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What's the syntax behind syntactic priming?

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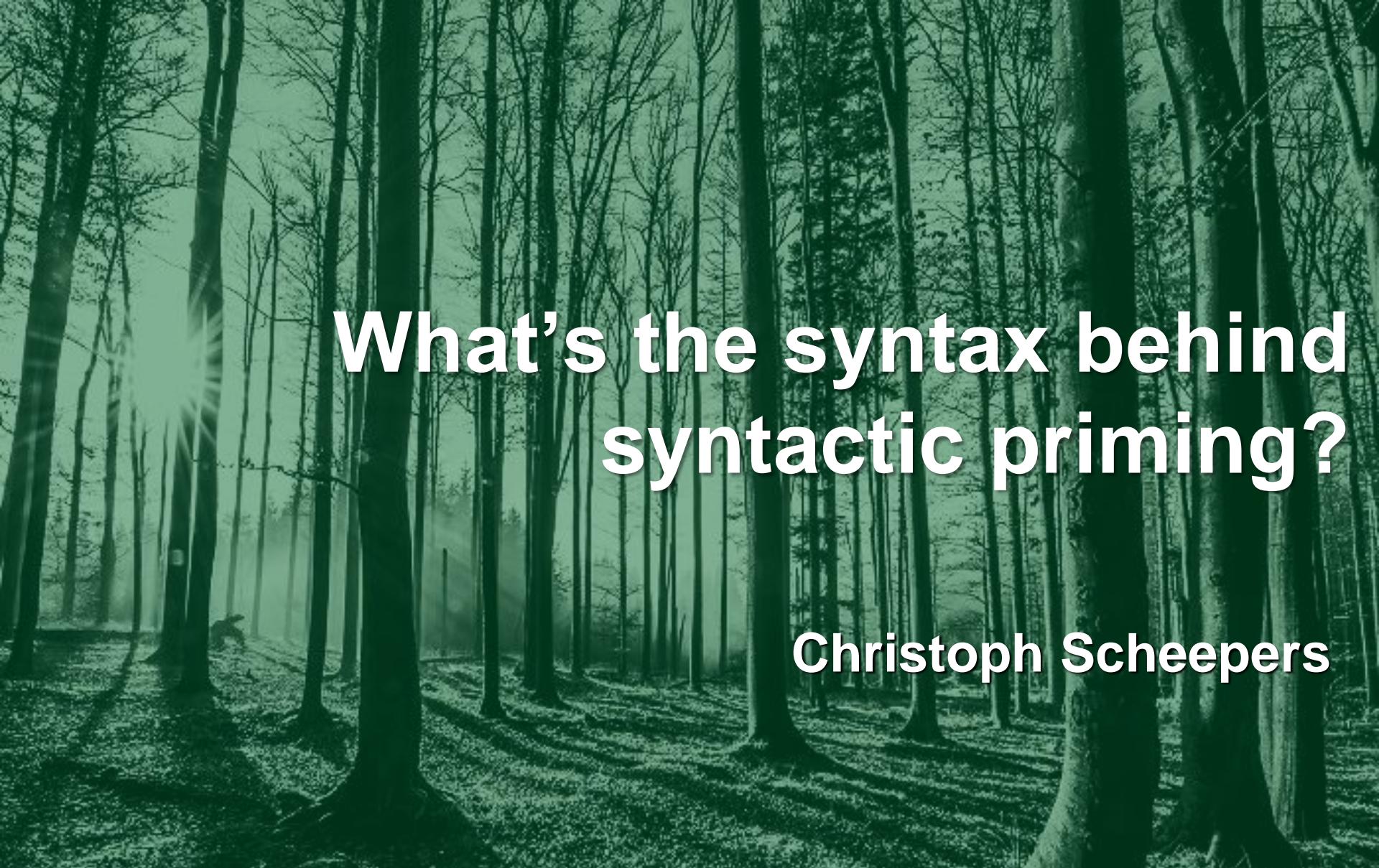
Some of the authors of this publication are also working on these related projects:



Attachment ambiguities [View project](#)



Relative Clause Attachment in Direct vs. Indirect Speech [View project](#)



What's the syntax behind syntactic priming?

Christoph Scheepers

Introduction

Syntactic Priming

- Facilitation of linguistic processing when structures are repeated
 - Producers unknowingly re-generate structures they have produced or understood before
 - Comprehenders find structures easier to process when they are similar to previously encountered ones
- Typically measured in experiments where participants are encouraged to produce a particular structure in one trial (**prime**) and are free to produce the same or an alternative structure in a following trial (**target**)
- Useful **implicit** method for investigating the kinds of abstract structural representations activated during language use (cf. Pickering & Branigan, 1999; Branigan & Pickering, 2017)
 - *If processing of a stimulus A is affected by prior processing of B to a greater extent than by prior processing of C, then the representation underlying A is more similar to the representation underlying B than it is to the representation underlying C.*

Syntactic Priming

- In **production**, syntactic priming is well documented for a range of structural alternations, e.g.

- **Ditransitive Structure Priming (PO/DO)**

(e.g. Bock, 1986; Pickering & Branigan, 1998; etc. etc.)

- *Peter read the girl a book* (prime) > *Mary gave the dog a bone* (target)
- *Peter read a book to the girl* (prime) > *Mary gave a bone to the dog* (target)

- **Transitive Structure Priming (Active/Passive)**

(e.g. Bock, 1986; Bock & Loebell, 1990; etc. etc.)

- *The boss fired the employee* (prime) > *Lightning strikes the house* (target)
- *The employee was fired by the boss* (prime) > *The house is struck by lightning* (target)

- **N-modifier priming (Adjective/Relative Clause)**

(e.g. Cleland & Pickering, 2003)

- *The green circle* (prime) > *The red sheep* (target)
- *The circle that's green* (prime) > *The sheep that's red* (target)

Syntactic Priming

- As I will argue, most of these structural priming phenomena involve lexical choices of some sort

- Ditransitive Structure Priming (PO/DO)**

- Choice between two alternative **verb frames**
 - PO: [_{VP} [_V *give*] [_{NP} *the book*] [_{PP} *to the man*]]
 - DO: [_{VP} [_V *give*] [_{NP} *the man*] [_{NP} *the book*]]

- Active/Passive Priming**

- Choice between transitive (active) versus intransitive (passive) **verb frame**
- **inclusion of by-PP**

- N-modifier priming**

- Choice between **different lexical items** for modification
- Adjective: [_{NP} *the* [_{N'} [_{Adj} *red*] [_N *sheep*]]])
- Relative pronoun: [_{NP} [_{NP} *the* [_N *sheep*]]] [_{RC} [_{RelPro} *that*] [_{S'} *is red*]]])

Syntactic Priming

- As I will argue, most of these structural priming phenomena involve lexical choices of some sort

- Ditransitive Structure Priming (PO/DO)**

- Choice between two alternative **verb frames**
 - PO: [VP [V give] [NP the book] [PP to the man]]
 - DO: [VP [V give] [NP the man] [NP the book]]

- Active/Passive Priming**

- Choice between transitive (active) versus intransitive (passive) structures
- **inclusion of by-PP**

- N-modifier priming**

- Choice between **different lexical items** for modification
 - Adjective: [NP the [N' [Adj red] [N sheep]]])
 - Relative pronoun: [NP [NP the [N sheep]] [RC [RelPro that] [S' is red]]])

Note:

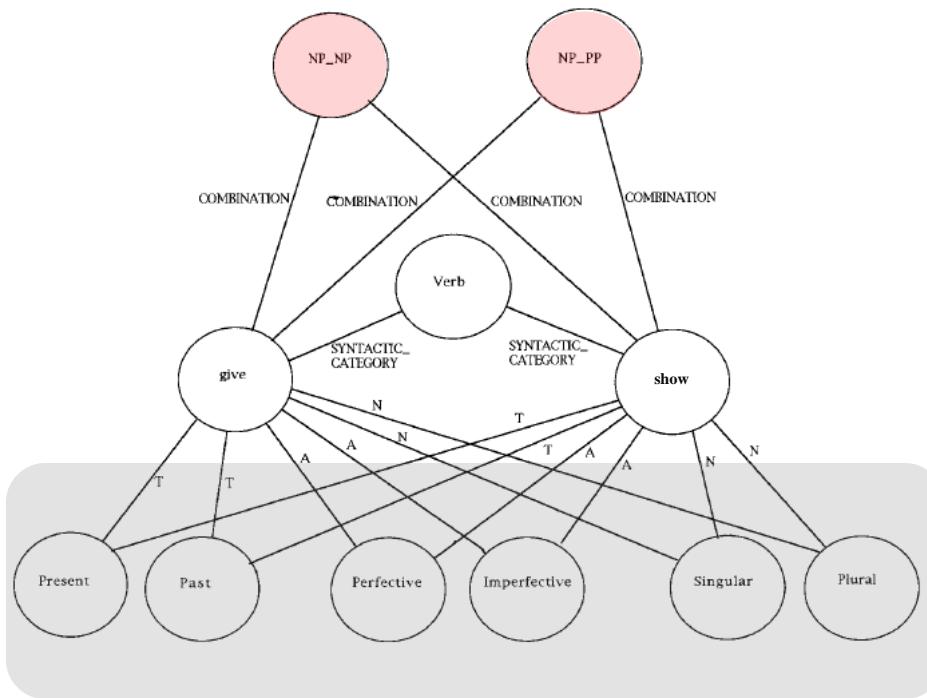
In Mahowald et al., (2016)'s meta analysis of syntactic priming, around **85%** of the included studies were on PO/DO and active/passive priming!

Pickering & Branigan (1998)

- Very influential paper (986 citations, Google Scholar)
- One of the first to make specific suggestions about syntactic representations involved in structural priming
- Based on evidence from sentence completion studies on ditransitive structure priming (“PO/DO”).
- Main findings:
 - Structure of prime completion (e.g., *The racing driver gave the overall to the mechanic [PO]* vs. *The racing driver gave the mechanic the overall [DO]*) makes either PO or DO completions more likely in subsequent target trials (e.g., *The patient showed ...*)
 - Structural priming is enhanced when prime and target share the same verb (e.g., “*showed*” in both cases) – **lexical boost**
 - (Non-)repetition of verb-related features such as *tense, aspect, or number* are irrelevant for PO/DO priming

Pickering & Branigan (1998)

- Spreading activation architecture inspired by Roelofs (1992, 1993)
- Verb-lemma nodes (“give”, “show”, etc.) link to **combinatorial nodes** that are shared between verbs of the same subcategory
 - Verb can either be followed by a NP and another NP (DO) or by a NP and a PP (PO)
- Used to explain both abstract and lexically boosted priming of ditransitive structures, e.g.
 - After producing ..**gave** the mechanic the overall (prime), residual activation from the **NP_NP** node makes it easier to produce a DO sentence using **show** in the target
 - After producing ..**showed** the mechanic the overall (prime), residual activation from both the **NP_NP** node and its **link to the show node** primes subsequent DO production using **show** even further (lexical boost)
- “Weak” lexicalization of syntactic information



Pickering & Branigan (1998)

- What do combinatorial nodes actually represent?
- Pickering & Branigan (1998ff.) entertain the possibility that these nodes encode information akin to context-free phrase structure rules, e.g.

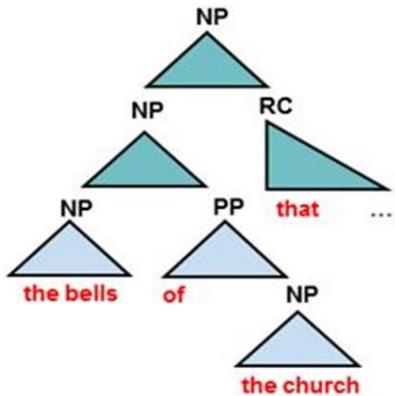
```
VP → V , NP , PP      [PO]  
VP → V , NP , NP      [DO]
```

- Immediate (local) dominance relations
- Linear precedence of verb arguments

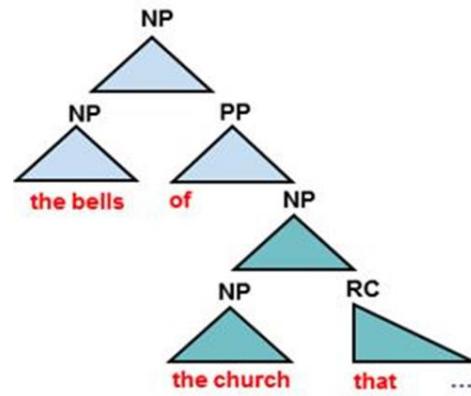
Relative Clause Attachment

*The tourist guide mentioned **the bells of the church that...***

'high' attachment



'low' attachment

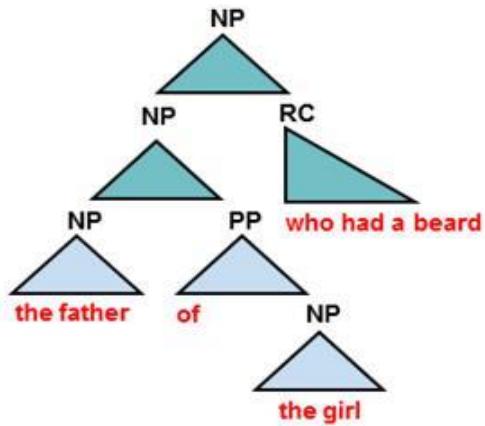


Concerns the **hierarchical configuration** of constituents
in **recursively** generated structure that is unlikely to be **pre-stored**

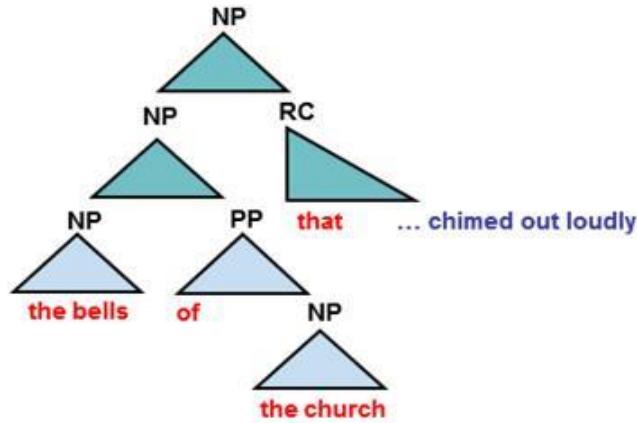
Relative clause attachment priming

(e.g., Scheepers, 2003; Desmet & Declerq, 2006)

