Split and compose

Deriving long-distance dependencies in a continuation-based grammar

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Overview

Goal of this talk: present a refined version of the **continuation-based theory** of scope and binding (Barker & Shan, 2014).

- The continuation-based grammar provides a promising approach to **binding without c-command**.
- But it cannot properly handle **long-distance dependencies** (Leong & Erlewine, 2019).
- We propose **a new rule SPLIT**, which allows us to address the problem together with **function composition** (Steedman, 2000).

Outline

1. **Background**: Continuation-based grammar
2. **Problem**: Long-distance dependencies
3. **Proposal**: Split and compose
4. **Account**

Background: Continuation-based grammar

Binding and c-command

Traditional assumption: Binding requires **c-command** from an A-position (Reinhart, 1983).

(1) a. Every girl$_i$ praised her$_i$ mother. b. ?*Her$_i$ mother praised every girl$_i$.

But it has been known that there are some counterexamples (Barker, 2012).

(2) a. [Every girl$_i$'s teacher] praised her$_i$ mother. (binding from a possessor)

b. We [sell no wine$_i$] before its$_i$ time. (binding out of a VP)

As a result, some recent theories have incorporated a certain kind of **linear order** into the account of binding (Barker & Shan, 2014; Bruening, 2014; Chierchia, 2020).

Continuations-based grammar

Here, we adopt the **continuation-based grammar** proposed in the seminal work by Barker and Shan (henceforth **B&S**).

- It is an extension of the standard categorial grammar with a mechanism to handle **scope-taking**.
- For the sake of time, I don't explain the formal details on continuations.

Continuation-based grammar: Introducint the towers

Idea: **Scope-level information is computed separately** from the predicate-argument structure (written separated by a vertical line).

(3) everyone : $\dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \rightsquigarrow \dfrac{\forall x.\,[\,]}{x}$

In general, ...

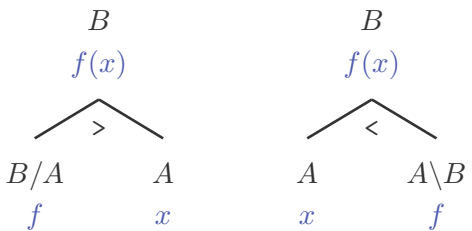
- Semantics: $\dfrac{\alpha[\,]}{a}$
- Syntactic category: $\dfrac{C \mid B}{A}$

become C when it takes scope

take scope over B

behaves as A locally

Rules: Function application



Rules: LIFT and LOWER

We have rules to go back and forth between scope-takers and non-scope-takers.

- LIFT ($\Uparrow$) turns A into a vacuous scope-taker.

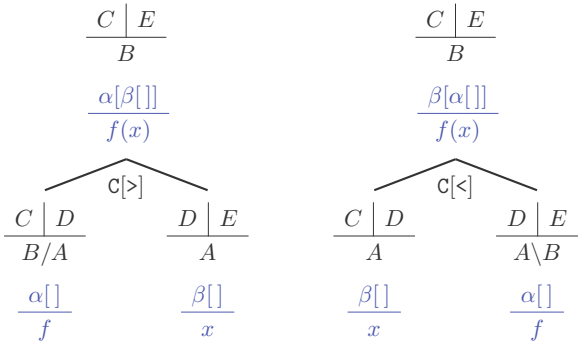
$$\dfrac{B \mid B}{A}$$
$$\dfrac{[\,]}{x}$$
$$\mid \Uparrow$$
$$A$$
$$x$$

- LOWER ($\Downarrow$) collapses a tower.

$$B$$
$$\alpha[x]$$
$$\mid \Downarrow$$
$$\dfrac{B \mid A}{A}$$
$$\dfrac{\alpha[\,]}{x}$$

