Long-distance dependencies in continuation grammar

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Abstract

We discuss the treatment of movement and variable binding across finite clause boundaries in the continuation-based grammar of Barker and Shan (2014) and related work. We propose extensions to the theory which make such dependencies compatible with a ban on cross-clausal scope-taking as implemented in Charlow (2014). We demonstrate, however, that this resulting grammar systematically makes incorrect predictions for weak crossover in sentences that combine long-distance movement and variable binding, thus undermining one of the major advantages of continuation-based grammars according to Shan and Barker (2006). We conclude with a critical outlook and a comparison to contemporary LF syntax approaches to scope-taking.

1 Introduction

In a notable application of theoretical computer science principles to natural language grammar, Chris Barker and Chung-Chieh (Ken) Shan have developed categorial grammars which incorporate the notion of *continuations*. In brief, a *continuation* is the computational future of an expression, i.e. the procedures that would then apply to it. (See especially Shan and Barker (2006) §1.2 and citations therein.) Barker and Shan argue that continuations are not only a useful conceptual device for the description of natural language phenomena, but in fact enable a grammatical framework which is in many ways superior to its alternatives. Their continuation-based grammars make positive predictions for phenomena such as superiority, binding, crossover, polarity licensing, donkey anaphora, and reconstruction effects (Barker 2002; Shan 2004, 2007; Shan and Barker 2006; Barker and Shan 2006, 2008, 2014). We refer to these works collectively as B&S.

In this paper, we consider the treatment of examples with embedded clauses in the B&S framework. As has been noted by B&S themselves and Charlow (2014), the B&S framework as unamended overgenerates interpretations for sentences with quantifiers in scope islands — including embedded finite clauses — as it does not inherently impose any restrictions on quantifier scope-taking. We discuss an approach to restricting scope-taking out of scope islands discussed by Charlow (2014), but which in turn complicates examples with long-distance movement and binding. Although these complications can be overcome, the necessary amendments in turn lead to incorrect predictions for crossover effects. We argue that this discussion poses a fundamental challenge to the B&S framework as a model of grammatical behavior when a wider range of data is considered.

We begin in §2 with an introduction to the principles and notation of the B&S grammar as presented in B&S 2014 Part 1. In §3, we discuss scope-taking across clause boundaries and present a restricted theory for long-distance dependencies in the B&S framework. In §4, we discuss the amended theory's predictions for crossover effects. We conclude in §5 with a critical evaluation of the treatment of scope-taking restrictions in the B&S framework, in comparison with LF-based theories for scope-taking and movement.

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$$\begin{array}{c} \dfrac{A \mid \mathrm{S}}{\mathrm{S}} \\ \text{expression} \\ \dfrac{f[\,]}{a} \end{array} \overset{\downarrow}{\Rightarrow} \begin{array}{c} A \\ \text{expression} \\ f(a) \end{array} \qquad \begin{array}{c} A \\ \text{expression} \\ a \end{array} \overset{\text{LIFT}}{\Longrightarrow} \begin{array}{c} \dfrac{B \mid B}{A} \\ \text{expression} \\ \dfrac{[\,]}{a} \end{array} \qquad \begin{array}{c} \dfrac{A \mid B}{\mathrm{DP}} \\ \text{expression} \\ \dfrac{f[\,]}{x} \end{array} \overset{\text{BIND}}{\Longrightarrow} \begin{array}{c} \dfrac{A \mid \mathrm{DP} \rhd B}{\mathrm{DP}} \\ \text{expression} \\ \dfrac{f([\,]x)}{x} \end{array}$$

Figure 1: Freely-applying type-shifters in B&S: LOWER (↓), LIFT, and BIND

$$\begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \\ \text{Mary} \\ \dfrac{[\,]}{\mathbf{m}} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{(\mathrm{DP}\backslash \mathrm{S}) / \mathrm{DP}} \\ \text{likes} \\ \dfrac{[\,]}{\textbf{likes}} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \\ \text{everyone} \\ \dfrac{\forall y\,.\,[\,]}{y} \end{array} = \begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{S}} \\ \text{Mary likes everyone} \\ \dfrac{\forall y\,.\,[\,]}{\textbf{likes}\, y\, \mathbf{m}} \end{array} \overset{\downarrow}{\Rightarrow} \begin{array}{c} \mathrm{S} \\ \text{Mary likes everyone} \\ \forall y\,.\,\textbf{likes}\, y\, \mathbf{m} \end{array}$$

Figure 2: Scope-taking of object *everyone* in *Mary likes everyone*

2 Background: Barker & Shan's continuation-based grammar

We begin by briefly presenting the grammar in Part 1 of B&S (2014) with the notation there.