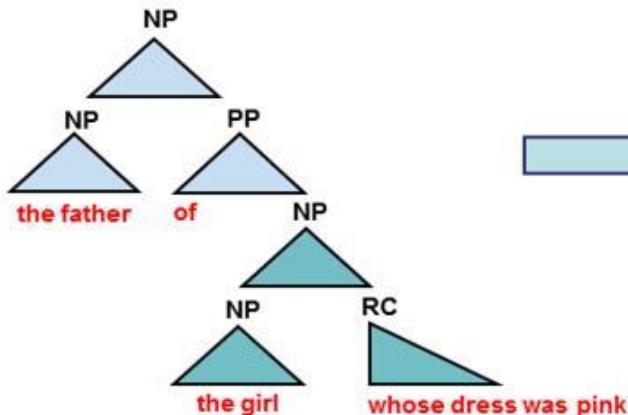
HA Prime



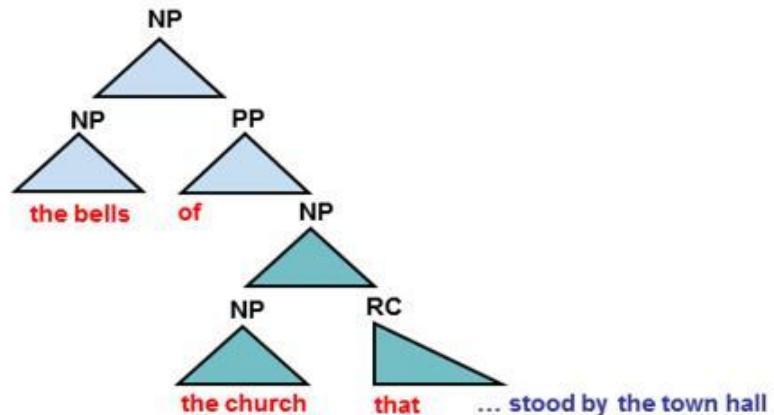
HA Target more likely



LA Prime



LA Target more likely



Implications of RC-Attachment Priming

Persistence of (global) hierarchical configuration information

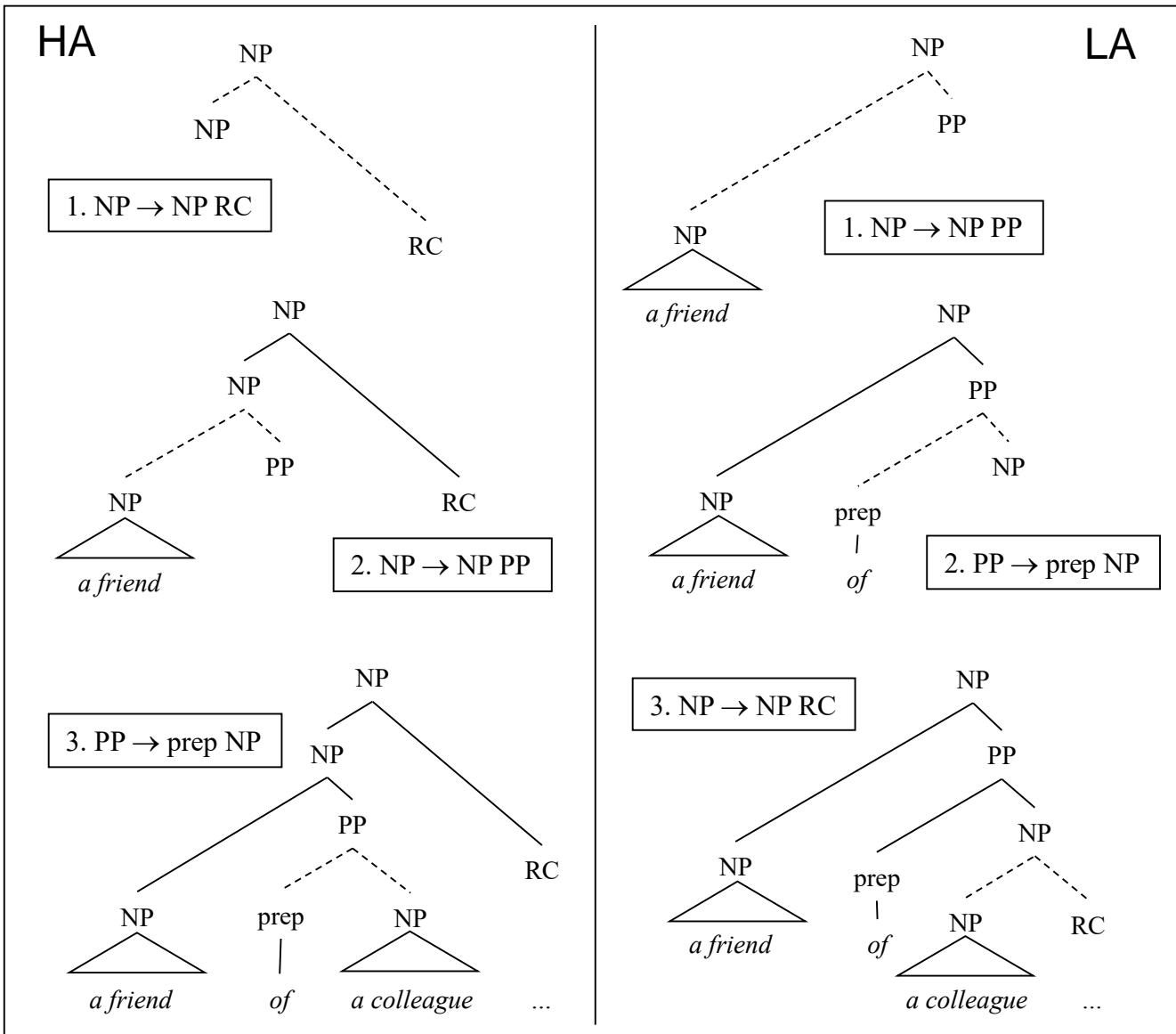
- Not related to:

- Subcategorization (verb frames etc.)
- Alternations of constituent order
- Lexical choices
- Use of specific context free rules:

$$\begin{array}{l} \text{NP} \rightarrow \text{Det , N} \\ \text{NP} \rightarrow \text{NP , PP} \\ \text{NP} \rightarrow \text{NP , RC} \\ \text{PP} \rightarrow \text{Prep , NP} \\ \text{RC} \rightarrow \text{RelPro , S'} \end{array}$$

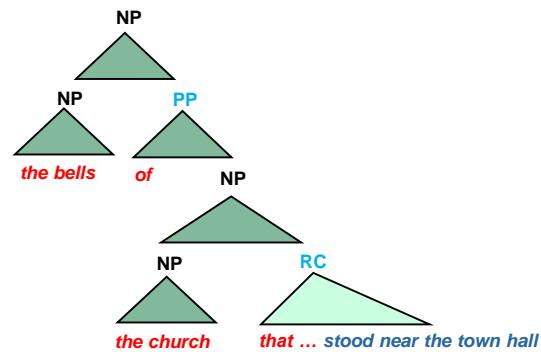
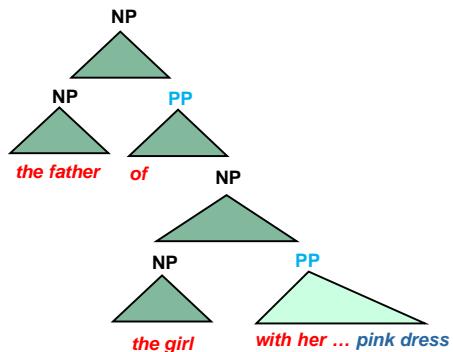
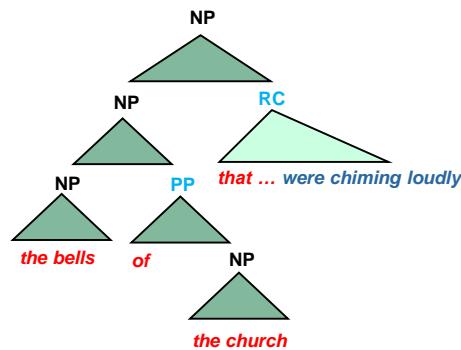
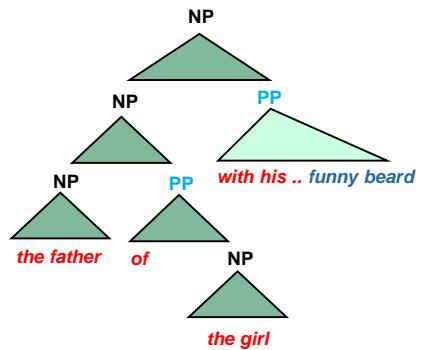
Rule sequences

(Scheepers, 2003)



Cross-structural priming (PP > RC)

Loncke, Van Laere, & Desmet (2011)



NP → NP , PP ($\times 2$)

NP → NP , PP
NP → NP , RC

Cross-structural priming (Saxon Genitives > RC)

Scheepers (AMLaP 2006... I'm getting old...)

HA Primes:

The knights justed for the daughter of the King's ____.
(... *hand in marriage*)

LA Primes:

The knights justed for the hand of the King's ____.
(... *beautiful daughter*)

BL Primes:

The knights justed for the daughter of the King during ____.
(... *the tournament*)

Targets:

The tourist guide mentioned the bells of the church that ____.

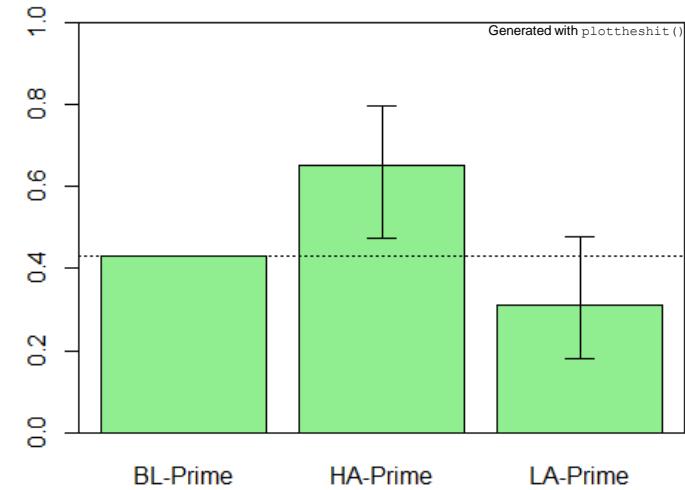
Cross-structural priming (Saxon Genitives > RC)

- Interesting to note:
 - Saxon Genitives not only imply very different rule sequences compared to RC(or PP)-modified NPs, but also different head-modifier relations
 - Consequences for interpretation:
 - *He insulted the friend of the colleague who lived next door.*
 - *He insulted the friend of the colleague from next door.*
- vs.
- *He insulted [the friend of the colleague]'s neighbour.*
 - *He insulted the friend of [the colleague]'s neighbour.*

Cross-structural priming (Saxon Genitives > RC)

Scheepers (AMLaP 2006... I'm getting old...)

HA Target-Completion Probabilities



HA Primes:

The knights jousted for **the daughter of the King's** ____.
(... *hand in marriage*)

LA Primes:

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(... *beautiful daughter*)

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The knights jousted for the daughter of the King during ____.
(... *the tournament*)

Targets:

The tourist guide mentioned the bells of the church that ____.



Bottom line

- Scrap the idea of (sequencing of) context free rules being at the heart of RC-attachment priming!

Lexicalized Tree Adjoining Grammar (LTAG)

E.g., Joshi, Levy, & Takahashi (1975); Joshi (1985); Joshi & Schabes (1997), Ferreira, 2000; Ferreira, Lau, & Bailey, 2004; Mazzai, Lombardo, & Sturt (2007)

- The primary difference between a (L)TAG and a standard CFG is that it consists of *elementary syntactic trees* rather than symbols as rewriting units
 - **Initial trees** minimal non-recursive structures describing simple sentences, NPs, PPs, etc.
 - **Auxiliary trees** minimal recursive structures used for adjunction
- **Extended domain of locality:** The full argument projection of a lexical item can be represented by a single elementary tree (domain of locality is thus larger than in a CFG)
- “*Complicate locally, simplify globally*” (Bangalore & Joshi, 2010)

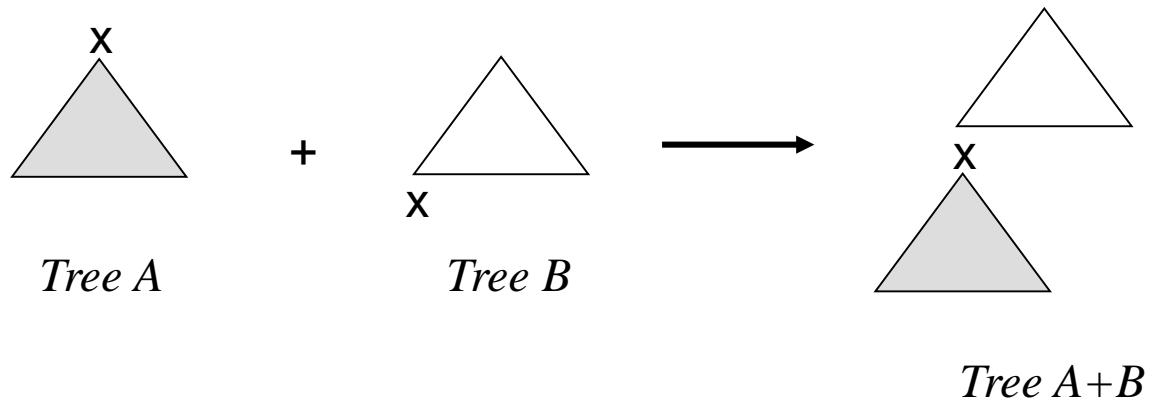
Lexicalized Tree Adjoining Grammar (LTAG)