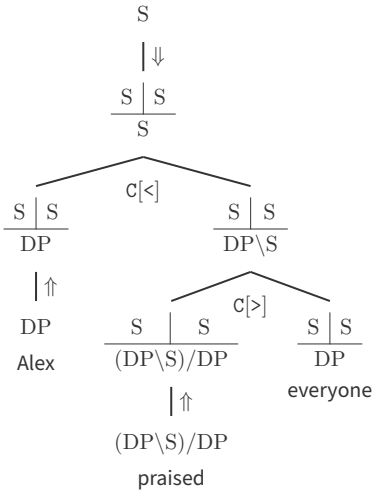
Rules: Continuized function application

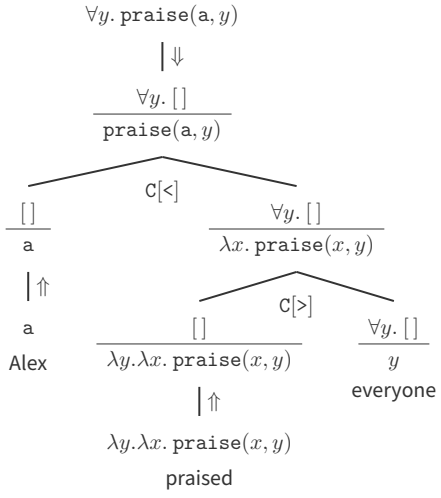
To combine two towers, we use the “continuized” version of function application.



- 1st level: function application
- 2nd level: **left-to-right** scope composition

Introducing continuations: Example





Binding via scope composition

An **unbound pronouns** is marked as $\mathrm{DP} \triangleright A$, semantically denoting a **function from entities** (Jacobson, 1999).

(4) She sneezed : $\mathrm{DP} \triangleright \mathrm{S} \rightsquigarrow \lambda x.\, \mathtt{sneeze}(x)$

The anaylsis of binding is decomposed into two parts.

[Binder]
A unary rule $\triangleright$ turns scope-takers into binders.

(5) everyone$^{\triangleright}$: $\dfrac{\mathrm{S} \mid \mathrm{DP} \triangleright \mathrm{S}}{\mathrm{DP}} \rightsquigarrow \dfrac{\forall x.\, [\,](x)}{x}$

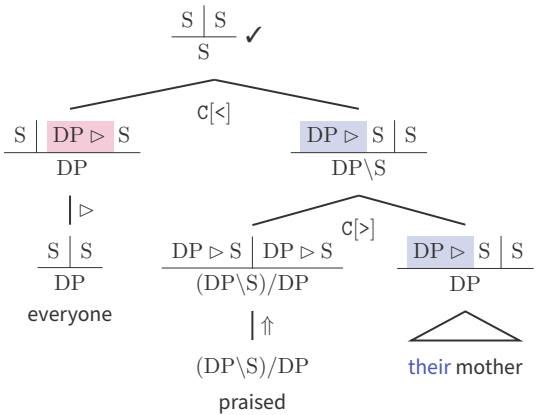
[Bindee]
Pronouns lexically encode $\mathrm{DP} \triangleright$.

(6) she : $\dfrac{\mathrm{DP} \triangleright \mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \rightsquigarrow \dfrac{\lambda x.\, [\,]}{x}$

Binding via scope composition

Binding is established via scope composition.

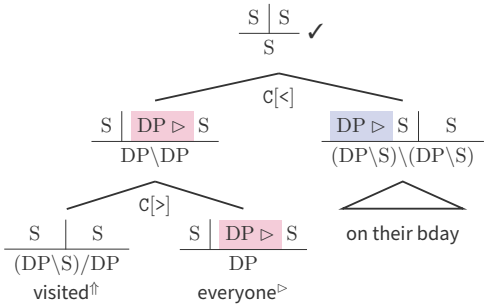
(7) Everyone$_i$ praised their$_i$ mother.



Binding via scope composition: Example (contd.)

Notably, binding is predicted to follow linear order, not c-command.

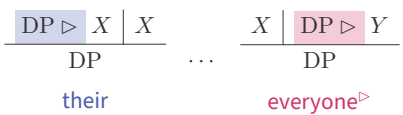
(8) Alex [visited everyone$_i$] on their$_i$ birthday.