The B&S grammar is a combinatory categorial grammar which includes continuation-passing expressions. In addition to common $\backslash$ and $/$-type constructors for left and right composition, B&S introduce the $\backslash\!\!\backslash$ and $/\!\!/$ constructors for continuation-passing expressions. Informally, $A \backslash\!\!\backslash B$ "would be a B if we could add an A somewhere (specific) inside of it" whereas $C /\!\!/ D$ "would be a C if we could add a D surrounding it" (B&S 2014: 6).

Syntactic categories are presented above each expression and semantic denotations are presented below. B&S also introduce the notation of "multi-level towers" defined as follows:

(1)
$$\begin{array}{c} \dfrac{C \mid B}{A} \\ \text{expression} \\ \dfrac{f[\,]}{a} \end{array} := \begin{array}{c} C /\!\!/ (A \backslash\!\!\backslash B) \\ \text{expression} \\ \lambda\kappa\,.\,f[\kappa\, a] \end{array}$$

An expression with the syntactic category $\dfrac{C \mid B}{A}$ behaves internally like an A and takes scope over an expression of category B to produce an expression of category C.

The composition of multi-level towers follows the schema in (2). Composition on the lowest level of the multi-level tower follows the direction of composition of the lowest level of the tower's category (here, the functor f of category $A \backslash B$ taking the left A expression x as its argument), whereas procedures on higher levels compose linearly.

(2)
$$\begin{array}{c} \dfrac{C \mid D}{A} \\ \text{left-exp} \\ \dfrac{g[\,]}{x} \end{array} \quad \begin{array}{c} \dfrac{D \mid E}{A \backslash B} \\ \text{right-exp} \\ \dfrac{h[\,]}{f} \end{array} = \begin{array}{c} \dfrac{C \mid E}{B} \\ \text{left-exp right-exp} \\ \dfrac{g(h[\,])}{f(x)} \end{array}$$

In addition, B&S introduce three type-shifters, shown in Figure 1, which apply freely to the relevant expressions. The LOWER type-shifter $\downarrow$ can apply to expressions of type $\dfrac{A \mid \mathrm{S}}{\mathrm{S}}$ for arbitrary A.

2.1 Scope-taking

Continuation-passing through multi-level towers is used to model scope-taking expressions. Scope-taking operations occupy the higher levels of multi-level towers, which are then passed as continuations in composition with their evaluation delayed. This is illustrated in Figure 2. Quantifiers such as *everyone* are two-level towers which introduce a variable on the lower level, together with a corresponding operator on a higher level.

The composition of multi-level towers as in (2) and the definition of LOWER ensures an important result: Content on a higher level of a multi-level tower takes scope over content on the same level to its right and over content on lower levels.

In contrast to quantifiers, non-scope-taking expressions such as *Mary* and *likes* do not inherently have continuation-passing, multi-level denotations.

$$
\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{DP} \\ \text{someone} \\ [\,] \\ \hline \exists x\,.\,[\,] \\ \hline x \end{array}
\quad
\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \mid \mathrm{S} \\ \hline (\mathrm{DP}\backslash \mathrm{S})\,/\,\mathrm{DP} \\ \text{likes} \\ [\,] \\ \hline [\,] \\ \hline \textbf{likes} \end{array}
\quad
\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{DP} \\ \text{everyone} \\ \forall y\,.\,[\,] \\ \hline [\,] \\ \hline y \end{array}
=
\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \\ \text{sm. likes ev.} \\ \forall y\,.\,[\,] \\ \hline \exists x\,.\,[\,] \\ \hline \textbf{likes}\,y\,x \end{array}
\overset{\downarrow}{\Rightarrow}
\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{S} \\ \text{sm. likes ev.} \\ \forall y\,.\,[\,] \\ \hline \exists x\,.\,\textbf{likes}\,y\,x \end{array}
\overset{\downarrow}{\Rightarrow}
\begin{array}{c} \mathrm{S} \\ \text{sm. likes ev.} \\ \forall y\,.\,\exists x\,.\,\textbf{likes}\,y\,x \end{array}
$$

Figure 3: Inverse scope reading of *Someone likes everyone*

The expressions *Mary* and *likes* in Figure 2 are the result of applying the LIFT type-shifter in Figure 1. This was done so that their composition can proceed following the schema in (2), which applies to towers with matching numbers of levels. Notice that LIFT as defined in Figure 1 adds a continuation-passing no-op (identity function) to a top layer of its input. B&S also allow LIFT to apply to sub-parts of denotations, to introduce a no-op intermediate layer. This is called *internal* LIFT.