E.g., Jo
Ferreira

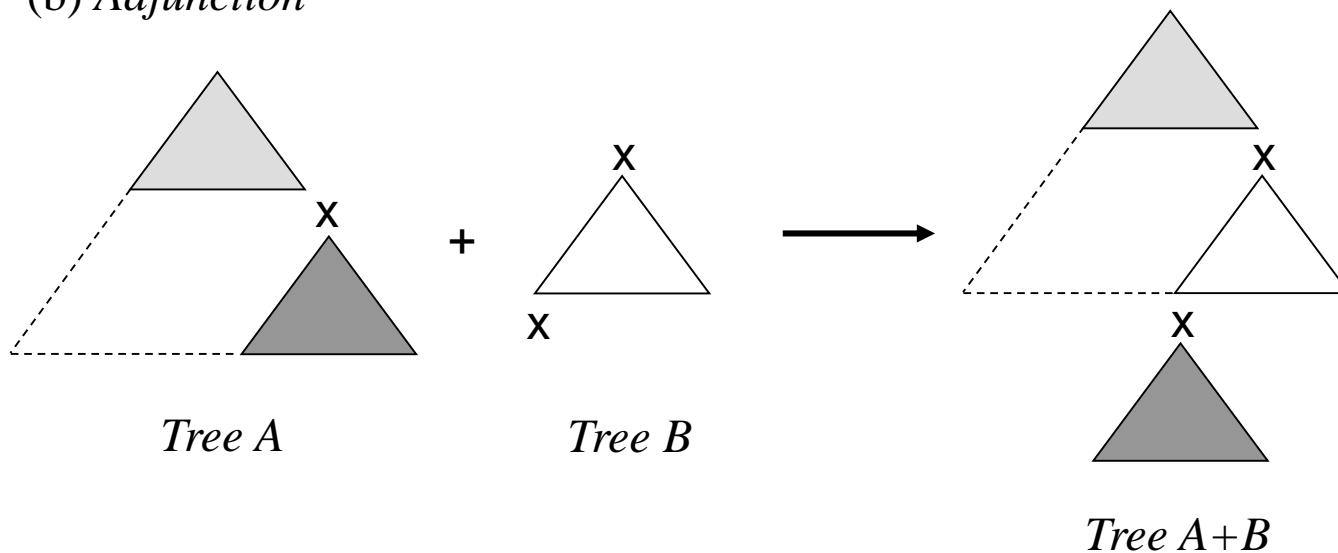
- Conceptually **very similar** to other lexicalist formalisms, e.g.
- Theoretical framework:
 - Combinatory Categorial Grammar (CCG, e.g. Steedman, 1987; 1993; 1996; 1998)
 - Head-driven Phrase Structure Grammar (HPSG, e.g. Pollard & Sag, 1987)
 - Other unification-based accounts (e.g., Kempen & Hoekamp, 1987; de Smedt & Kempen, 1991)
- Examples:
 - of tree adjoinings
 - tree (combinatory category, to the larger grammar)
- “*Complicate locally, simplify globally*” (Bangalore & Joshi, 2010)

Lexicalized Tree Adjoining Grammar (LTAG)

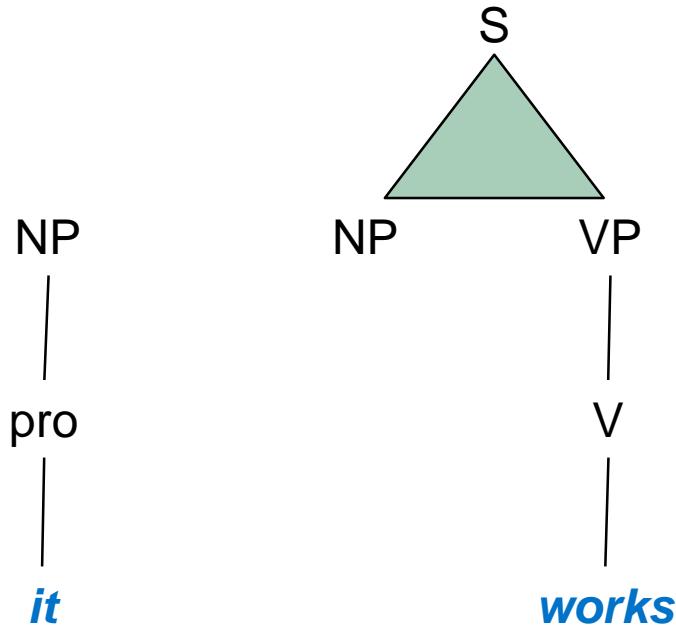
(a) *Substitution*



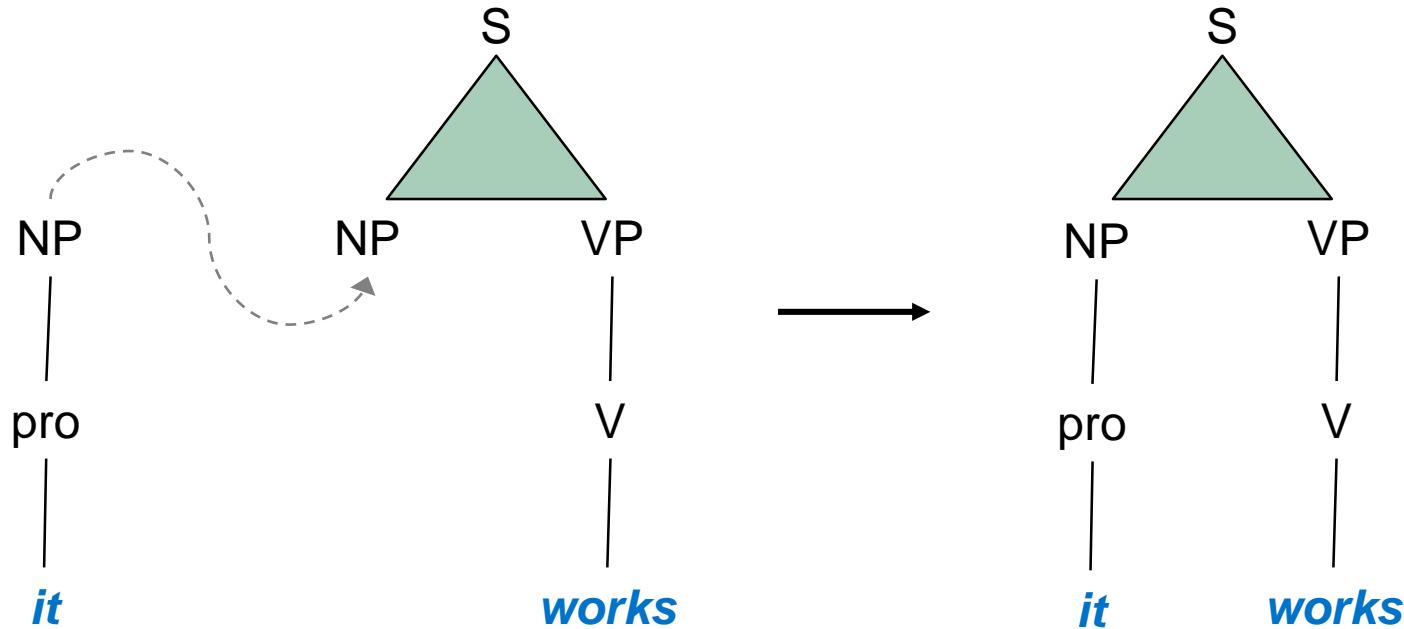
(b) *Adjunction*



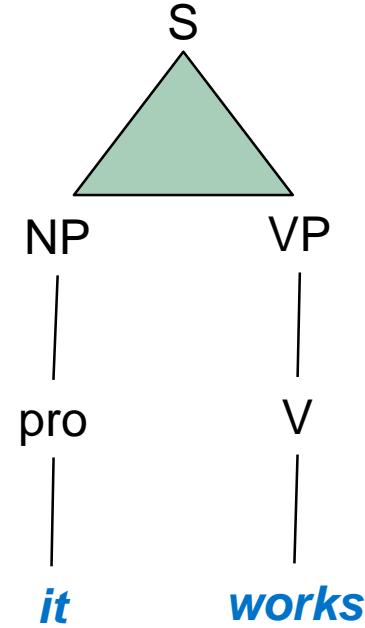
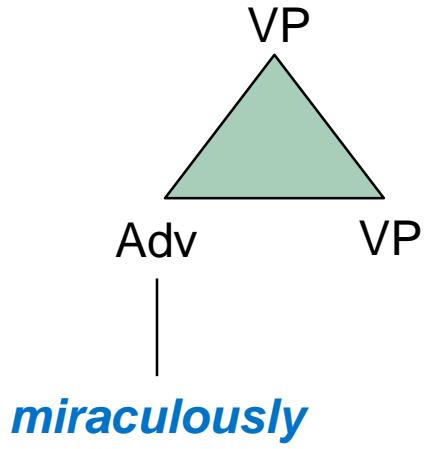
Lexicalized Tree Adjoining Grammar (LTAG)



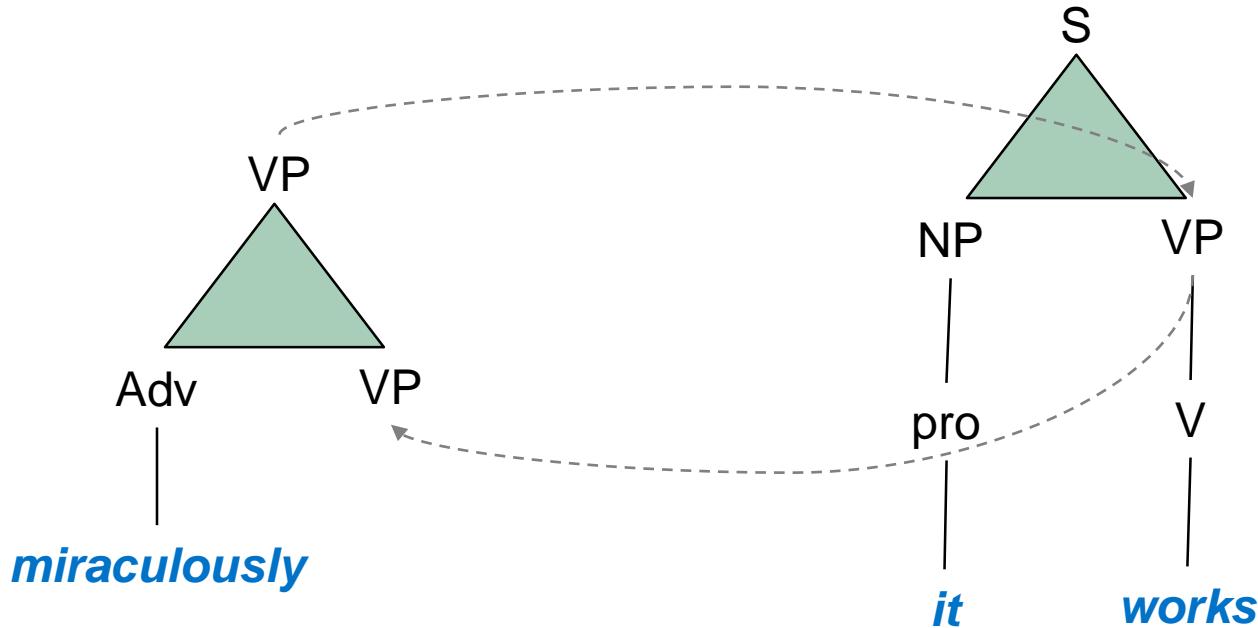
Lexicalized Tree Adjoining Grammar (LTAG)



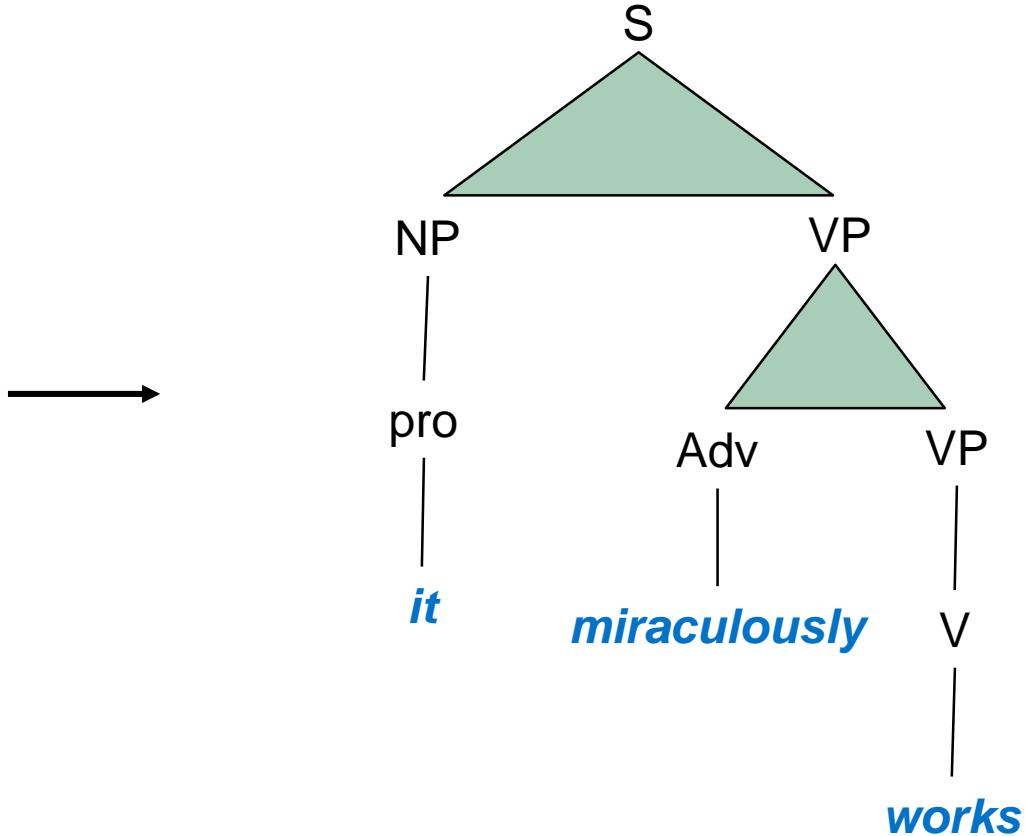
Lexicalized Tree Adjoining Grammar (LTAG)