Binding via scope composition: Crossover

Hence, **the crossover effect** (Postal, 1971) is predicted as a result of the **left-to-right** nature of scope composition.

(9) ?*Their$_i$ mother praised everyone$_i$.



For *wh*-dependencies, they assume a gap at the object position.

(10) ?*Whom$_i$ did their$_i$ mother praise (gap)?

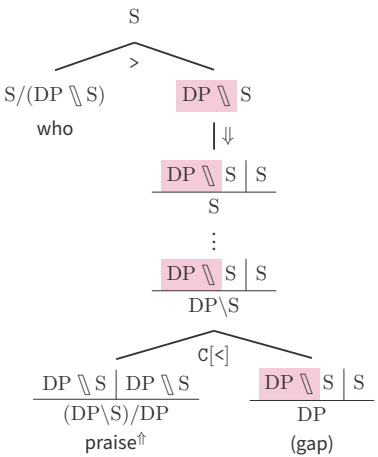
Wh-dependencies: Gap

More concretely, gaps are formalized as scope-takers.

Let $A \setminus\!\!\setminus B$ be a category for "B missing A inside".

(11) (gap) : $\dfrac{\mathrm{DP} \setminus\!\!\setminus \mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \rightsquigarrow \dfrac{\lambda x.\,[\,]}{x}$

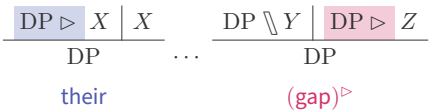
A *wh*-phrase expects $\mathrm{DP} \setminus\!\!\setminus \mathrm{S}$ on its right (i.e., a sentence with a gap inside),



Wh-dependencies (contd.)

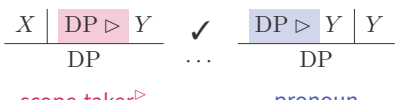
Then, the *wh*-crossover can also be explained with the left-to-right scope composition.

(10) Whom$_i$ did their$_i$ mother praise (gap)?



Interim summary

- Scope composition follows linear order.
- Binding is derived via scope.



Problem: Long-distance dependencies

Scope islands and long-distance dependencies (LDDs)

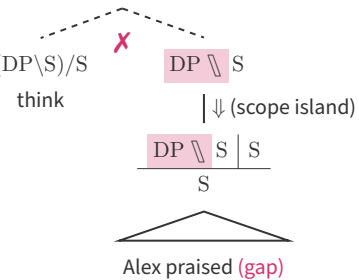
Finite clauses constitute **scope islands**: Scope-taking cannot go out of them.

(12) Someone thinks [Alex praised everyone]. (*$\forall > \exists$)

Thus, we need to LOWER the tower at every finite-clause boundary (Charlow, 2014).

But then, we cannot derive LDDs!

(13) Whom$_i$ does Kim think [Alex praised __]?

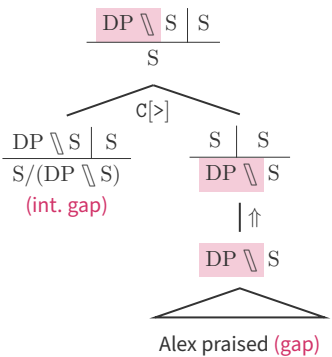


Intermediate gap (?)

A possible remedy: introduce an **intermediate gap** at the clausal edge (Leong & Erlewine, 2019).

Like successive cyclic movement:

(13) Whom$_i$ does Kim think ___ [Alex praised ___]?



Crossover effect in LDDs

However, we encounter another problem regarding **the crossover effect**.

(14) ?*Whom$_i$ does Kim think [their$_i$ mother praised __]?

The intermediate gap can wrongly lisence binding in (14)!

(14) Whom$_i$ does Kim think __ [their$_i$ mother praised __]?

What went wrong?

Leong and Erlewine (2019) pointed out that the issue stemed from the treatment of *wh*-dependencies.