Now consider the application of these techniques for a sentence with multiple scope-taking expressions. In Figure 3, we model the inverse scope reading of *Someone likes everyone*. The existential *someone* occurs linearly to the left of the universal *everyone*, but the quantificational part of *everyone* has undergone internal LIFT so that it takes scope over an expression that linearly precedes it.

2.2 Pronominal binding

The syntactic category $A \triangleright B$ represents a B that contains an unbound pronoun of category A. A pronoun such as *he* has the denotation in (3): it introduces a variable on the lower level and a corresponding λ binder which will take scope, allowing for binding by an expression to its left.

(3)
$$
\begin{array}{c} \mathrm{DP} \triangleright \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{DP} \\ \text{he} \\ \lambda x\,.\,[\,] \\ \hline x \end{array}
$$

To bind a pronoun, the BIND type-shifter in Figure 1 is applied to a DP, turning it into an expression that binds a pronoun to its right. The linear nature of binding naturally explains contrasts such as in (4):

(4) a. Every girl$_i$ loves her$_i$ mother.
  b. *Her$_i$ mother loves every girl$_i$.

2.3 Movement

Continuation-passing on higher levels of towers also provides an in-situ account of movement dependencies. First, a silent gap of category $A \,/\!\!/\, A$ for some A is placed in the "trace" position of a moved expression. A common choice for a gap will be category (DP $\backslash\!\!\backslash$ S) $/\!\!/$ (DP $\backslash\!\!\backslash$ S) which can be written as a multi-level tower as in (5). Notice that gaps introduce a variable and corresponding λ binder which allows for binding from above, just as pronouns do.

(5)
$$
\begin{array}{c} \mathrm{DP} \,\backslash\!\!\backslash\, \mathrm{S} \mid \mathrm{S} \\ \hline \mathrm{DP} \\ \overline{} \\ \lambda x\,.\,[\,] \\ \hline x \end{array}
$$

Second, the FRONT type-shifter (6) is applied specifically to expressions which are in a "moved" position. FRONT ensures that the expression composes with rightward material, i.e. the material that it has "moved over." FRONT also has a secondary effect of requiring the rightward material to be of the form $(A \,\backslash\!\!\backslash\, B)$, which will be important below.

(6)
$$
\frac{C \mid B}{A} = C \,/\!\!/\, (A \,\backslash\!\!\backslash\, B) \xrightarrow{\text{FRONT}} C \,/\, (A \,\backslash\!\!\backslash\, B)
$$

2.4 Crossover effects

A hallmark of the B&S framework is its explanation of "crossover" effects (Postal, 1971), such as in (7). The linear nature of continuation-passing and evaluation, together with the framework's treatment of pronominal binding and movement, leads to a natural explanation for such asymmetries (Shan and Barker, 2006).

(7) a. Which girl$_\mathrm{i}$ did you introduce ___ to her$_\mathrm{i}$ second cousin?
  b.?? Which girl$_\mathrm{i}$ did you introduce her$_\mathrm{i}$ second cousin to ___?

$$\begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{S} \mid \text{S} \\ \hline \text{DP} \\ \text{someone} \\ [\,] \\ \hline \exists x\,.\,[\,] \\ \hline x \end{array} \quad \begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{S} \mid \text{S} \\ \hline (\text{DP}\backslash\text{S})\,/\,\text{S} \\ \text{said} \\ [\,] \\ \hline [\,] \\ \hline \textbf{said} \end{array} \quad \begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{S} \mid \text{S} \\ \hline \text{DP} \\ \text{everyone} \\ \forall y\,.\,[\,] \\ \hline [\,] \\ \hline y \end{array} \quad \begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{S} \mid \text{S} \\ \hline \text{DP}\backslash\text{S} \\ \text{is married to Sue} \\ [\,] \\ \hline [\,] \\ \hline \textbf{married to s} \end{array} \; = \; \begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{S} \mid \text{S} \\ \hline \text{S} \\ \text{sm. said ev. is married to Sue} \\ \forall y\,.\,[\,] \\ \hline \exists x\,.\,[\,] \\ \hline \textbf{said}\,(\textbf{married to s}\,y)\,x \end{array}$$

Figure 4: B&S overgenerates the unattested inverse-scope reading of *Someone said everyone is married to Sue* (10)

First, consider the grammatical example in (7a). The gap in (7a) linearly precedes the pronoun *her* and is therefore able to bind it. This computation is sketched in (8). Applying BIND (Figure 1) to the gap in (5) yields (8) below.