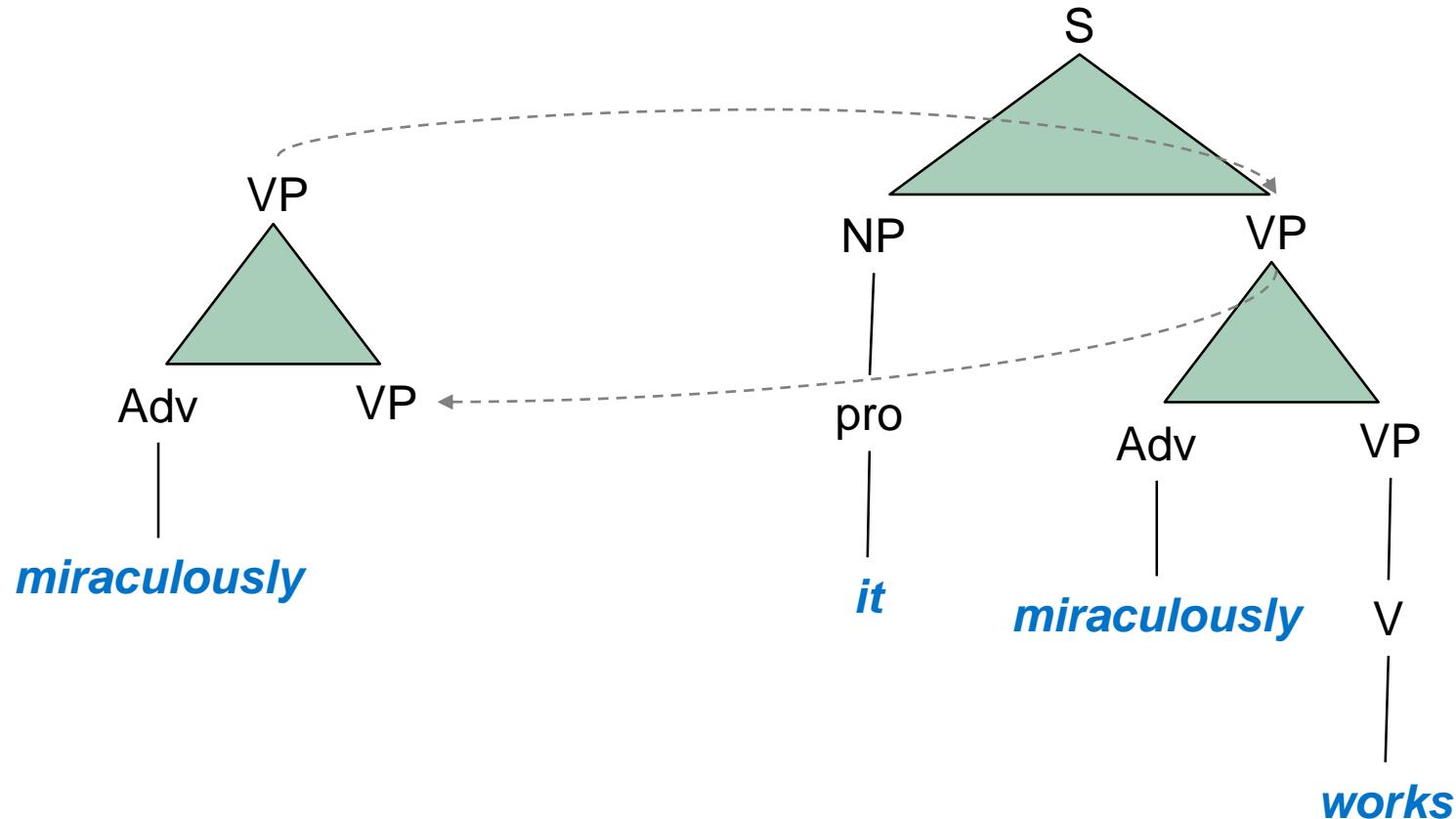
Lexicalized Tree Adjoining Grammar (LTAG)



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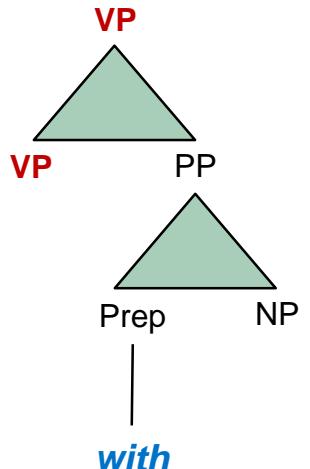


Lexicalized Tree Adjoining Grammar (LTAG)



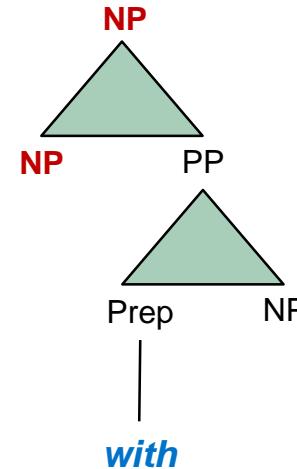
Lexicalized Tree Adjoining Grammar (LTAG)

- **Extended domain of locality** also implies that one needs different lexical entries for different *uses* of the same word, e.g.:
 - “with” used to modify VP or NP, as in
 - *They grilled the politician with tricky questions about a no-deal Brexit.*
 - *They grilled the politician with the deliberately messy blond hair.*
 - Requires an auxiliary tree for (VP-modifying) *instrumental* “with” and a separate auxiliary tree for (NP-modifying) *attributive* “with”



instrumental

vs.



attributive

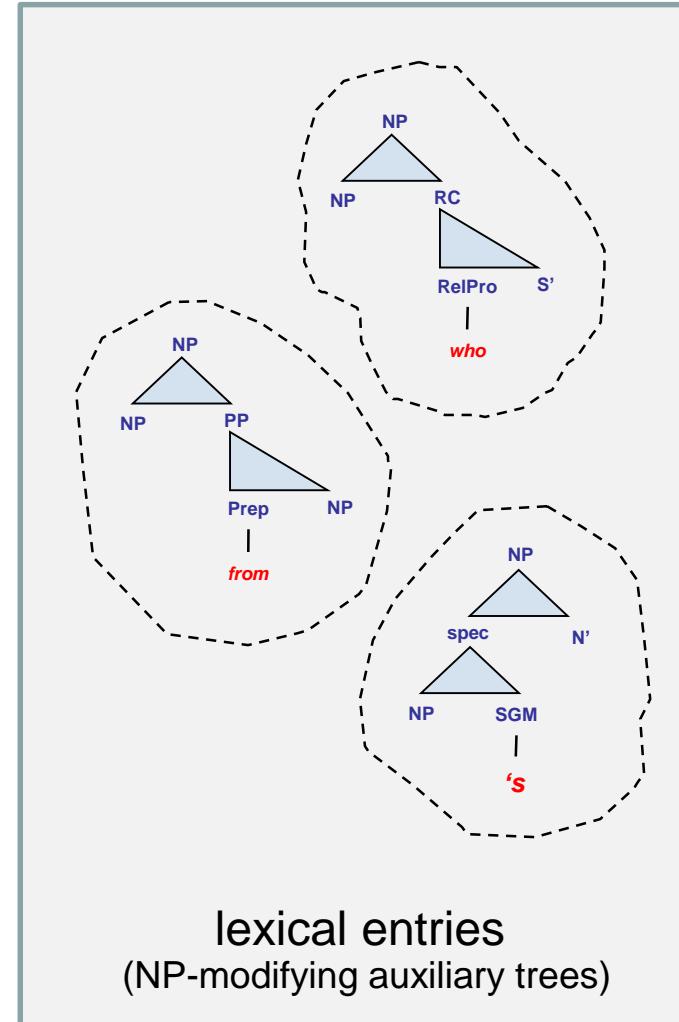
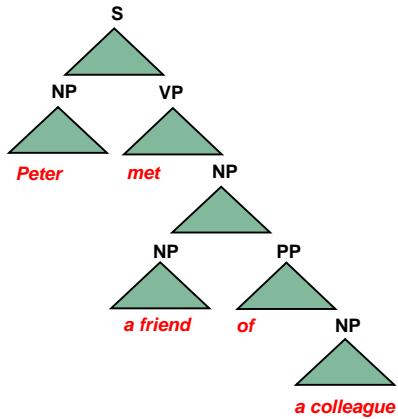
RC-attachment priming

- Using a framework such as LTAG allows for a relatively simple, general explanation of the previously described sentence completion results surrounding priming of RC-attachments
- Assumptions:
 - Sentence completion involves both comprehension (of a sentence fragment) and production (of a sentence continuation)
 - The local details of the critical auxiliary tree for adjunction do not matter (and nor does the associated ‘semantics’)
 - RC-attachment priming mainly just involves the hierarchical positioning of the adjoined auxiliary tree.

RC-attachment priming

Fragment:

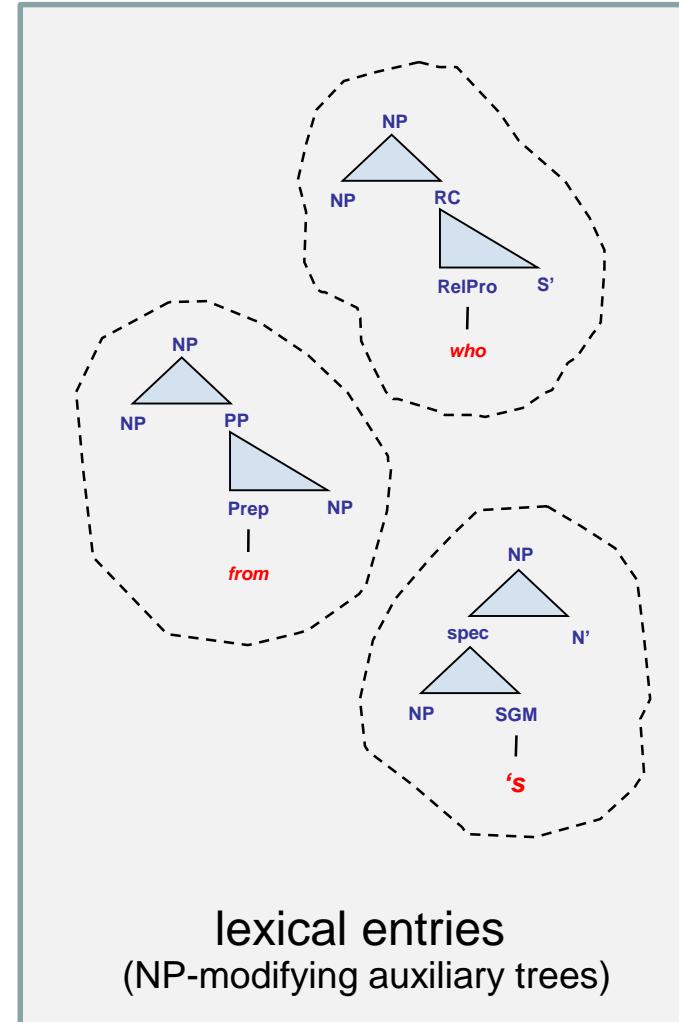
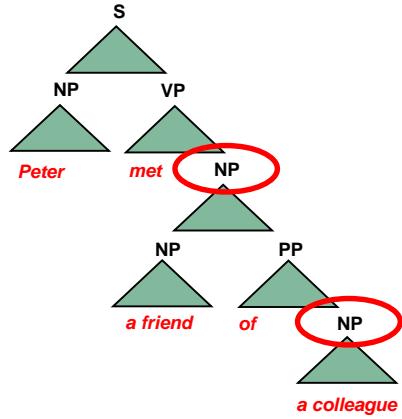
Peter met a friend of a colleague {**who** / **from** / '**s**}



RC-attachment priming

Fragment:

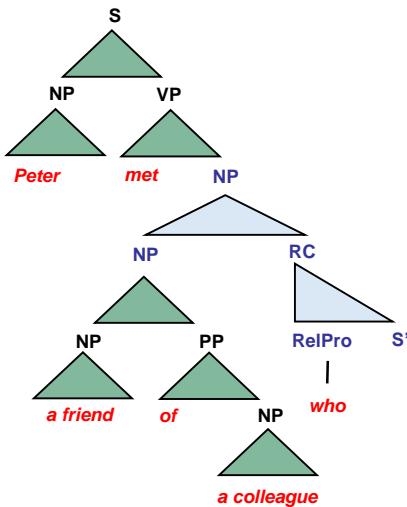
Peter met a friend of a colleague {**who** / **from** / '**s**}