- B&S posited ***wh*-gaps as scope-takers**.
  - To account for binding from *wh*-phrases.
- But scope-taking is confined to **scope islands**.
  - We probably need a different mechanism for *wh*-dependencies.

Q. How should we make the continuation-based grammar compatible with LDDs?

Proposal: Split and compose

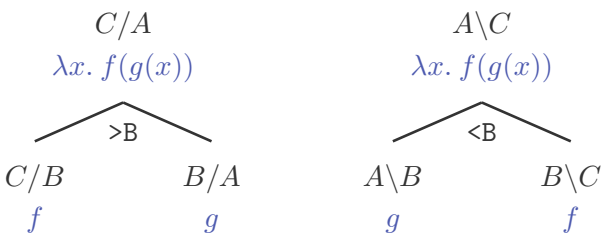
Overview

To address the issue …

- We adopt a **gap-free** approach to LDDs (Steedman, 2000), which employs **function composition**.
- We propose **a new rule SPLIT**, so that we can integrate function composition into the continuation-based grammar.

Function composition

The function composition rules link two functions together.



Function composition: *Wh*-dependencies

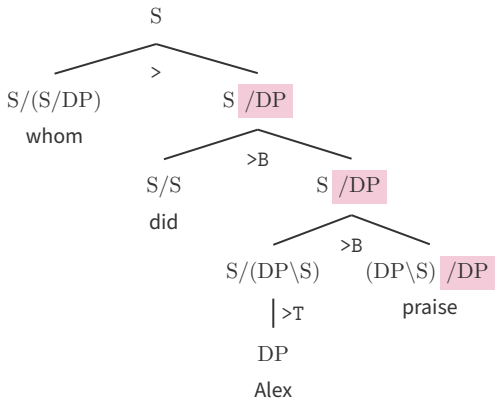
Let us derive the following.

(15) Whom did Alex praise?

First, we apply type-raising to *Alex*.

Then, we can combine *did*, *Alex*, and *praise* via function composition.

Overall, the missing object $/\mathrm{DP}$ **percolates** up the tree.

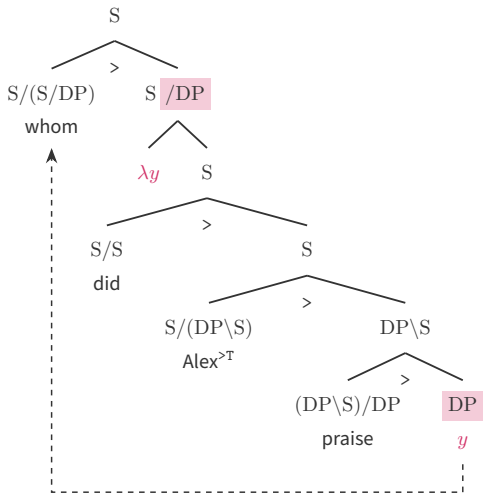


Function composition: Analogy with movement

The percolation of $/\mathrm{DP}$ can be understood in analogy with **movement** (Steedman, 2024).

That is, successive application of >B is like …

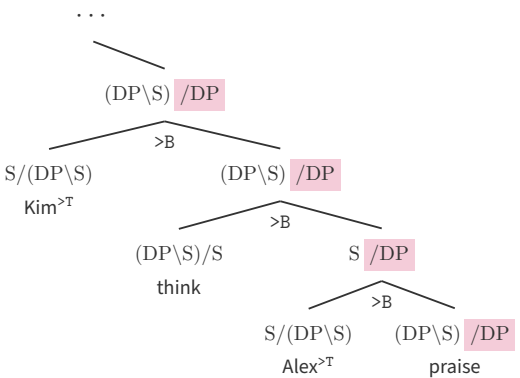
- Leave a "trace" y.
- Apply function application instead.
- Abstract y at the top



Function composition: LDDs

Nice thing: function composition can be applied **over clause boundaries**.

Hence, the missing object $/\mathrm{DP}$ can percolate up over finite clause boundaries.



To integrate function composition into the continuation-based grammar, we propose the following unary rule.