(8)
$$\begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{S} \\ \hline \text{DP} \\ \_\_ \\ \lambda x\,.\,[\,] \\ \hline x \end{array} \quad \overset{\text{BIND}}{\Longrightarrow} \quad \begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{DP} \triangleright \text{S} \\ \hline \text{DP} \\ \_\_ \\ \lambda x\,.\,[\,]x \\ \hline x \end{array}$$

Using this gap (8) in the gapped clause serves to bind the pronoun to its right, as in (9). A FRONT-ed constituent combines with the resulting gapped clause and simultaneously binds the gap and pronoun.

(9)
$$\ldots \begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{DP} \triangleright \text{S} \\ \hline \text{DP} \\ \_\_ \\ \lambda x\,.\,[\,]x \\ \hline x \end{array} \ldots \begin{array}{c} \text{DP} \triangleright \text{S} \mid \text{S} \\ \hline \text{DP} \\ \text{her} \\ \lambda y\,.\,[\,] \\ \hline y \end{array} \ldots = \begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{S} \\ \hline \text{S} \\ \ldots \_\_ \ldots \text{her} \ldots \\ \lambda x\,.\,[\,] \\ \hline \ldots x \ldots x \ldots \end{array}$$

In contrast, the gap in (7b) is to the right of the pronoun and therefore has no opportunity to bind the pronoun. Depending on how the pronoun and gap are LIFT-ed, the gapped clause in (7b) will either have a type with $\text{DP} \triangleright \text{DP} \mathbin{\backslash\!\!\backslash} \text{S}$ on a single higher level, or have $\text{DP} \triangleright \text{S}$ and $\text{DP} \mathbin{\backslash\!\!\backslash} \text{S}$ on two different higher levels. If the gapped constituent has type $\text{DP} \triangleright \text{DP} \mathbin{\backslash\!\!\backslash} \text{S}$ on a higher level, or $\text{DP} \triangleright \text{S}$ above $\text{DP} \mathbin{\backslash\!\!\backslash} \text{S}$, it cannot directly combine with a FRONT-ed constituent since FRONT-ed constituents can only combine with expressions of type $A \mathbin{\backslash\!\!\backslash} B$. Thus, the gapped clause must have its pronoun bound first by another DP before its gap can be filled. Finally, if $\text{DP} \mathbin{\backslash\!\!\backslash} \text{S}$ is above $\text{DP} \triangleright \text{S}$, the gapped clause can combine with the FRONT-ed constituent but cannot simultaneously bind the pronoun, requiring the pronoun to be free or bound from further to the left.

3 Scope-taking across clause boundaries

With this background in place, we now turn to the treatment of complex examples with embedded clauses in the B&S continuation grammar.

An important property of the B&S framework reviewed above is that the scope-taking potential of any expression is unbounded. As is widely known, however, many quantifiers, including universals, are unable to take scope out of finite clauses for most speakers.[1] For example, example (10) modified from Fox (2000, p. 62) is judged by most speakers to be infelicitous, as only its anomalous surface scope reading is available. See the recent discussion in Wurmbrand (2018), as well as references there.

(10) #Someone said [everyone is married to Sue].

The current system incorrectly predicts the inverse scope reading of (10) to be available, as in Figure 4. A modification must be made to the B&S framework to restrict the scope-taking of quantifiers.

In recognition of this problem, and building on discussion in B&S (2008: 27–28), Charlow (2014: 64–66, 90) suggests that all finite clauses — and all scope islands, more generally — *must be evaluated*, i.e. by "collapsing it into a single level" (p. 65).[2] We codify this requirement in (11):

(11) **Scope Island Evaluation:**
If the expression is a scope island, apply LOWER as many times as possible ($\downarrow$*).[3]

[1] In contrast, indefinite quantifiers are known to be insensitive to a wide range of constraints on quantifier scope; see e.g. Fodor and Sag (1982), Abusch (1994). We concentrate on the scope-taking potential of universal quantifiers here.