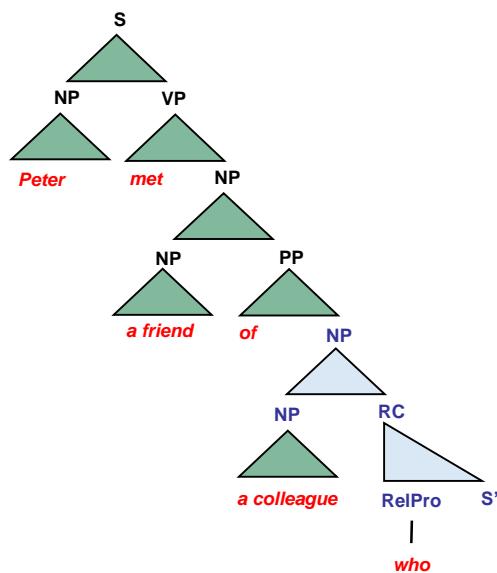
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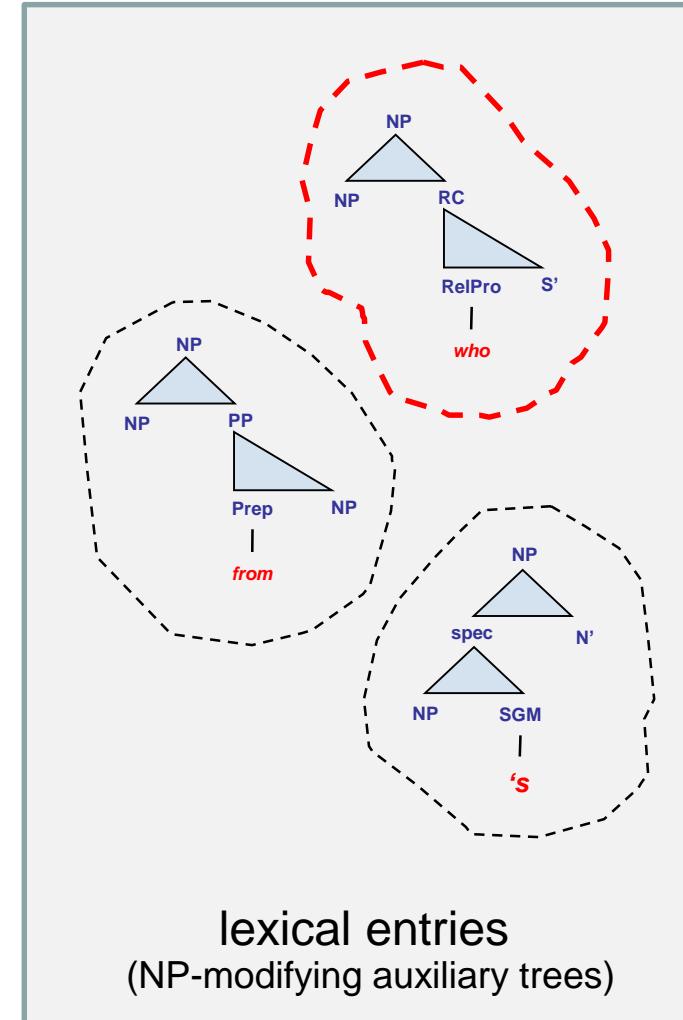
Peter met a friend of a colleague {**who** / **from** / '**s**}



'high'



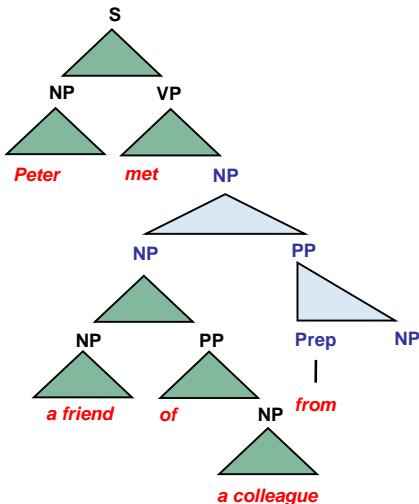
'low'



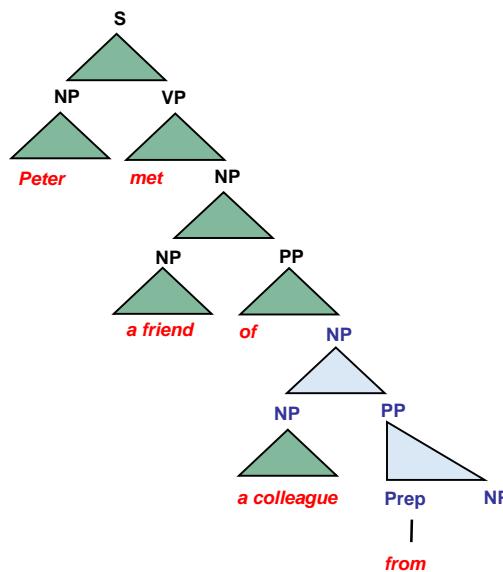
RC-attachment priming

Fragment:

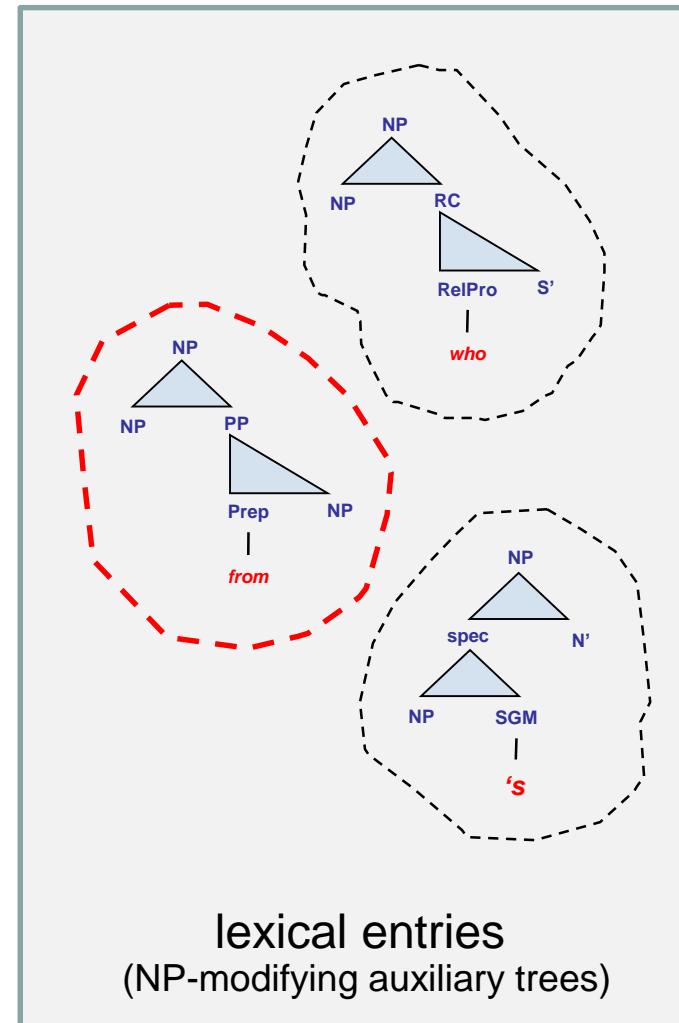
Peter met a friend of a colleague {**who** / **from** / '**s**}



'high'



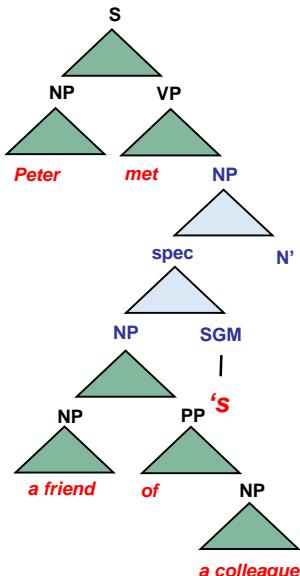
'low'



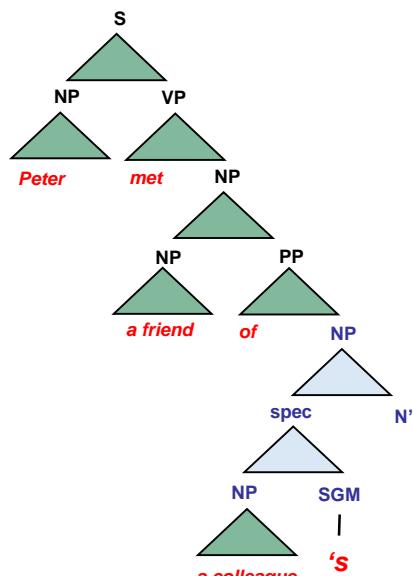
RC-attachment priming

Fragment:

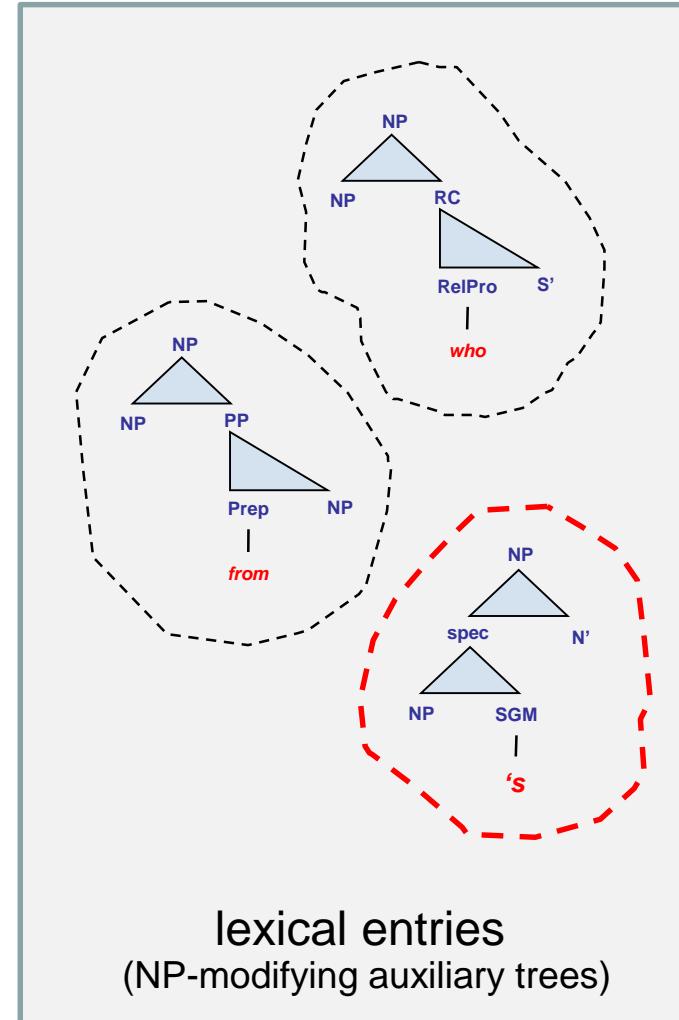
Peter met a friend of a colleague {**who** / **from** / '**s**}



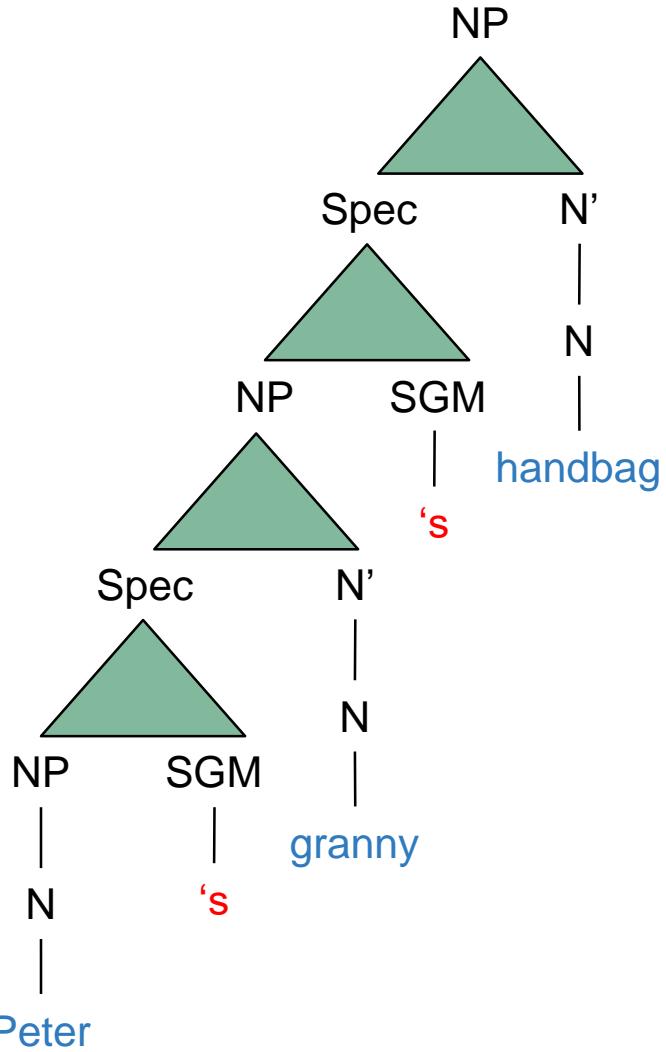
'high'



'low'

