\ ]}}{x}$$

*who(se)/which*

Given that the feature F triggers the pied-piping mechanism, we expect that relative pronouns can participate in pied piping:

- (46) a. the man [who] John saw  
 b. the man [whose mother] John saw  
 c. the man [the mother of whom] John saw

In addition, we also expect that a reconstructed pronoun can be bound by a quantifier that follows it:

(47) John is a man [[whose opinion of her<sub>i</sub>] every woman<sub>i</sub> respects --]

Both of these patterns fall out from the analysis.

Finally, we predict that if the reconstruction site precedes a pronoun, a bound reading should be good, as in (47), but if the reconstruction site follows a pronoun, an attempt at binding should give rise to crossover effects:

(48) a theory [[every proponent<sub>i</sub> of which] {?he<sub>i</sub>/?his<sub>i</sub> advisor} cites --]

Native speakers report that this sentence is somewhat hard to process, but the reported judgments tend to support the predicted contrast.

## 5. Idioms

Idiom chunks—DPs that serve as parts of idioms, such as *care* in *take good care of someone*, or *lip service*, as in *pay lip service to*—generally must occur as an argument of a limited, specific set of verbs in order to receive their idiomatic interpretation. Yet they can sometimes be separated from the relevant verb in *wh*-interrogatives and in relative clauses:

- (49) a. How much care did (Mary say that) John took of Bill?  
 b. the lip service that (Mary said that) John paid to civil liberties

In order for the idiomatic interpretations to be licensed, there must be some mechanism for transmitting information about the idiom chunk from its displaced position to the rest of the idiomatic expression. This has traditionally served as an argument for syntactic reconstruction (see, e.g., Sportiche 2006), since one way to make the needed connection is to syntactically reconstruct the idiom chunk, at which point it will be reunited with the rest of its idiom.

Although the approach here is primarily semantic, nevertheless a limited amount of syntactic information does flow from the gap site to the fronted constituent, as we have seen above in pied piping examples. To handle idiom licensing, we need only provide some fine-grained syntactic features that will enable suitable syntactic bookkeeping to take place. For example, the relevant idiomatic sense of *strings* as in *to pull strings* may subcategorize for a  $DP_S$  ('S' for strings), and of course the noun *strings* will itself have category  $N_S$ . Then we have the following derivation for *Which strings did John pull?*:

$$(50) \left( \begin{array}{c|c} \frac{((DP/N)?S)_F | S}{DP_\gamma/N_\gamma} & \frac{\alpha | \alpha}{N_S} \\ \hline \textit{which} & \textit{strings} \\ \frac{\mathbf{which}(\lambda f.[\ ])}{f} & \frac{[\ ]}{\mathbf{connections}} \end{array} \right)$$

$$\left( \begin{array}{c|c} \frac{\alpha | \alpha}{DP} & \left( \begin{array}{c|c} \frac{\alpha | \alpha}{(DP \setminus S)/DP_S} & \frac{DP_S \setminus S | S}{DP_S} \\ \hline \textit{John} & \textit{pull} \\ \frac{[\ ]}{\mathbf{j}} & \frac{[\ ]}{\mathbf{use}} \end{array} \right) \\ \hline \frac{[\ ]}{\mathbf{j}} & \frac{\textit{pull}}{\lambda x.[\ ]} \\ \hline \mathbf{j} & \mathbf{x} \end{array} \right)$$

The remainder of the derivation goes exactly as in (22) except that the category of the question body is  $DP_S \setminus S$  instead of  $DP \setminus S$ , and likewise for the category that the fronted

wh-phrase is seeking to combine with. If *strings* were replaced with an ordinary nominal, or if *pull* were replaced with an ordinary transitive verb, the two halves of the derivation would not match appropriately. Because the gap faithfully transmits (via the scope-taking mechanism) the detailed syntactic category expected at the gap site to form part of the category of the entire gapped clause, further embedding the idiomatic verb (e.g., *Which strings did Mary get so upset that John pulled?*) will not disrupt the licensing connection.