[2] The discussion in Charlow (2014) builds on the B&S tradition but presents a distinct grammatical framework based on the notion of monads. In the interest of space, here we only evaluate the B&S framework with the added restriction in (11) and further refinements presented in this section, and leave the full consideration of the Charlow framework for future work.

$$\ldots\left(\begin{array}{c}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{DP}\\ \text{everyone}\\ \forall y\,.\,[\,]\\ \hline [\,]\\ \hline y\end{array}\quad\begin{array}{c}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{DP}\backslash\mathrm{S}\\ \text{is married to Sue}\\ [\,]\\ \hline [\,]\\ \hline \textbf{married to s}\end{array}\right)^{\downarrow^*} = \ldots\left(\begin{array}{c}\mathrm{S}\\ \text{ev. is m-t-S}\\ \forall y\,.\,\textbf{m-t-s}\,y\end{array}\right) = \begin{array}{c}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{S}\\ \text{sm. said ev. is m-t-S}\\ \exists x\,.\,[\,]\\ \hline \textbf{said}(\forall y\,.\,\textbf{m-t-s}\,y)x\end{array}$$

Figure 5: Scope Island Evaluation blocks *everyone* from scoping out of the embedded clause in (10)

Here we concentrate on the behavior of embedded finite clauses as scope islands. The principle of Scope Island Evaluation forces a full LOWER of the embedded clause in (10), successfully blocking *everyone* from scoping above the matrix quantifier, as illustrated in Figure 5.

However, recall that pronouns and movement gaps "take scope" in the B&S framework just as quantificational expressions do, placing a λ binder on the higher level of towers to allow for their binding from the left. In contrast to quantifiers, pronouns and gaps must be able to take scope out of embedded finite clauses, as evidenced by the availability of movement and variable binding across the bracketed clause boundaries in (12):

(12) a. Which girl did you say [Mary saw ___]?
b. Every girl$_\mathrm{i}$ said [Mary saw her$_\mathrm{i}$].

Scope Island Evaluation (11) thus interrupts the interpretation of embedded pronouns and gaps, incorrectly predicting the ungrammaticality of examples such as (12) without further refinement. We propose such refinements here, first discussing long-distance movement dependencies in §3.1 and then turning to long-distance variable binding in §3.2. This allows us to adopt Scope Island Evaluation as a principle to accurately limit quantifier scope, while also maintaining the availability of long-distance movement and variable binding as in (12).

3.1 Movement with intermediate gaps

Gaps in B&S introduce a λ binder on a higher level and a corresponding variable below (5). Clauses with DP gaps that undergo Scope Island Evaluation will be of category DP$\backslash$S — precisely the category of a clause that is missing a DP to its left. In short-distance movement, the fully LOWER-ed gapped clause is adjacent to the moved item and can immediately combine with it; however, in long-distance movement as in (12a), the moved item cannot immediately compose with the gapped clause.

For example, the embedded clause in (12a) will be as in (13) after Scope Island Evaluation:

(13)
$$\left(\begin{array}{c}\mathrm{DP}\mathbin{\backslash\!\!\backslash}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{S}\\ \text{Mary saw \_\_\_}\\ \lambda x\,.\,[\,]\\ \hline \textbf{saw}\,x\,\textbf{m}\end{array}\right)^{\downarrow^*} = \begin{array}{c}\mathrm{DP}\backslash\mathrm{S}\\ \text{Mary saw \_\_\_}\\ \lambda x\,.\,\textbf{saw}\,x\,\textbf{m}\end{array}$$

There are two problems with this denotation in (13). First, its type is DP$\backslash$S (see footnote 3), rather than the expected S type for embedded clauses, and therefore will not be able to compose with the standard S-selecting denotation for *say*. Second, since the λ binder for the gap is on the lowest level of the tower, it ceases to propagate as a scope-taking expression. Just as it correctly blocks quantifier scope-taking out of embedded clauses, Scope Island Evaluation incorrectly blocks movement dependencies across embedded clause boundaries.

We propose to resolve this problem with the use of additional, *intermediate gaps*. We first LIFT the fully LOWER-ed embedded clause in (13) into a two-level tower, which can then combine with an immediately preceding gap to yield its original denotation prior to Scope Island Evaluation:

(14)
$$\begin{array}{c}\mathrm{DP}\mathbin{\backslash\!\!\backslash}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{DP}\\ \text{\_\_\_}\\ \lambda y\,.\,[\,]\\ \hline y\end{array}\quad\begin{array}{c}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{DP}\backslash\mathrm{S}\\ \text{Mary saw \_\_\_}\\ [\,]\\ \hline \lambda x\,.\,\textbf{saw}\,x\,\textbf{m}\end{array} = \begin{array}{c}\mathrm{DP}\mathbin{\backslash\!\!\backslash}\mathrm{S}\mid\mathrm{S}\\ \hline \mathrm{S}\\ \text{\_ Mary saw \_}\\ \lambda y\,.\,[\,]\\ \hline \textbf{saw}\,y\,\textbf{m}\end{array}$$

The structure in (14) can now compose with the embedding verb and further material, passing the λ

[3] In addition, if the category of a one-story tower expression is $A \mathbin{\backslash\!\!\backslash} B$, we optionally shift its category to $A\backslash B$ with no change to its denotation.

binder for the inner gap further to the left, to later be successfully saturated by the "moved" element.