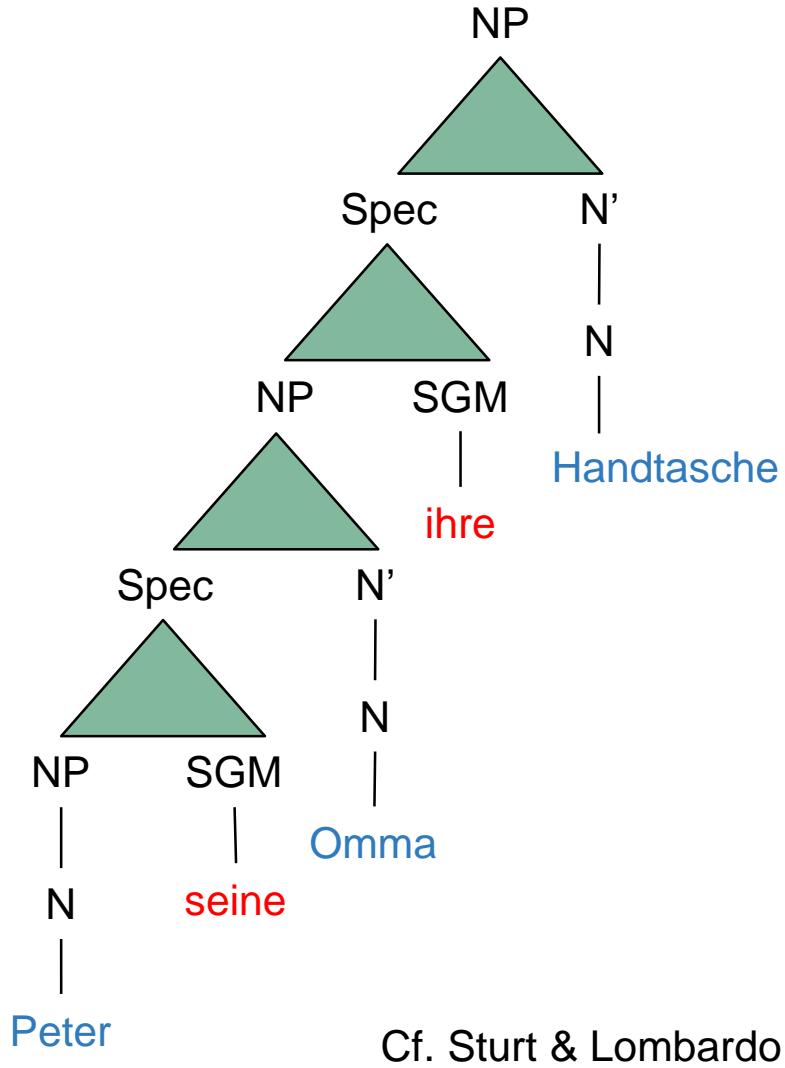
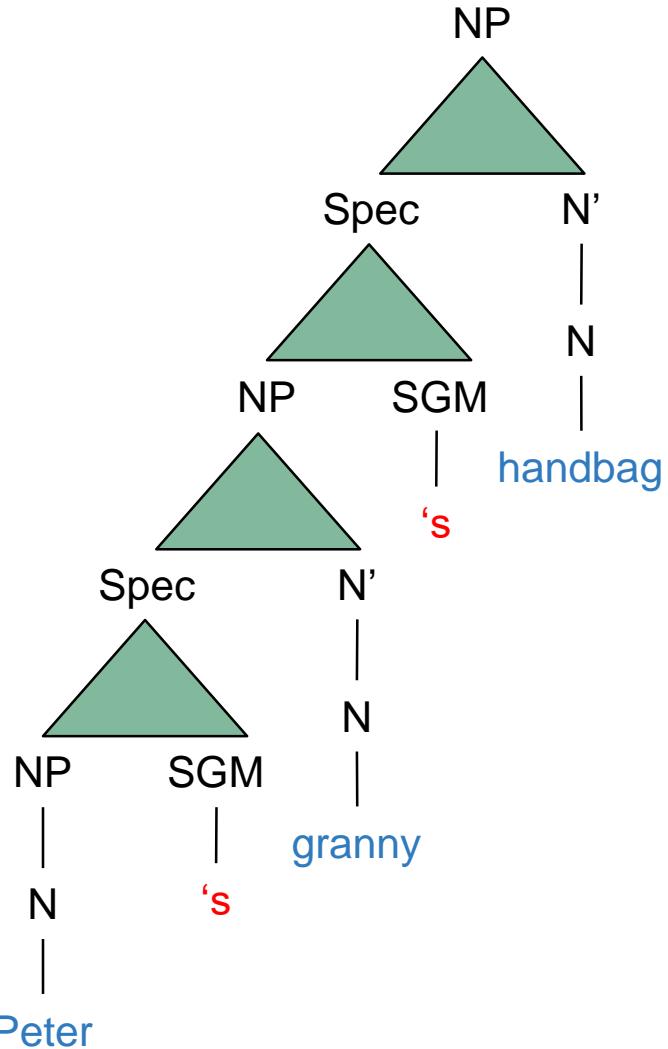


Interlude: Saxon Genitive [‘s]



Cf. Sturt & Lombardo (1997)

Interlude: Saxon Genitive [‘s]



Cf. Sturt & Lombardo (1997)

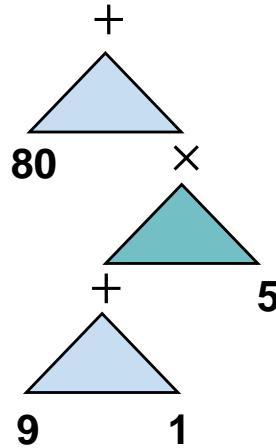
RC-attachment priming

- What matters for RC-attachment priming is really just the hierarchical positioning ('high' vs. 'low') for adjunction of the final element (*who* / *from* / 's) into the preceding tree representation
- Internal details of the adjoined aux. tree are irrelevant for high- vs. low-attachment priming
 - Cf. *cross-structural* priming effects
- However, such details (combined with the attachment decision) constrain further planning of the sentence continuation
 - E.g., adjoining the preposition "from" *high* means you're likely to continue with an NP that says something about where the *visitor* was from in (e.g.) *the visitor of the colleague from outer space*

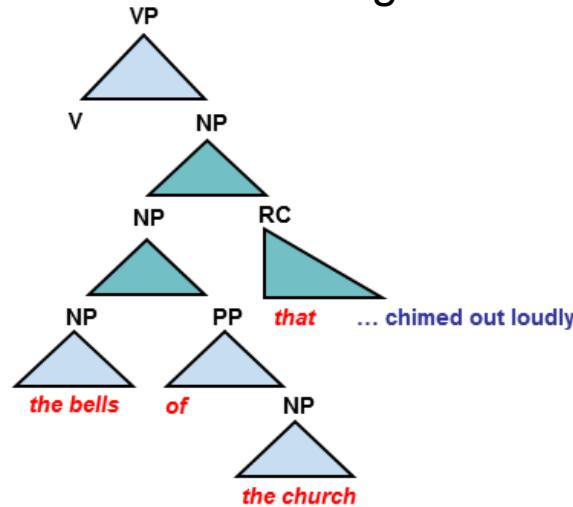
“Cross-domain” priming of RC-attachments

(e.g., Scheepers et al., 2011; Van de Cavey & Hartsuiker, 2016; Pozniak et al., 2018; Scheepers et al., 2019)

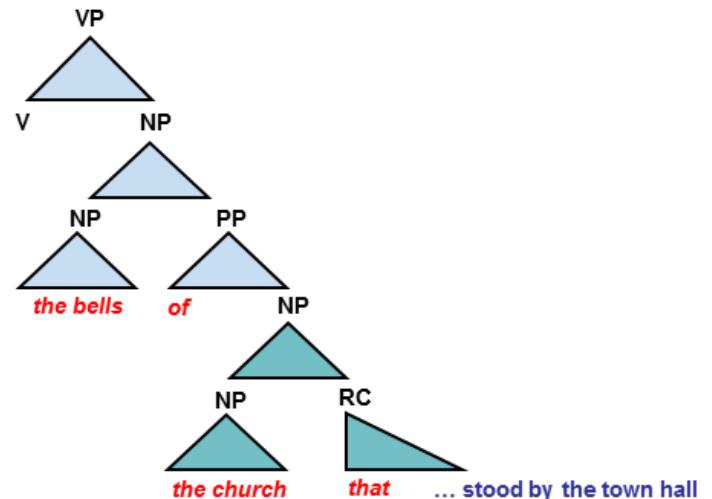
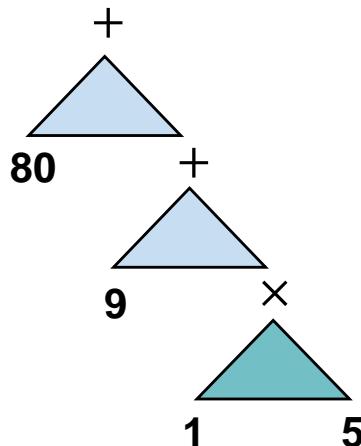
HA Prime: $80 + (9 + 1) \times 5$



Linguistic Targets

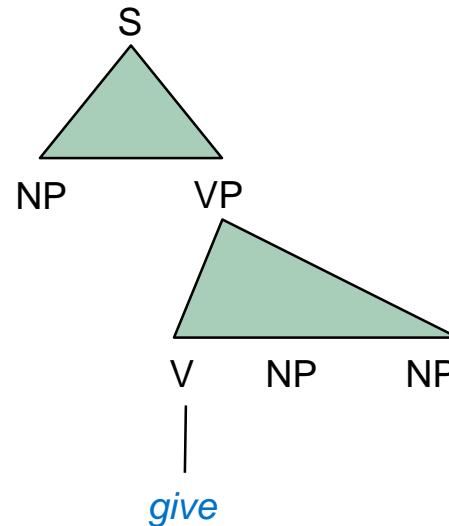
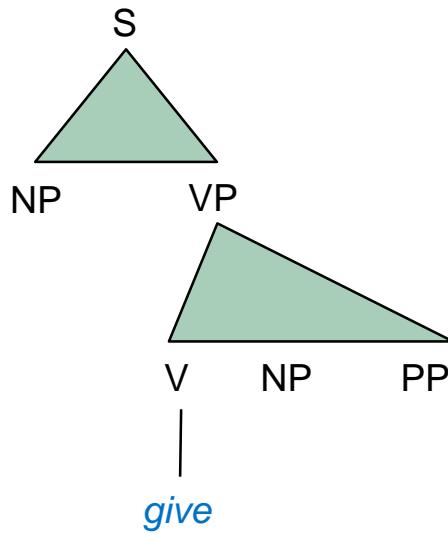


LA Prime: $80 + 9 + 1 \times 5$



Ditrans (PO/DO) priming

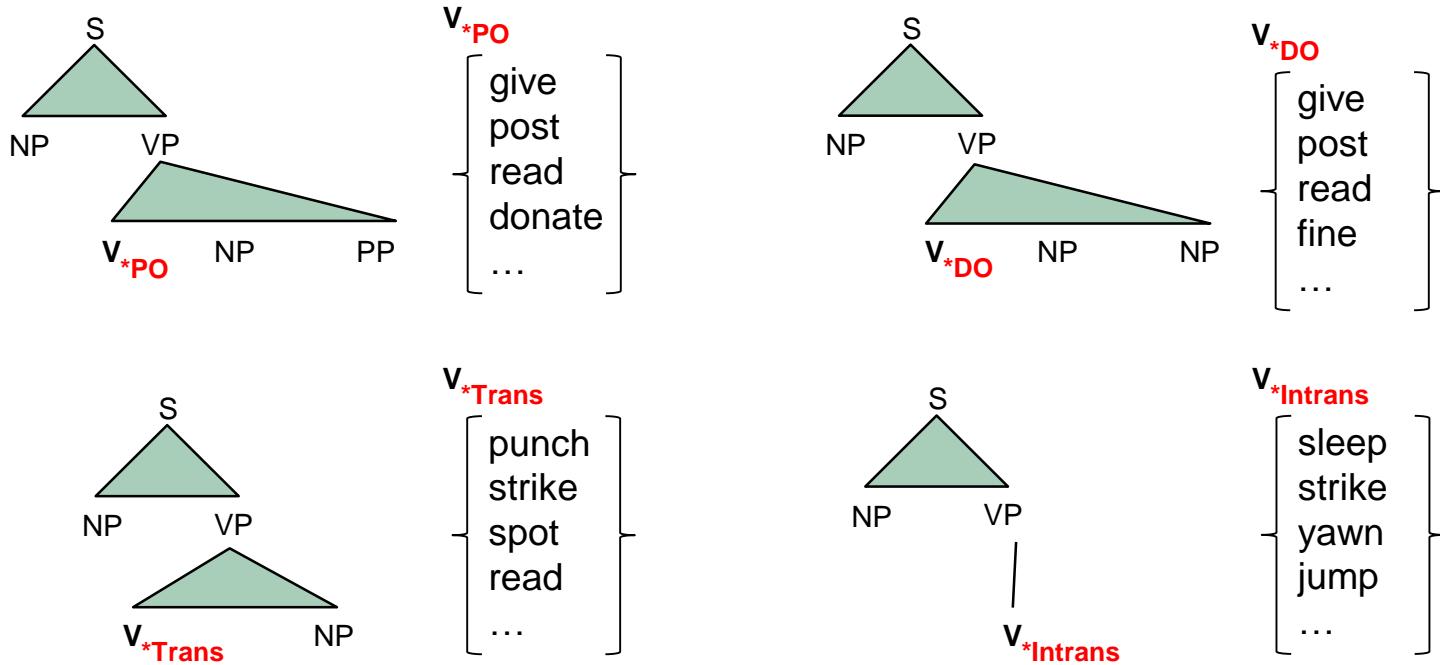
- In LTAG, generation of either PO (*He gave the bone to the dog*) or DO (*He gave the dog the bone*) requires **choosing between different** (non-recursive) **initial trees**, here for the verb “give”



- Note that, just like CFG rules, LTAG trees not only specify the *types* of arguments required, but also their linear sequencing
- Extended domain of locality: LTAG trees ‘project maximally’
- Potential problem of *strong lexicalization* assumption in LTAG
 - Cannot straightforwardly explain “abstract” priming (without verb repetition)

Ditrans (PO/DO) priming

- LTAG allows for ***type abstraction*** of elementary trees into lexically ‘unanchored’ trees (generalized *tree families*) representing (e.g.) realisations of different subcategorization frames (see, e.g., Kallmeyer & Oswald, 2013).



