

On Internal Merge

Steedman (2023) on CCGs and Minimalism

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Hopf Algebra seminar

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Introduction

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Inclusiveness Condition (Chomsky, 1995): The output of a system must not contain anything beyond its input, meaning syntactic derivation rules cannot add information (indices, traces, syntactic categories, etc.) to whatever has been specified in the categories that the derivation begins with.

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- This is taken as a core tenet of Steedman (2023): a derivation begins with inputs specifying exactly the combinatory potential to be used.
- The universal, type-dependent and language-independent rules are then applied to combine the inputs, which do not alter information.

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- Unite internal merge with external merge without adding discontinuity into the grammar, using as minimal expressive power as possible.
 - ▶ Contrary to other proposals that eliminate movement (GPSG trace–feature passing, CG–nonstandard constituency, LFG lexicalization of locality, HPSG structural unification, etc.).
 - ▶ These are too restrictive (grammar collapses to CFG) or too expressive (require additional constraints to then limit this).

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- Expressive power of this system: "low near-context-free".
- Categories are defined functionally and semantically with functions and arguments, and IM discontinuities base-generated in the logical forms.

Topics

- Components of CCG
 - ▶ Lexical items
 - ▶ Function application/composition
 - ▶ Type raising
- External Merge
- Internal Merge
- Linguistic examples

Defining CCGs and External Merge

Components of CCG

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- (1) Bare Phrase Structural notation for linguistic categories
 - ▶ *The Categorical Assumption*: Linguistic Categories are defined syntactically and semantically as functions and/or arguments.
- (2) Contiguous merger universal rules
 - ▶ *The Adjacency Assumption*: Rules are purely functional binary operations, limited to application, composition, and substitution, applying to strictly adjacent, phonologically-realized categories, which synchronously and monotonically compose logical forms (lf) and concatenate phonological forms (pf).

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- Logical form: f a application of f to a , left association, variable-binding λ operator
 - ▶ f, a variables over logical forms corresponding to categories
 $\lambda y. pres(walk\ y)$

(2) Merge: Function application

Contiguous Merge I: Application Rules

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Contiguous Merge I: Application Rules

- a. Forward application ($>$)

$$X /_* Y : f \quad Y : a \Rightarrow X : f a$$

- b. Backward application ($<$)

$$Y : a \quad X \backslash_* Y : f \Rightarrow X : f a$$

(2) Merge: Function application (cont.)

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- a. $Y : a \quad X/Y : f \not\equiv X : f \quad a$
- b. $(X/Y)/W : f \quad Y : a \not\equiv X/W : \lambda w.f \quad w \quad a$
- c. $X_i/Y : f \quad Y : a \not\equiv X_j : f \quad a$

Examples of Merge

1. Mary walks.

$$\frac{\overline{NP_{3s} : mary} \quad \overline{S \setminus NP_{3s} : \lambda y. pres(walk y)}}{S : pres(walk mary)} <$$

Merge: Function Composition

Contiguous Merge IIa: Function Composition

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Contiguous Merge IIa: Function Composition

- a. Forward composition ($>\mathbf{B}$)

$$X/\diamond Y : f \quad Y/Z : g \Rightarrow X/Z : \lambda z.f(gz)$$

- b. Backward composition ($<\mathbf{B}$)

$$Y\backslash Z : g \quad X\backslash\diamond Y : f \Rightarrow X\backslash Z : \lambda z.f(gz)$$

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- c. Forward crossing composition ($>\mathbf{B}_\times$)

$$X/\times Y : f \quad Y\backslash Z : g \Rightarrow X\backslash Z : \lambda z.f(gz)$$

- d. Backward crossing composition ($<\mathbf{B}_\times$)

$$Y/Z : g \quad X\backslash\times Y : f \Rightarrow X/Z : \lambda z.f(gz)$$

Merge: Function Composition (cont.)

Consistency and Inheritance apply here too:

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Function composition yields constituency effects:

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Function composition yields constituency effects:

$$\frac{\frac{\text{will}}{(S\backslash NP)/VP \quad \lambda p \lambda y.\text{will}(py)} \quad \frac{\text{wear}}{VP/NP : \lambda x \lambda y.(wear \ xy)}}{(S\backslash NP)/NP : \lambda x \lambda y.\text{will}(wear \ xy)} \text{>B}$$

Merge: Second-level Function Composition

Contiguous Merge IIb: Second-level Function Composition

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Contiguous Merge IIb: Second-level Function Composition

- a. Forward level-2 composition ($>\mathbf{B}^2$)

$$X/\diamond Y : f \quad (Y/Z)|W : g \Rightarrow (X/Z)|W : \lambda w \lambda z. f(gwz)$$