Idea: It **“splits” a tower** with the slash at the bottom level.

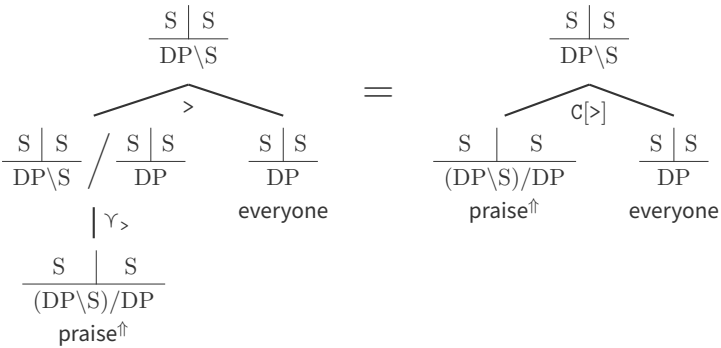
$$\frac{\frac{C \mid E}{B} \,/\, \frac{D \mid E}{A}}{\lambda \frac{\beta[\,]}{x} . \frac{\alpha[\beta[\,]]}{f(x)}} \;\Upsilon_{>}\; \frac{C \mid D}{B/A} \qquad \frac{\alpha[\,]}{f}$$

$$\frac{\frac{C \mid D}{A} \,\backslash\, \frac{C \mid E}{B}}{\lambda \frac{\beta[\,]}{x} . \frac{\beta[\alpha[\,]]}{f(x)}} \;\Upsilon_{<}\; \frac{D \mid E}{A\backslash B} \qquad \frac{\alpha[\,]}{f}$$

SPLIT: Intuition

SPLIT is a **partially-applied** version of the continuized function application.

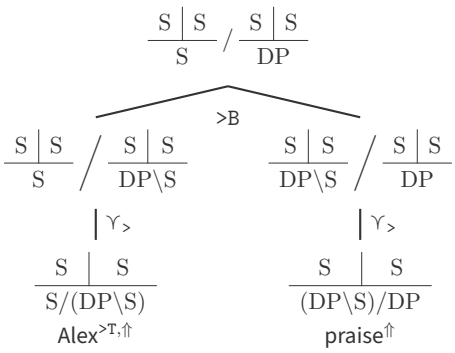
Indeed, $\Upsilon_{>}$ plus > is equivalent to $\mathsf{C}[>]$ (it is a conservative extension).



Split and compose

SPLIT gives us functions from one tower to another.

Upshot: These higher-order functions can be composed via function composition.



Simplified notation

Since it is a bit cumbersome to write functions between towers every time, we use the following abbreviations.

$$A^{\Uparrow} = \frac{\mathrm{S} \mid \mathrm{S}}{A} \quad \text{(pure scope-taker)}$$

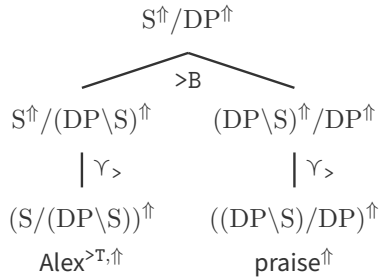
$$A^{\triangleright} = \frac{\mathrm{S} \mid \mathrm{DP} \triangleright \mathrm{S}}{A} \quad \text{(binder)}$$

$${}^{\triangleright}A = \frac{\mathrm{DP} \triangleright \mathrm{S} \mid \mathrm{S}}{A} \quad \text{(bindee)}$$

$${}^{\triangleright}A^{\triangleright} = \frac{\mathrm{DP} \triangleright \mathrm{S} \mid \mathrm{DP} \triangleright \mathrm{S}}{A} \quad \text{(lifted with } \mathrm{DP} \triangleright \mathrm{S})$$

Split and compose, in the simplified notation

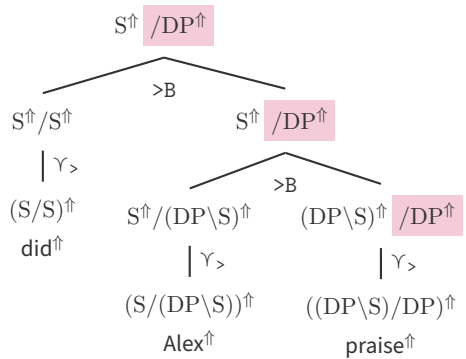
With this notation, the derivation is closer to the one without towers.