- Abstract priming may reflect re-use of such ‘unanchored’ initial trees

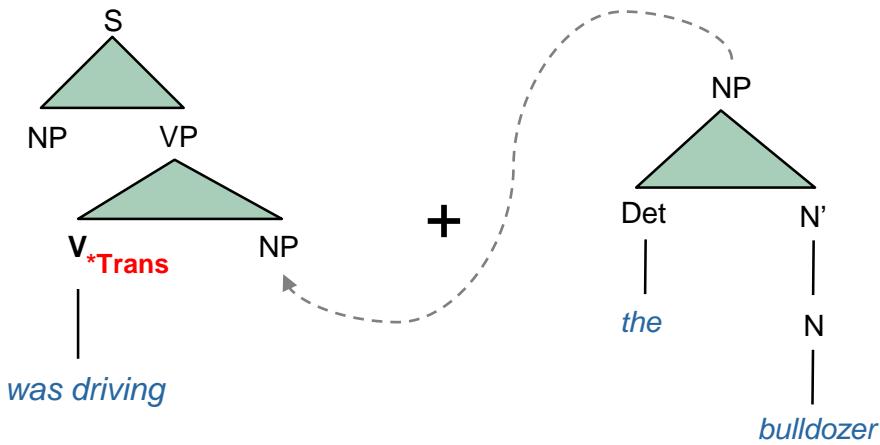
Active / passive priming

- Few concrete suggestions in the literature as to what syntactic priming of active/passive structures actually entails
 - Does **not** seem to involve thematic role assignments or ‘deep structure’ relations (e.g., Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Messenger et al., 2012)
- One potentially important clue (Bock & Loebell, 1990):
 1. ***The construction worker was driving the bulldozer.***
 2. ***The construction worker was hit by the bulldozer.***
 3. ***The construction worker was digging by the bulldozer.***

=> 2. and 3. prime passives (e.g., ***the house is struck by a lightning***) about equally strongly

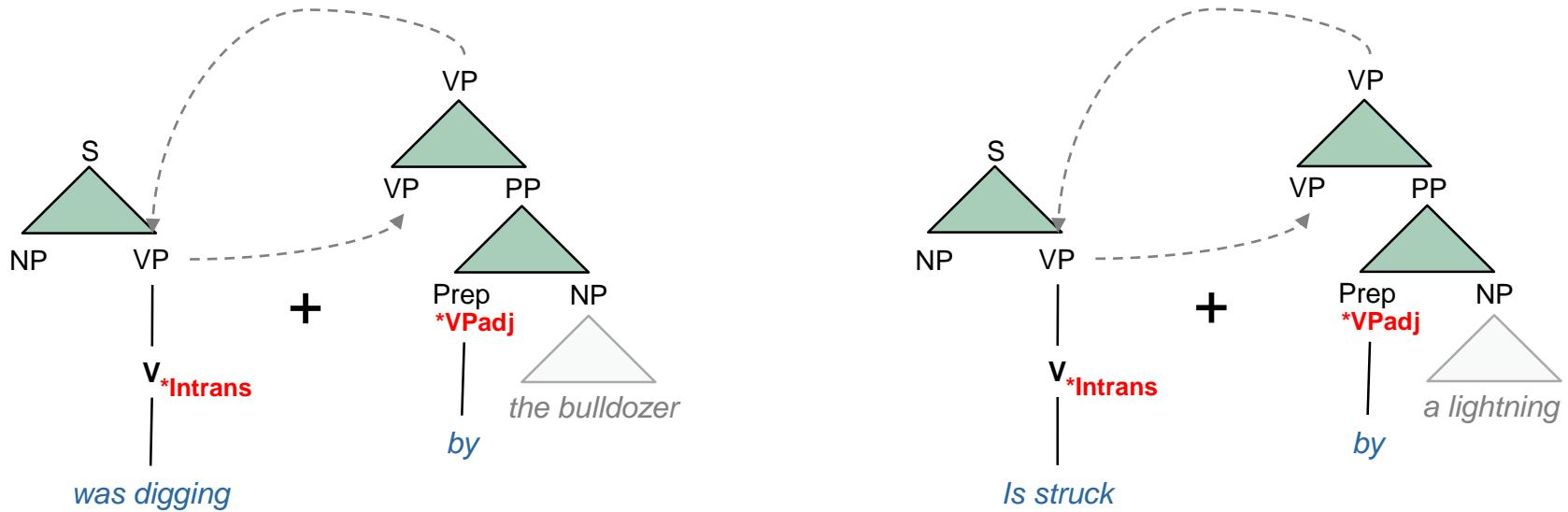


Active / passive priming



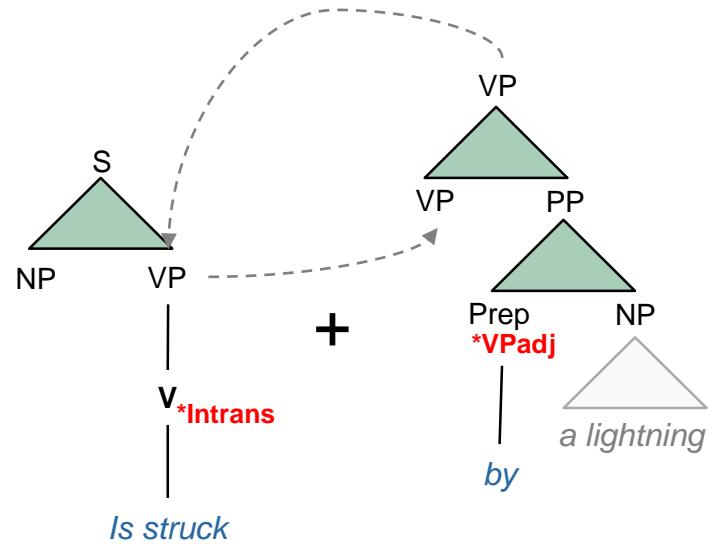
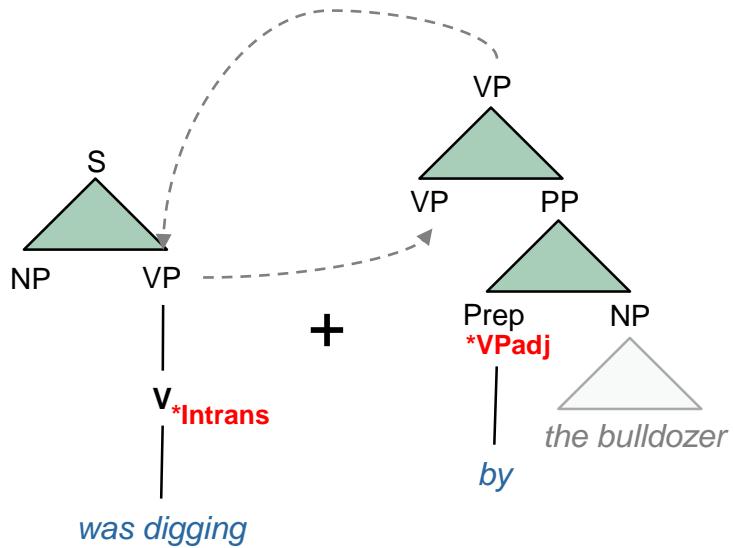
- Transitive actives (baseline condition) imply the use of a transitive initial verb frame and substitution of an NP into the direct object node

Active / passive priming



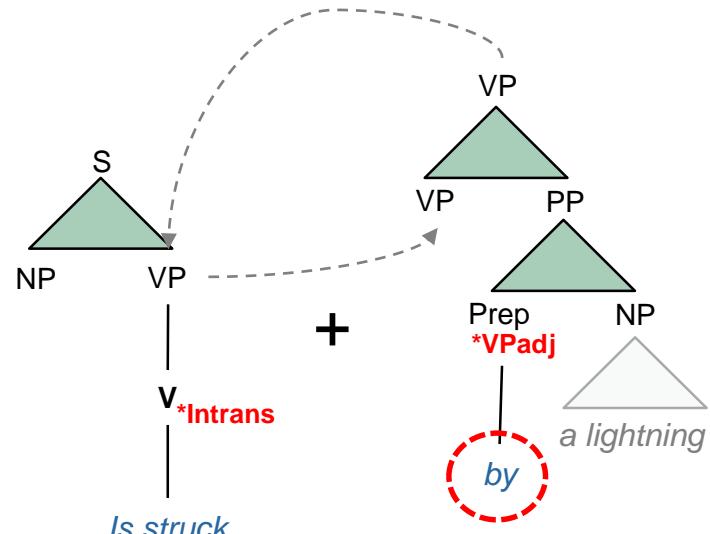
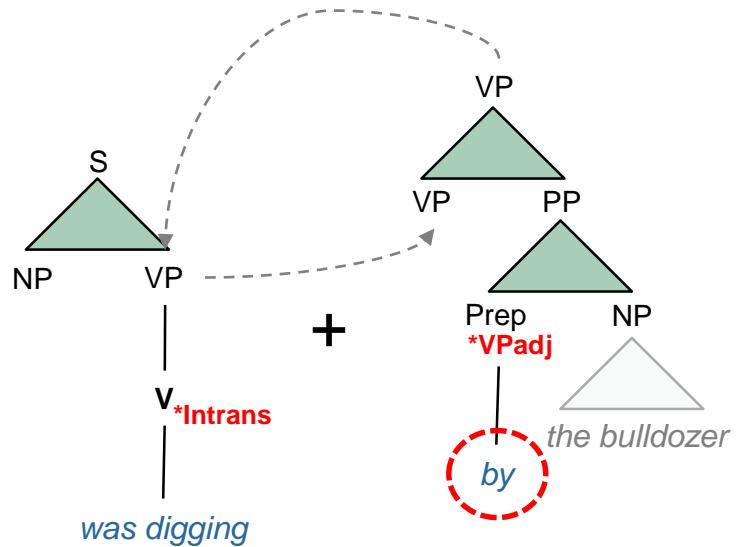
- In contrast, *intransitive active locatives* and *passives* imply combining an intransitive initial verb tree with a VP-adjoining preposition
 - Passives are intransitive (no direct object)
 - *AGENT* by-phrases as adjuncts (or ‘*argument adjuncts*’, cf. Grimshaw, 1990)

Active / passive priming



- Difficult to tell whether it's ***intransitivity*** or ***PP-adjunction*** (or both) that contribute to active/passive priming
 - Participants are typically encouraged to make reference to the *agent* as well as the *patient* (truncated passives are commonly excluded from analysis)
 - It's testable nonetheless...

Active / passive priming



- Even repetition of the word “by” could play a role
 - Appears at odds with Bock (1989) showing that, e.g., “*Susan baked a cake for her boss*” primes, e.g., “*Christoph submitted his visa application to the Russian embassy* (- just in time!)”
 - However, findings from PO/DO priming (substitution of a PP argument into an initial verb tree) may not necessarily generalise to active/passive priming (adjoining optional by-PP)

A hypothetical active / passive priming experiment

- The construction worker was driving the bulldozer (**trans, AV**)
- The construction worker was driving the bulldozer by the lake (**trans, AV, by-PP**)
- The construction worker was driving the bulldozer near the lake (**trans, AV, x-PP**)
- The construction worker was hit (**intrans, PV**)
- The construction worker was hit by the bulldozer (**intrans, PV, by-PP**)
- The construction worker was hit near the bulldozer (**intrans, PV, x-PP**)
- The construction worker was digging (**intrans, AV, by-PP**)
- The construction worker was digging by the bulldozer (**intrans, AV, by-PP**)
- The construction worker was digging near the bulldozer (**intrans, AV, x-PP**)

*All as potential primes of “**the house is struck by a lightning**”*

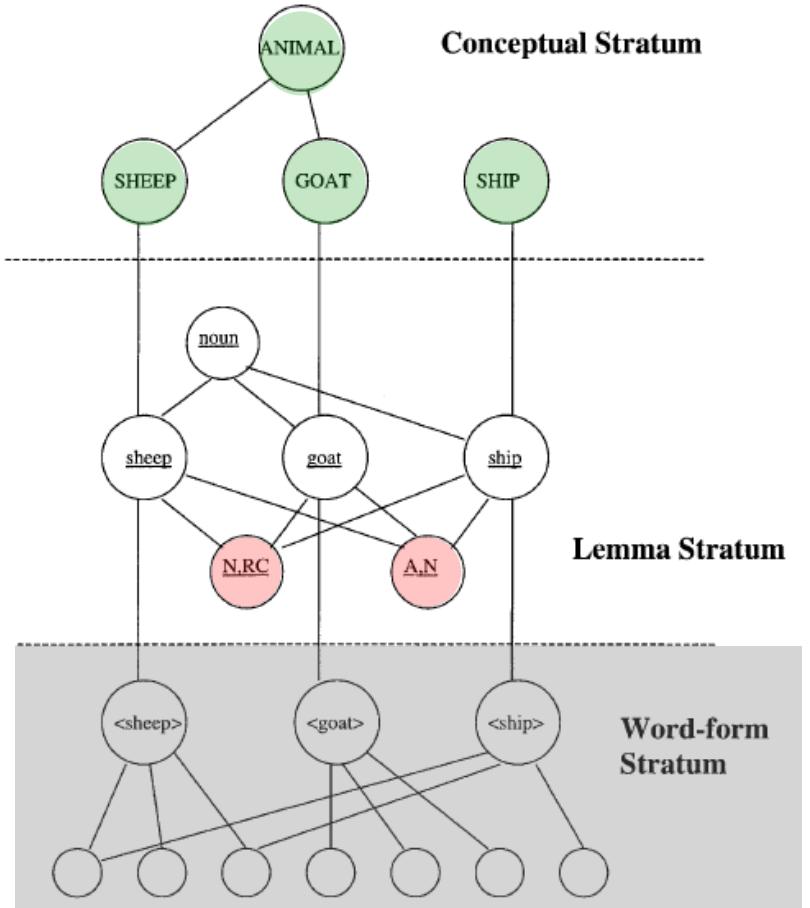


N-modifier priming

- Cleland & Pickering (2003) showed that NP-internal structure (**Adj-N** vs. **N-RC** phrases) is also subject to priming:
 - Specifically, such priming:
 - Occurs without lexical repetition (e.g., *the circle that's blue* <primes> *the sheep that's red* instead of alternative *the red sheep*)
 - Is further enhanced (“**lexical boost**”) when the head-noun is repeated (e.g., “sheep” in both prime and target)
 - Is even enhanced when head-nouns are just semantically related (e.g., “sheep” in the prime, “goat” in the target) (“**conceptual boost**”)
 - Not enhanced when head-nouns are phonologically related (e.g., “sheep” in prime, “ship” in target)
 - Only marginally enhanced when adjectives are repeated (e.g., “red” in both prime and target)