## 6. Reflexives and *each other* anaphors

One classic reconstruction effect involves reflexives. Normally, reflexives must be bound by some less oblique coargument in the same clause:

- (51) a. John liked a picture of himself.  
 b. \*Mary liked a picture of himself.  
 c. \*John claimed Mary liked a picture of himself.  
 d. \*A picture of himself was liked by John.

But in reconstruction situations, the reflexive can be separated from its binder:

- (52) a. Which picture of himself does John like \_\_?  
 b. the picture of herself that Mary likes \_\_

Assuming that the anaphors in (52) are grammatically bound, the analysis here requires reconstruction.

One additional wrinkle: as (53) shows, a reconstructed reflexive can even take an antecedent that is not in the same minimal clause as the reconstruction site.

- (53) Which picture of himself does John claim Mary liked \_\_?

This suggests that reconstruction somehow enables a reflexive to take advantage of a wider range of possible binders than it would have been able to if it had been generated in the reconstruction position.

The approach here follows Dowty's 2007:97 suggestion that reflexives are scope-taking expressions. Building on Szabolcsi's 1992 proposal that reflexives express the combinator

$W = \lambda\kappa\chi.\kappa\chi\chi$ :

$$\begin{array}{c}
 \alpha \mid \alpha \\
 \hline
 (DP \setminus S) / DP \\
 \textit{saw} \\
 \hline
 [] \\
 \hline
 \mathbf{saw}
 \end{array}
 \quad
 \begin{array}{c}
 DP \setminus S \mid DP \setminus S \\
 \hline
 DP \\
 \textit{himself} \\
 \hline
 \lambda x. [] x \\
 \hline
 x
 \end{array}
 =
 \begin{array}{c}
 DP \setminus S \mid DP \setminus S \\
 \hline
 DP \setminus S \\
 \textit{saw himself} \\
 \hline
 \lambda x. [] x \\
 \hline
 \mathbf{saw} x
 \end{array}
 \Rightarrow
 \begin{array}{c}
 \text{LOWER} \quad DP \setminus S \\
 \Rightarrow \quad \textit{saw himself} \\
 \lambda x. \mathbf{saw} x x
 \end{array}$$

On this view, reflexives are an in-situ VP modifier: they take scope over a VP, and return a new VP whose next argument (the subject) gets copied into the anaphor position.<sup>7</sup>

(55) Which picture of himself did John see?

$$\begin{array}{c}
 ((DP/N)?S)_F \mid S \\
 \hline
 \alpha \mid \alpha \\
 \hline
 DP/N \\
 \textit{which} \\
 \hline
 \mathbf{which}(\lambda f. []) \\
 \hline
 [] \\
 \hline
 f
 \end{array}
 \quad
 \begin{array}{c}
 S \mid S \\
 \hline
 DP \setminus S \mid DP \setminus S \\
 \hline
 N \\
 \textit{picture of himself} \\
 \hline
 [] \\
 \hline
 \lambda x. [] x \\
 \hline
 \mathbf{pic} x
 \end{array}
 \Rightarrow
 \begin{array}{c}
 \text{FRONT} \\
 \Rightarrow
 \end{array}
 \begin{array}{c}
 ((DP/N)?S) / ( \frac{DP \setminus S \mid DP \setminus S}{DP} \setminus S ) \\
 \textit{which picture of himself} \\
 \hline
 \lambda \gamma. \mathbf{which}(\lambda f. \gamma( \frac{\lambda x. [] x}{f(\mathbf{pic} x)} ))
 \end{array}$$

The only difference between this analysis and the one for quantificational binding of an ordinary pronoun is that the gap within the pied-pied material is a reflexive-pronoun type gap rather than a standard pronoun, with corresponding adjustments in the question body.

This approach automatically gives good results for the following examples:

- (57) a. John saw no pictures of himself.  
 b. Which picture of himself did John claim Mary liked?