Split and compose (contd.)

Let's see how *wh*-dependencies can be derived.

We can see that **the "lifted" DP argument** $/\mathrm{DP}^{\Uparrow}$ percolates up the tree.

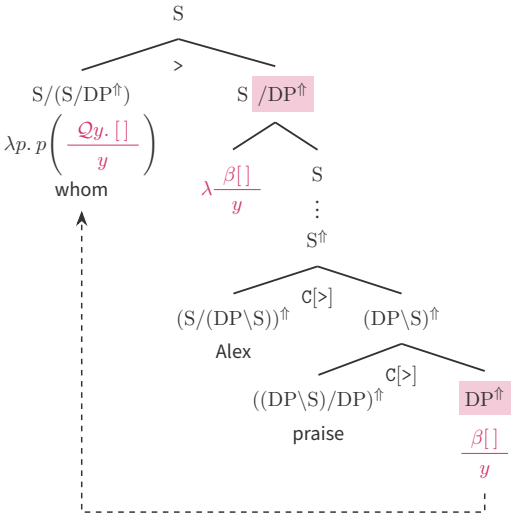


Split and compose (contd.)

Using the analogy with movement again, it is as if we have moved up $\mathrm{DP}^{\Uparrow}$.

At the end, $\beta[\,]$ is replaced with $\mathcal{Q}y.[\,]$.

In effect, $\mathcal{Q}y.[\,]$ is **reconstructed** into the object position.



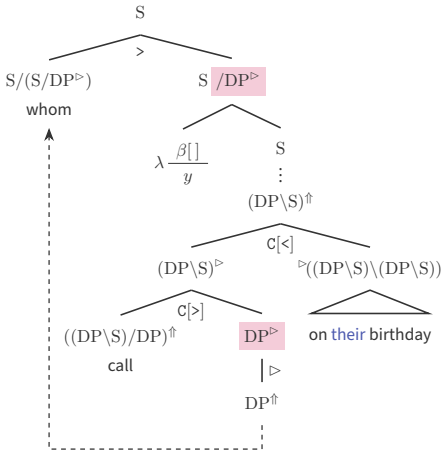
Account

Order-sensitivity of binding

We show how our account allows a *wh*-phrase to bind a pronoun.

(16) Whom$_i$ did Alex call __ on their$_i$ birthday?

We can bind a pronoun by applying $\triangleright$ to the pre-movement $\mathrm{DP}^{\Uparrow}$.

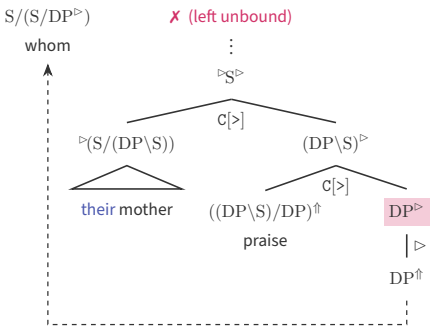


Order-sensitivity of binding: Crossover

What about the crossover case?

(10) Whom$_i$ did their$_i$ mother praise ___ ?

The *wh*-scope is reconstructed into the object position, from which it cannot bind the pronoun. Thus, like B&S's original theory, our account predicts that binding exhibits **order-sensitivity**.

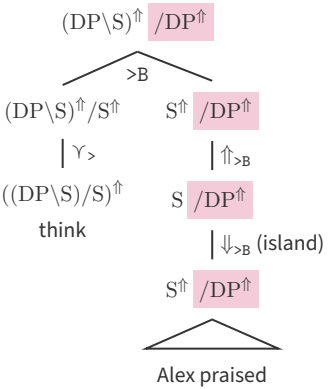


Crossover in LDDs

Now let's turn to LDDs.