Interestingly, decades of work in the derivational syntactic tradition has argued for the presence of intermediate gaps at clause edges in cases of long-distance movement, as a reflex of *successive cyclic movement* (Chomsky, 1977). We review one empirical argument for such intermediate gaps here.

Reflexive pronouns in English must be bound by a local antecedent, leading to the ungrammaticality of (15). However, the reflexive *herself* can be successfully bound in (16), modified from Barss (1986: 25):

(15) *Keely$_\mathrm{i}$ thinks [Ted likes a picture of herself$_\mathrm{i}$].

(16) Which picture of herself$_\mathrm{i}$ does Keely$_\mathrm{i}$ think [Ted likes ___]?

In general, *wh*-moved constituents can be bound in their gap position, which B&S accomplish through delayed evaluation of "moved" material. But the grammaticality of (16) teaches us more: *herself* cannot be successfully bound if evaluated in the observable gap position in (16), but can be bound if we postulate an intermediate gap as in (17):

(17) Which picture of herself$_\mathrm{i}$ does Keely$_\mathrm{i}$ think ___ [Ted likes ___]?

In B&S's representational theory of movement dependencies, then, the adoption of Scope Island Evaluation offers independent motivation for the presence of intermediate gaps as in (17), serving to explain facts such as the grammaticality of (16).

3.2 Long-distance binding with PROLIFT

The Scope Island Evaluation requirement poses a similar problem for embedded pronouns. Pronouns, like gaps, introduce a λ binder on a higher level and a corresponding variable below; enforcing Scope Island Evaluation on the embedded clause in (12b) containing an unbound pronoun fixes the scope of that pronoun by placing it on the bottom level of the tower, as in (18).

(18)
$$\left(\begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \mid \mathrm{S}}{\mathrm{S}} \\ \text{Mary saw her} \\ \dfrac{\lambda x\ .\ [\,]}{\textbf{saw}\, x\, \textbf{m}} \end{array}\right)^{\downarrow *} = \begin{array}{c} \mathrm{DP} \rhd \mathrm{S} \\ \text{Mary saw her} \\ \lambda x\ .\ \textbf{saw}\, x\, \textbf{m} \end{array}$$

The resulting denotation in (18) could by itself be an utterance with a free variable, i.e. an open proposition, but it is not an appropriate denotation for an embedded clause. Just as with embedded clauses containing gaps in §3.1, the resulting object of category DP $\rhd$ S cannot combine with an S-selecting verb such as *say*. But unlike in §3.1, we are unable to resolve this problem by adding an intermediate gap. There is no gap that will compose with (18) and serve to extend its scope.

More generally, there are *no* existing expressions in the B&S framework that can combine with an expression of category DP$\rhd$S. To see this, we first note that except for pronouns which introduce them, lexical items never make reference to $\rhd$-categories. The only way that a $\rhd$-containing category is bound is by a DP which has undergone BIND, which have a category of the form $\dfrac{A \mid \mathrm{DP} \rhd B}{\mathrm{DP}}$. The $\rhd$-containing category (in this case, DP $\rhd$ S) is thus required to be on a higher level of the tower, rather than the bottom.

We thus propose a new type-shifter PROLIFT (19) that lifts the pronoun out of the bottom layer of a tower. Semantically, the variable in g is locally saturated and then abstracted over on a higher level.

(19)
$$\begin{array}{c} \dfrac{B \mid C}{\mathrm{DP} \rhd A} \\ \text{expression} \\ \dfrac{f[\,]}{\lambda x\ .\ g(x)} \end{array} \xRightarrow{\text{PROLIFT}} \begin{array}{c} \dfrac{\mathrm{DP} \rhd B \mid C}{A} \\ \text{expression} \\ \dfrac{\lambda x\ .\ f[\,]}{g(x)} \end{array}$$

Using PROLIFT returns the pronoun's λ binder and its corresponding DP$\rhd$-category to a higher level, from which position it can propagate to the left until it is bound. The adoption of a principle such as Scope Island Evaluation, motivated by observed limitations on quantifier scope, together with the grammatical possibility of binding embedded pronouns as in (12b), makes the PROLIFT a necessary addition to the grammar.