<sup>7</sup>In general, non-subject arguments can bind reflexives in English; as Dowty comments, his strategy requires postulating a family of categories, including also, for instance, for ditransitive cases such as *Mary described Bill to himself*, a more general lexical category schema  $\frac{\alpha/DP \mid \alpha/DP}{DP}$ .

Unfortunately, this simple analysis also generates the following kind of ungrammatical examples:

(58) \*John claimed Mary liked a picture of himself.

The reason that (58) is generated is that there is no way to block the reflexive from taking scope over the higher, non-local verb phrase.

The approach to reflexives explored here will only be viable if it is possible to find a way to constrain scope-taking operators. There is little agreement on how best to manage scope preferences and scope requirements in the literature at this point. One possible strategy in the approach taken here would be to impose restrictions on the categories of the towers that clause-embedding predicates can take as complements; but I leave this for future research.

Reconstruction of anaphors such as *each other* can be handled analogously:

(59) a. Which of each other's papers did they read \_\_?  
 b. the descriptions of each other that they offered \_\_

Like reflexives, *each other* must generally be c-commanded by the element that binds it. We can therefore give *each other* a scope-taking analysis on which it takes scope just equal

to the scope of its binder, e.g., category  $\frac{DP \setminus S \mid DP \setminus S}{DP}$ . The semantics will require that

the binder be the kind of object that the quantificational part of *each other* can distribute over, but otherwise the derivation will proceed exactly as shown above for *himself*.

## 7. Conclusions

Shan and Barker 2006 propose that crossover follows under their continuation-based framework for scope-taking, given two assumptions: that pronouns find their binders by taking scope, and so participate in the same scope-taking system as their binders; and that the evaluation order that governs scope relations defaults to left-to-right.

This paper, building on Shan and Barker 2006 and Barker 2009, explores a number of reconstruction effects. A fully explicit fragment provides derivations for reconstruction effects involving bound pronouns, reconstructed binders, wh-questions, relative clauses, and wh-relatives.

The formal system involves a general combination schema, along with four freely-applied type-shifters: LIFT, LOWER, BIND, and FRONT. The resulting grammar is directly compositional, variable-free, and does not make use of QR or any syntactic movement operations. Thus a continuation-based system allows us to model crossover as a processing constraint in the competence grammar, without needing to say anything special in order to handle a respectable variety of reconstruction examples.

In each case of reconstruction, the analysis hinges on the application of the FRONT type-shifter, repeated here:

$$\boxed{\text{FRONT} \\ C_F // (A \setminus B) \Rightarrow C / (A \setminus B)}$$

This type shifter turns what would otherwise be an in-situ scope-taker (such as a wh-phrase) into an expression that has been syntactically displaced to the left. Because it adjusts the syntactic category of an expression without adjusting its semantic value, the semantic value of the resulting expression is guaranteed to be exactly as if the displaced constituent were delayed, that is, as if it were evaluated in the position of the gap in the gapped clause. This accounts for the semantic reconstruction effects, including bindability as well as ability to bind.

Crucially, the effects due to the FRONT type-shifter are perfectly compatible with default left-to-right evaluation, so the reconstruction effects discussed do not constitute counterexamples to the Shan/Barker approach to crossover. Indeed, I have presented empirical data from a range of constructions that in fact crossover is not suspended in reconstruction situations: for instance, if a reconstructed quantifier follows a pronoun, it cannot bind the pronoun, so crossover remains in effect.

Furthermore, since the FRONT type-shifter does not involve syntactic movement, there is no syntactic reconstruction. This is why reconstruction often does not trigger Principle C violations, since there is no syntactic structure inside the reconstruction gap site.

Shan and Barker 2006 emphasize that the FRONT type-shifter is motivated entirely by a desire to give the simplest possible analysis to wh-question formation, without considering reconstruction examples. Nevertheless, it provides analyses not only of syntactic pied piping, but also a variety of reconstruction effects, in a way that remains fully compatible with a principled explanation for crossover.

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