(14) Whom does Kim think [Alex praised __]?

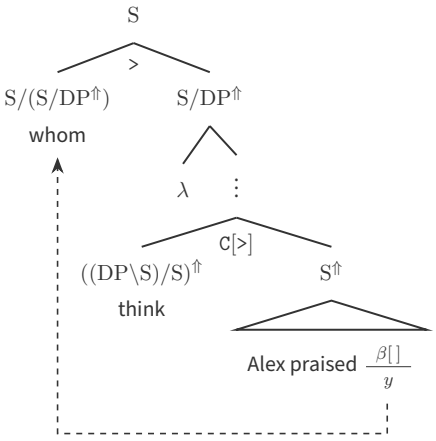
We can basically maintain the original analysis (without towers). Namely, we can inherit $/\mathrm{DP}^{\Uparrow}$ over finite clause boundaries.



Weak crossover in LDDs (contd.)

Crucially, our account does NOT assume intermediate gaps.

In movement-based terms, *wh*-phrases are moved “in one step”.

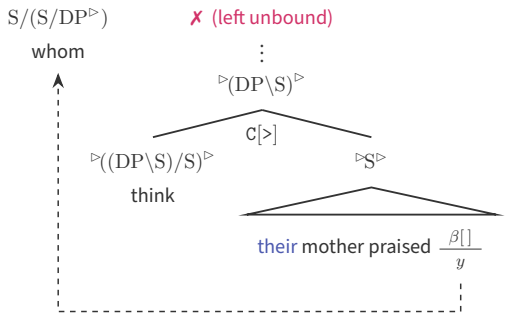


Weak crossover in LDDs (contd.)

As we don't have any int. gaps, we retain the **order-sensitivity even in LDDs**.

(14) ?*Whom$_i$ does Kim think [their$_i$ mother praised __]?

This is predicted to be bad for the same reason as the non-embedded case (10).



Summary of the account

- The **gap-free** account with function composition derives *wh*-dependencies in a way similar to movement.
- Our proposed rule SPLIT allows the scope of a *wh*-phrase to be **reconstructed** to its original position.
- As a result, we can predict the crossover effect even in LDDs.

Conclusion: We presented a refined version of the **continuation-based theory** that is compatible with **long-distance dependencies**.

Thank you for listening!

For any follow-up questions, please contact me at:
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References i

Barker, C. (2012). Quantificational binding does not require c-command. *Linguistic Inquiry*, *43*(4), 614–633. https://doi.org/10.1162/ling_a_00108

Barker, C., & Shan, C.-c. (2014). *Continuations and Natural Language*. Oxford University Press.

Bruening, B. (2014). Precede-and-command revisited. *Language*, *90*(2), 342–388. https://doi.org/10.1353/lan.2015.0045

Charlow, S. (2014). *On the semantics of exceptional scope* [Doctoral dissertation, New York University].

Chierchia, G. (2020). Origins of weak crossover: When dynamic semantics meets event semantics. *Natural Language Semantics*, *28*(1), 23–76. https://doi.org/10.1007/s11050-019-09158-3

References ii

Jacobson, P. (1999). Towards a variable-free semantics. *Linguistics and Philosophy*, *22*(2), 117–185. https://doi.org/10.1023/A:1005464228727

Leong, C. S.-Y., & Erlewine, M. Y. (2019). Long-distance dependencies in continuation grammar. *Proceedings of PACLIC 33*, 114–122.

Postal, P. (1971). *Cross-over phenomena*. Holt, Rinehart; Winston.

Reinhart, T. (1983). *Anaphora and semantic interpretation*. Routledge.

Steedman, M. (2000). *The Syntactic Process*. MIT Press.

Steedman, M. (2024). On internal merge. *Linguistic Inquiry*, 1–59. https://doi.org/10.1162/ling_a_00521