4 Crossover in long-distance configurations

We have seen that the adoption of Scope Island Evaluation (11), intermediate gaps, and PROLIFT together resolve a number of limitations of B&S's original framework with regards to the behavior of embedded clauses. However, we now demonstrate that the combination of these three improvements together lead to incorrect predictions for crossover effects with gaps and pronouns in embedded clauses:

a.

$$\ldots \overset{\downarrow^*}{\Longrightarrow} \begin{array}{c} \text{DP} \triangleright (\text{DP} \mathbin{\backslash\!\!\backslash} \text{S}) \\ \text{her mother loves \_\_\_} \\ \lambda x \,.\, \lambda y \,.\, \textbf{loves}\, y\, (\textbf{mom}\, x) \end{array} \xRightarrow{\text{LIFT}} \begin{array}{c} \text{S} \mid \text{S} \\ \hline \text{DP} \triangleright (\text{DP} \mathbin{\backslash\!\!\backslash} \text{S}) \\ \text{her mother loves \_\_\_} \\ [\,] \\ \hline \lambda x \,.\, \lambda y \,.\, \textbf{loves}\, y\, (\textbf{mom}\, x) \end{array} \xRightarrow{\text{PROLIFT}} \begin{array}{c} \text{DP} \triangleright \text{S} \mid \text{S} \\ \hline \text{DP} \backslash \text{S} \\ \text{her mother loves \_\_\_} \\ \lambda x \,.\, [\,] \\ \hline \lambda y \,.\, \textbf{loves}\, y\, (\textbf{mom}\, x) \end{array}$$

b.

$$\begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{DP} \triangleright \text{S} \\ \hline \text{DP} \\ \text{\_\_\_} \\ \lambda z \,.\, [\,] z \\ \hline z \end{array} \quad \begin{array}{c} \text{DP} \triangleright \text{S} \mid \text{S} \\ \hline \text{DP} \backslash \text{S} \\ \text{her mother loves \_\_\_} \\ \lambda x \,.\, [\,] \\ \hline \lambda y \,.\, \textbf{loves}\, y\, (\textbf{mom}\, x) \end{array} = \begin{array}{c} \text{DP} \mathbin{\backslash\!\!\backslash} \text{S} \mid \text{S} \\ \hline \text{S} \\ \text{\_\_\_ her mother loves \_\_\_} \\ \lambda z \,.\, [\,] \\ \hline \textbf{loves}\, z\, (\textbf{mom}\, z) \end{array}$$

Figure 6: The revised B&S grammar overgenerates, undoing the weak crossover violation in (20b).

(20) a. Which girl$_i$ do you think [___ loves her$_i$ mother]?

b.?? Which girl$_i$ do you think [her$_i$ mother loves ___]?

In particular, our revised B&S framework predicts the crossover violation configuration in (20b) to be grammatical.

Let us see how our revised B&S framework from §3 makes such a prediction. One option for the interpretation of the embedded clause *her mother loves* ___ in (20b) yields an expression of category DP $\triangleright$ (DP $\backslash$ S) after Scope Island Evaluation. In Figure 6a, we apply LIFT and PROLIFT to this structure.[4] Then in Figure 6b, we introduce the intermediate gap which has undergone BIND (8), also used in the grammatical (9) above. This BIND-shifted gap (8) serves to introduce a λ binder on the higher level for the gap and also simultaneously bind the pronoun. This is possible despite the fact that the pronoun precedes the gap position in the embedded clause. This demonstration shows that the B&S framework as amended here in §3 now overgenerates, predicting structures of the form in (20b) to be grammatical, contrary to fact.

Before applying PROLIFT and combining with the intermediate gap, the pronoun in the gapped clause needed to be bound before the gap could be filled. However, PROLIFT gives its raised λ operator widest scope as shown in Figure 6a, which generates a configuration in which the pronoun and gap are located on different levels. When the BIND-shifted intermediate gap is introduced as in Figure 6b, then, the pronoun can be bound at the same time as the gap is filled, since these operations occur on different levels. The upshot is that applying a combination of Scope Island Evaluation, intermediate gaps and PROLIFT on a long-distance crossover configuration predicts that (20b) is acceptable.