- b. Backward level-2 composition ($<\mathbf{B}^2$)

$$(Y\backslash Z)|W : g \quad X\backslash\diamond Y : f \Rightarrow (X\backslash Z)|W : \lambda w \lambda z. f(gwz)$$

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- Backward level-2 composition ($<\mathbf{B}^2$)
 $(Y \setminus Z)|W : g \quad X \setminus \diamond Y : f \Rightarrow (X \setminus Z)|W : \lambda w \lambda z. f(gwz)$
- Forward crossing level-2 composition ($>\mathbf{B}_\times^2$)
 $X/\times Y : f \quad (Y \setminus Z)|W : g \Rightarrow (X \setminus Z)|W : \lambda w \lambda z. f(gwz)$
- Backward crossing level-2 composition ($<\mathbf{B}_\times^2$)
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- Forward crossing level-2 composition ($>B_x^2$)
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Merge: Second-level Function Composition (cont.)

$$\frac{\frac{\text{may}}{(S \backslash NP) / VP \quad \lambda p \lambda y . \text{may}(py)} \quad \frac{\text{give}}{(VP / PP) / NP \quad : \lambda w \lambda x \lambda y . (\text{give } xwy)}}{((S \backslash NP) / PP) / NP \quad : \lambda w \lambda x \lambda y . \text{may}(\text{give } xwy)} \quad >_{B^2}$$

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- Categories can grow completely unbounded, meaning CCG here is non-context-free.

The Combinatory Projection Principle (CPP): Combinatory rules apply to contiguous categories ("Adjacency"), must respect the linearization specified in the slash direction for the governing category ("Consistency"), and must project unchanged onto the resulting category any further categorial, selectional, and linearization information specified in either the governing or the dependent category ("Inheritance").

Internal Merge

Internal Merge: Raising

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IM via raising and control

Raising-to-subject

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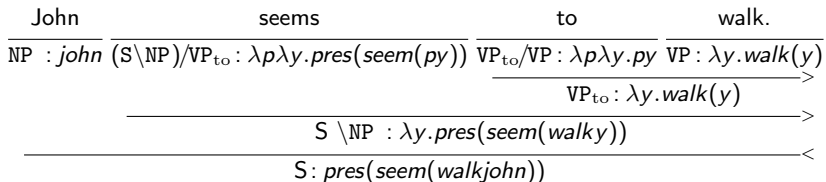
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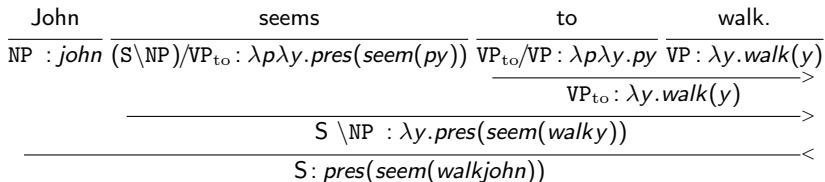
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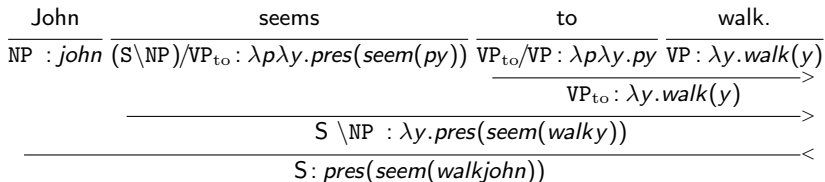


Subject-control

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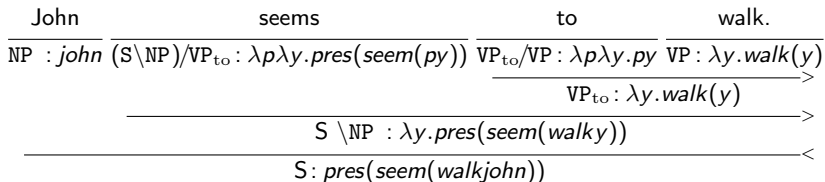
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try: $VP_{+a} / VP_{to} : \lambda p \lambda y. try(p y)y$

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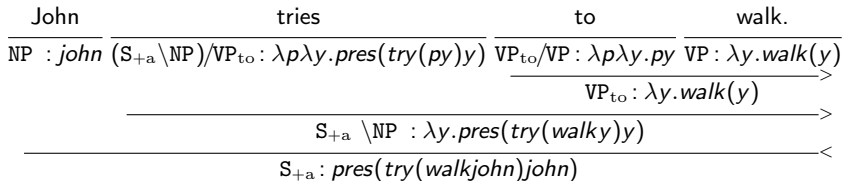
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IM via raising and control (cont.)