N-modifier priming

- Cleland & Pickering (2003) suggested an augmented version of the Pickering & Branigan (1998) architecture:
 - Nouns (“sheep”, “ship”, “goat” etc.) link to **combinatorial nodes** (explaining ‘abstract’ as well as ‘lexically boosted’ priming)
 - Nouns also link to **conceptual nodes** (explaining ‘conceptually boosted’ priming via spreading activation)
 - Word form-related features are irrelevant for priming
- To explain lexical/conceptual boost (suggesting that nouns somehow ‘know’ something about the modifiers they combine with), it is assumed that **combinatorial nodes** encode **sequences of constituents**
 - A noun can be followed by a relative clause or preceded by an adjective

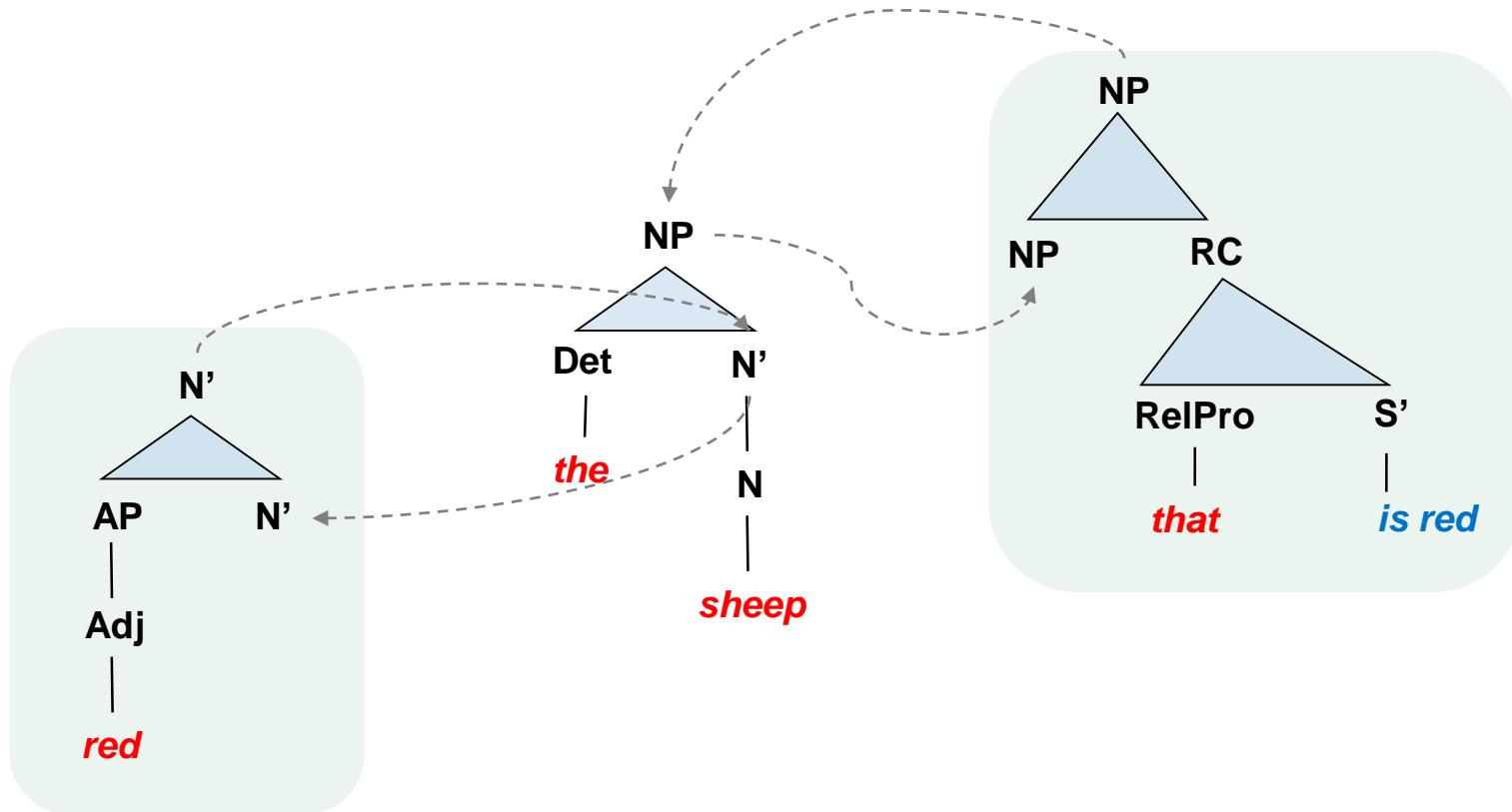




N-modifier priming

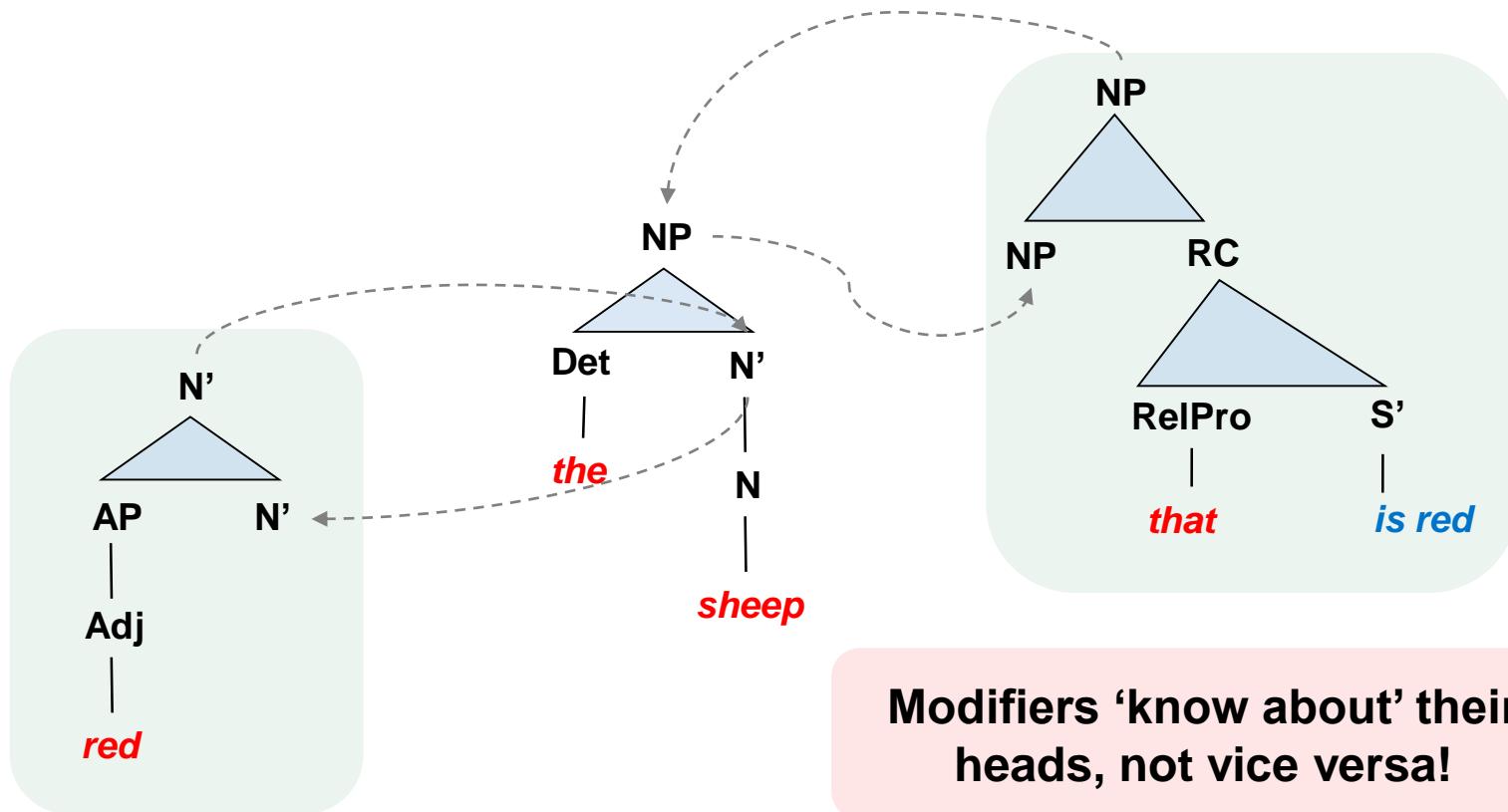
- Constituent sequences (?!...)
 - Finite-state grammar
 - Does not account for the *optional and recursive* nature of modifiers, e.g.
 - *the sheep*
 - *the red sheep*
 - *the little red sheep*
 - *the grumpy little red sheep*
 - ...
 - Might require a potentially ∞ number of combinatorial nodes in the Cleland & Pickering (2003) account
- More plausible that modifiers ‘know’ how to combine with nouns than the other way round

N-modifier priming: LTAG



- Choosing between **different** (optional & recursive!) **auxiliary trees** for adjunction into an NP like “*the sheep*”:
 - Use either an **adjective** or a **relative pronoun** to express the *redness* of the sheep

N-modifier priming: LTAG



- Choosing between **different** (optional & recursive!) **auxiliary trees** for adjunction into an NP like “*the sheep*”:
 - Use either an **adjective** or a **relative pronoun** to express the *redness* of the sheep

Lexical / conceptual boost

- In the context of N-modifier priming, the LTAG account does **not** straightforwardly explain the lexical/conceptual boost from head nouns!
- Then again, such **boost effects may actually not be diagnostic of grammatical relations per se**
 - Suggestion that such effects may reflect an *epiphenomenon* related to explicit memory (cf., Chang, Dell, & Bock, 2006; Chang et al., 2012)
 - Scheepers, Raffray, & Myachykov (2017): **Repetition of non-head constituents** (argument nouns) boosts PO/DO priming to the same extent as repetition of verbs!
 - Carminati, van Gompel, & Wakeford (2019): **Repetition of non-head constituents** (argument nouns) **does not** boost PO/DO priming to the same extent as repetition of verbs!
- Urgently needs to be resolved, as it concerns the question of whether ‘boost effects’ actually tell us something about (lexically-specific) syntactic representations or not!

Evidence for ‘lexicalized syntax’

- The assumption of lexically-specific syntax (cf. LTAG) by no means relies on the lexical boost to structural priming!
- E.g., the existence of *non-alternating* ditransitive verbs already suggests a theoretical requirement for lexically-specific syntactic representations:
 - *he donated P5000 to them* / **he donated them P5000*
 - **he fined P5000 to them* / *he fined them P5000*
- In fact, mere presentation of an isolated non-alternating verb (e.g., *donate* vs. *fine*) primes subsequent production of either a PO or a DO sentence that contains an alternating verb (e.g. *show*) (e.g., Melinger & Dobel, 2005; Salamoura & Williams, 2006)
- Syntactic priming magnitudes depend on long-term structural preferences associated with alternating ditransitive verbs (e.g., Bernolet & Hartsuiker, 2010; Segaert et al., 2014)

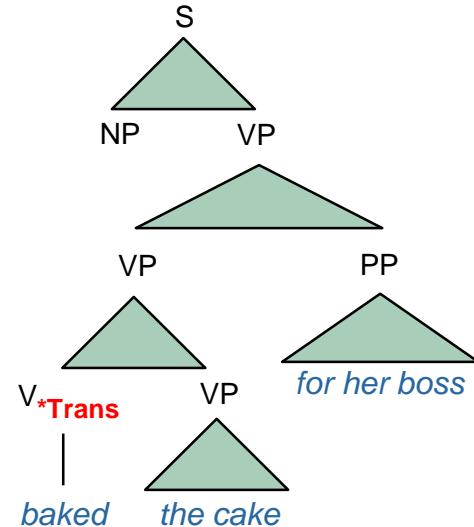
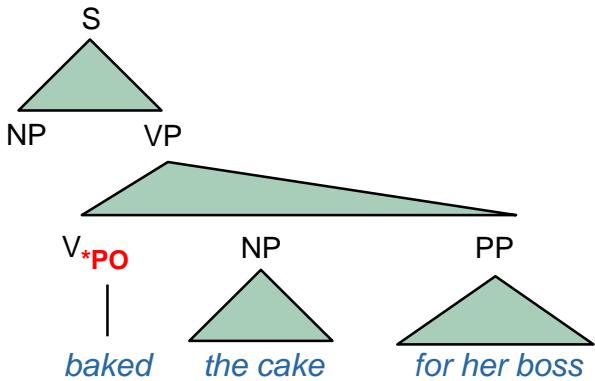


Discussion

- ***What's the syntax behind syntactic priming?***
 - Nobody really knows!
- Lexicalised representations in LTAG (and related formalisms) provide an elegant, generalized framework for explaining priming of high/low relative clause attachments in recursively generated NPs
 - from previously generated high/low relative clause attachments,
 - from high/low attachments of other types of NP-modifying constituents such as PPs and Saxon Genitive markers (***cross-structural***).
 - from mathematical equations (***cross-domain***)
- LTAG (and related formalisms) may also offer different (in some cases more plausible) explanations for other types of priming effects in the literature
 - Ditransitive structure priming
 - Active/passive priming
 - N-modifier structures

Discussion

- **Potential problems** (but not only for LTAG!), e.g.
 - “*Susan baked a cake for her boss*” primes “*The boy gave the bone to the dog*” (Bock, 1989)
 - Is “*for her boss*” a VP **argument** or **adjunct**?



- Risk of circular reasoning when considering priming evidence on its own.



Discussion

- Syntactic priming is an excellent implicit method for studying ‘mental’ syntactic representations involved in language use (cf. Pickering & Branigan, 1999; Branigan & Pickering, 2017)
- However, structural priming evidence alone will probably never enable us to come up with a plausible, computationally feasible theory of “mental syntax”.
- Needs to be informed by / complemented with additional evidence from (e.g.) linguistic analysis
 - To generate testable hypotheses
 - To avoid computationally implausible explanations
 - To avoid circular reasoning
- In order to draw conclusions about syntax, there needs to be a better understanding of the mechanism behind syntactic priming and related phenomena (cf. lexical boost)

A photograph of a forest with many tall, thin trees standing close together. Sunlight filters through the branches from the top left, creating bright rays and shadows on the ground. The forest floor is covered in fallen leaves and twigs.

Thank you!