We appear to be at an impasse. The ingredients that together lead to the overgeneration of (20b) were each independently motivated. Scope Island Evaluation (11) is necessary to account for the observed limitations on quantifier scope-taking (B&S, 2008; Charlow, 2014). Without it, quantifiers would be able to take scope out of scope islands, including embedded finite clauses. Meanwhile, intermediate gaps and PROLIFT are minimal alternations to the theory to make long-distance movement and binding dependencies compatible with Scope Island Evaluation. The intermediate gap introduced in Figure 6b is the same simple gap shifted with BIND (8) used by B&S to account for grammatical configurations of variable binding by movement (Shan and Barker, 2006). Given that each of these steps cannot be omitted from the theory, it appears that the B&S framework systematically overgenerates in a way that undermines this crucial argument for the approach: the explanation of crossover effects.

5 Discussion

The Barker and Shan grammar fragment is notable both technically, for being built on the theoretical notion of continuations as a model for scope-taking, and empirically, for its ambitious consideration and

[4]In the final step, we also shift the lower level type from DP $\mathbin{\backslash\!\!\backslash}$ S to DP $\backslash$ S, following footnote 3, as the lowest levels of towers are not naturally continuation-passing.

treatment of a wide range of challenging syntactic and semantic phenomena. One of the first and most prominent arguments presented for the framework is its account for binding and crossover effects (Shan and Barker, 2006). The apparently linear nature of crossover effects receives a natural explanation in the B&S framework, where scope-taking expressions compose linearly.

As has been recognized before, the B&S framework as presented does not by itself adequately restrict the scope-taking potential of quantifiers. Here we codified a suggestion made in Charlow (2014) following B&S (2008), that scope islands such as embedded finite clauses are recursively lowered so that scope-taking operations cannot take scope further: Scope Island Evaluation (11). We then presented minimal improvements to the theory to maintain the availability of long-distance movement and binding configurations, but ultimately showed in §4 that these tools lead to a fatal overgeneration.

Perhaps the greatest limitation of the B&S framework that this work highlights is its uniform treatment of pronouns, gaps, and quantifiers as scope-takers.[5] The ultimately problematic amendments we proposed in §3 were needed because the scope-taking of quantifiers, but not movement or bound pronoun relationships, is blocked by intervening finite clause boundaries. In fact, these dependencies can be further distinguished: *islands* such as relative clauses block movement dependencies across them (21a) (Ross, 1967), but do not block pronominal binding (21b):

(21) a. *Who$_i$ did you say [(that) Sarah ate [$_{island}$ the food that ___$_i$ made]]?
b. Who$_i$ did you say [___$_i$ ate [$_{island}$ the food that she$_i$ (herself) made]]?

In contrast, many common LF-based approaches to semantic interpretation — such as that introduced in Heim and Kratzer (1998) — utilize a fundamentally different mechanism for pronominal binding that is insensitive to intervening syntactic boundaries.[6] These theories do however relate quantificational scope-taking and movement, hypothesizing "covert" movement to account for quantifier scope — also known as *Quantifier Raising* (May, 1977).

At first glance, this may suggest that LF-based accounts will face similar difficulties in distinguishing between configurations of licit movement dependencies and licit quantifier scope-taking. However, the LF theorist will note that different forms of "overt" movement are already sensitive to different locality restrictions: for example, between A-movement, $\overline{\text{A}}$-movement, and head-movement. (See Rizzi (2013), Belletti (2018), for recent overviews and approaches.) The clause-boundedness of quantifier scope-taking then reduces to an existing and independently necessary task of developing syntactic theories to explain the different locality profiles of different types of movement. We hope that such work will, in the future, lead to principled accounts, beyond simply stipulating that QR cannot take place out of scope islands. See Wurmbrand (2018) for some discussion of recent approaches.

Of the Scope Island Evaluation requirement critiqued here, Charlow (2014) writes: "The requirement that scope islands must be evaluated is intended as nothing more and nothing less than the denotational correlate of prohibiting QR out of scope islands" (p. 90). We disagree with this characterization. The effects of adopting Scope Island Evaluation are far greater than simply limiting QR out of scope islands, leading to serious overgeneration if we are to maintain the B&S framework's existing explanations for binding and crossover facts.

Finally, we note that our discussion has followed B&S in taking crossover effects to be an issue of grammatical competence. As a reviewer notes, it is possible that crossover effects, as well as other locality effects such as restrictions on scope-taking and island effects on movement, may instead be due to considerations of on-line processing.

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[5] Dowty (2007, sec. 2.8) refers to this approach to pronominal binding as a "combinatory" approach, primarily discussing Jacobson (1999), in contrast to "free variable binding" theories such as LF-based theories, below. As an anonymous reviewer notes, there are other frameworks in the CCG tradition which do not assume such a unification, such as Steedman (2011).

[6] In turn, LF-based theories have been challenged for requiring c-command configurations for binding, rather than linear precedence; see Barker (2012).

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