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- For subject-control, the variable has two roles, one inside of the predicate p and one outside of it, i.e. once as a subject controller and once as the controllee.
- Thus, the c -command relationship used for operator binding is here *only* established at If , which is why IM is effectively reduced to EM with additional If machinery.

Type-raising

Universal quantifiers and type-raising

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$$\frac{\frac{\text{Everything}}{\text{NP} : \textit{everything}} \quad \frac{\text{flows}}{\text{S} \backslash \text{NP} : \lambda y. \textit{pres}(\textit{flow} y)}}{\text{S} : \textit{pres}(\textit{flow} \textit{everything})} <$$

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$$\frac{\text{Everything} \quad \text{flows}}{\text{NP} : \textit{everything} \quad \text{S} \backslash \text{NP} : \lambda y. \textit{pres}(\textit{flow} \ y)} \leftarrow$$
$$\frac{}{\text{S} : \textit{pres}(\textit{flow} \ \textit{everything})}$$

$$\frac{\text{Everything} \quad \text{flows}}{\text{S}/(\text{S} \backslash \text{NP}) : \lambda p \forall y [\textit{thing} \ y \Rightarrow p y] \quad \text{S} \backslash \text{NP} : \lambda y. \textit{pres}(\textit{flow} \ y)} \rightarrow$$
$$\frac{}{\text{S} : \forall y [\textit{thing} \ y \Rightarrow \textit{pres}(\textit{flow} \ y)]}$$

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$$\begin{array}{c}
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 \text{Someone} & \text{sees} & \text{everything} \\
 \hline
 S/(S\backslash NP) & (S\backslash NP)/NP & (S\backslash NP)\backslash((S\backslash NP)/NP) \\
 : \lambda p.p(\text{some person}) & : \lambda x\lambda y.pres(\text{see } xy) & : \lambda p\lambda y.\forall x[\text{thing } x \Rightarrow p \ x \ y]
 \end{array} \\
 \hline
 \begin{array}{c}
 S\backslash NP : \lambda y.\forall x[\text{thing } x \Rightarrow pres(\text{see } xy)] \\
 \hline
 S : \forall x[pres(\text{see } x(\text{some person}))]
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Type-raising (cont.)

Type-raised generalized quantifier is the only way for universal quantifiers to take wide-scope without quantifier-raising.

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A	girl	held	every	chipmunk.
$(S/(S \setminus NP_{3s}))/N_{3s}$	N_{3s}	$(S \setminus NP_{agr})/NP$	$((S \setminus NP_{agr}) \setminus ((S \setminus NP_{agr})/NP))/N_{3s}$	N_{3s}
$: \lambda n \lambda p. p(a \ n)$	$: \mathbf{girl}$	$: \lambda x \lambda y. \mathit{past}(\mathit{hold} \ xy)$	$: \lambda n \lambda p \lambda y. \forall x [n \ x \rightarrow p \ x \ y]$	$: \mathit{chipmunk}$
$S/(S \setminus NP_{3s}) : \lambda p. p(a \ \mathit{girl})$			$(S \setminus NP_{agr}) \setminus ((S \setminus NP_{agr})/NP)$	
			$: \lambda p \lambda y. \forall x [\mathit{chipmunk} \ x \rightarrow p \ x \ y]$	
		$S \setminus NP_{agr} : \lambda y. \forall x [\mathit{chipmunk} \ x \rightarrow \mathit{past}(\mathit{hold} \ xy)]$		
		$S : \forall x [\mathit{chipmunk} \ x \rightarrow \mathit{past}(\mathit{hold} \ x(a \ \mathit{girl}))]$		

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- Raised arguments pass their values to the If by binding a second-order variable p , rather than the verb itself, similar to IM.
 - ▶ someone: $NP^\uparrow : \lambda p \lambda \hat{y}. p(\text{some person}) \hat{y}$
 - ▶ an: $NP^\uparrow / N : \lambda n \lambda p \lambda \hat{y}. p(a\ n) \hat{y}$
 - ▶ every: $NP^\uparrow / N : \lambda n \lambda p \lambda \hat{y}. \forall x (n\ x \rightarrow p\ x\ \hat{y})$

Type-raising for generalized quantifiers

- Type-raising changes nothing about the derivations except reverses the direction of function application.
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- Type-raising allows for scrambling word orders.
- Caveat: not a free combinatory rule to be used for syntactic derivations, only available as a morpho-lexical schema.

Type-Raising: Scrambling in Germanic

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 *Sara & gave & cake & her\ sister. \\
 \hline
 S/\diamond_*(S\backslash NP) & ((S\backslash NP)/NP)/NP & (S\backslash NP)\backslash\diamond_*(S\backslash NP)/NP & (S\backslash NP)\backslash\diamond_*(S\backslash NP)/NP \\
 \hline
 & & * < B_\times & \\
 & *** & &
 \end{array}$$

Scrambling in Germanic

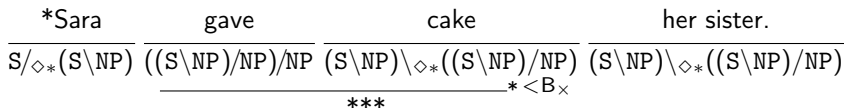
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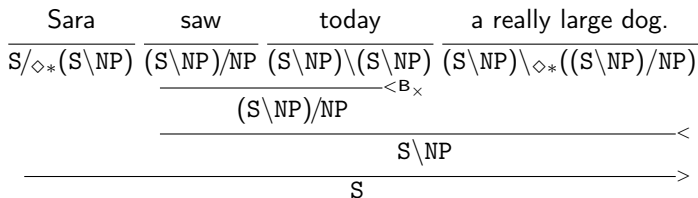
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German scrambling

Type-raising of arguments (morpho-lexical and order-preserving) can interact with function composition to derive scrambling effects in languages with freer word-order.

- (1) *Johann hat [auf dem Markt] [die Lebensmittel gekauft].*
Johann has at the market the groceries bought.

'Johann bought the groceries at the market.'

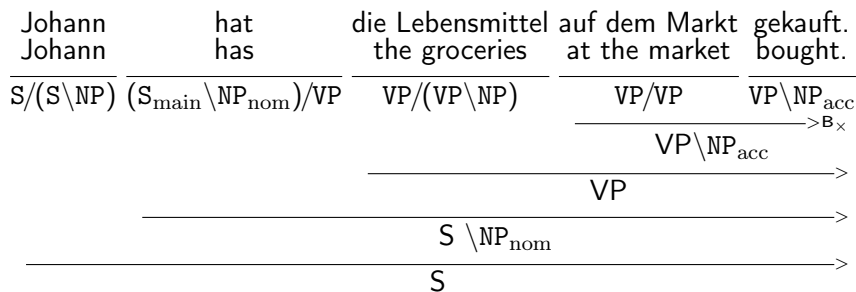
- (2) *Johann hat [die Lebensmittel] [auf dem Markt] gekauft.*
Johann has the groceries at the market bought.

'Johann bought the groceries at the market.'

- (3) **Johann [die Lebensmittel] hat [auf dem Markt] gekauft.*
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CCG and German scrambling



CCG and German scrambling (cont.)

*Johann	die Lebensmittel	hat	auf dem Markt	gekauft.
Johann	the groceries	has	at the market	bought.
$S/(S \setminus NP)$	$VP/(VP \setminus NP_{acc})$	$(S_{main} \setminus NP_{nom})/VP$	VP/VP	$VP \setminus NP_{acc}$
				$\rightarrow B_x$
			$VP \setminus NP_{acc}$	$\rightarrow B_x$
		$(S_{main} \setminus NP_{nom}) \setminus NP_{acc}$		$\rightarrow B_x$
		$***$		$*$

IM: Wh-Movement

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Topicalization:

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Topicalization:

$$\frac{\frac{\text{Books,}}{S_t/(S/NP) : \lambda p.p \text{ books}} \quad \frac{\text{she}}{S/(S \setminus NP_{3s}) : \lambda p.p \text{ her}} \quad \frac{\text{hates.}}{(S \setminus NP_{3s})/NP : \lambda x \lambda y. \text{pres}(\text{hate } x \ y)}}{S/NP : \lambda x. \text{pres}(\text{hate } x \ \text{her})} \rightarrow B}{S_t : \text{pres}(\text{hate books her})} \rightarrow$$

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$: \lambda p \lambda wh.p \ wh$	$: \lambda y \lambda p.pres(p \ y)$	$: \lambda p.p \ her$	$: \lambda x \lambda y.hate \ x \ y$
	$S_{inv}/VP : \lambda p.pres(p \ her)$		
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- Its syntactic category is specified as at the left edge of the sentence.
- Its argument is thus passed into the wh -item as p .

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- Probes, goals, valuations, feature deletion, and visibility conditions can all be eliminated.

References

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