A sensorimotor characterisation of syntax, and its implications for models of language evolution

Alistair Knott

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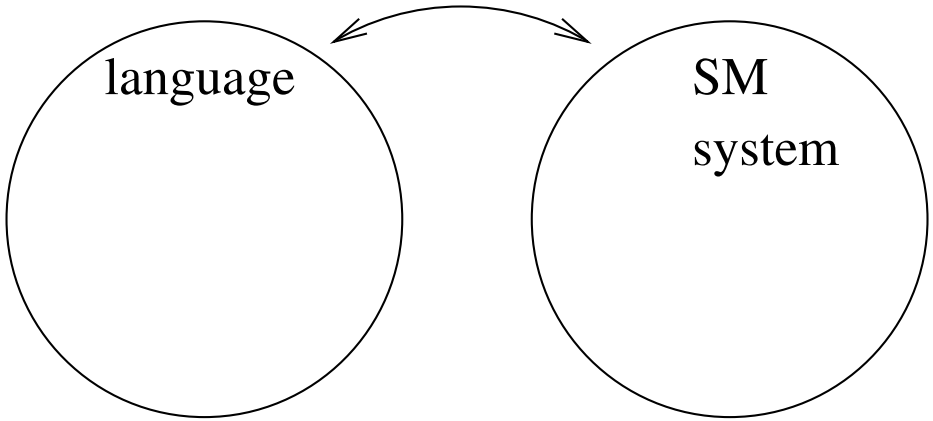

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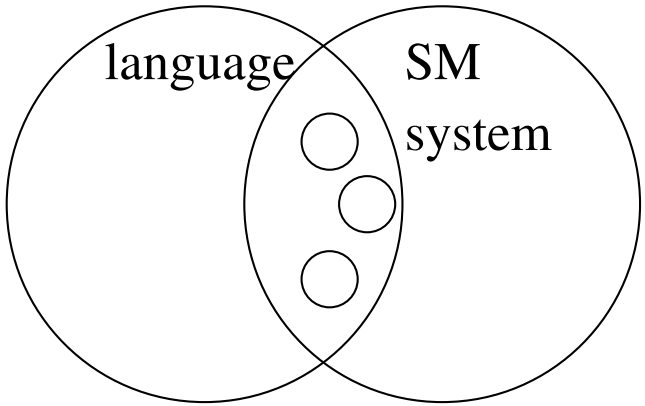

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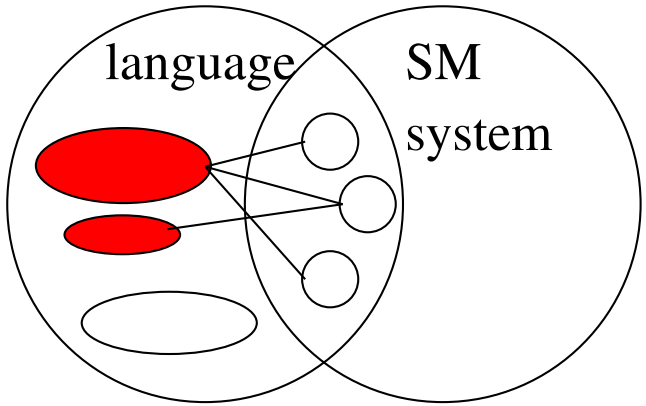
An alternative idea: language and the SM system share machinery. Some language circuits just 'read out' SM representations.



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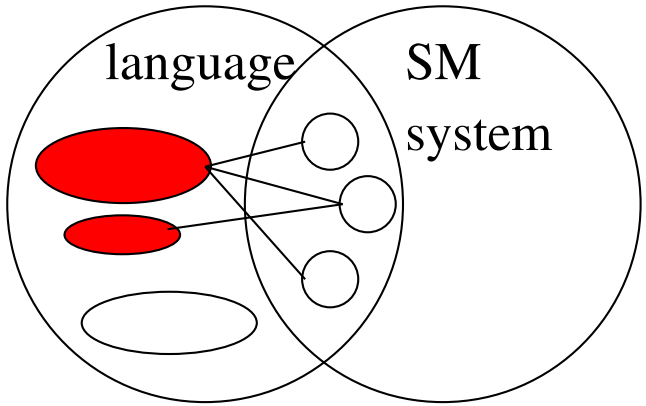
An alternative idea: language and the SM system share machinery. Part of the syntactic structure of language is sensorimotor in origin.



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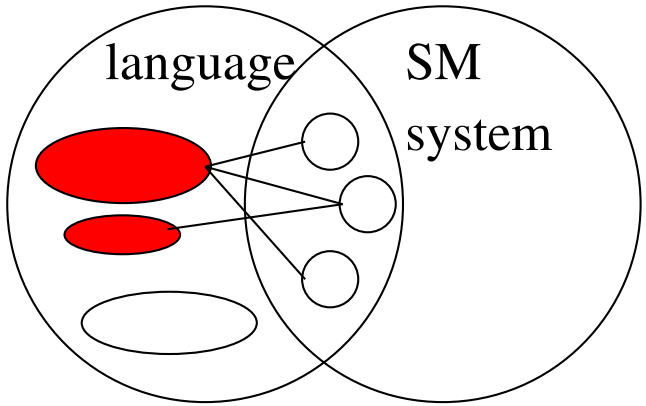

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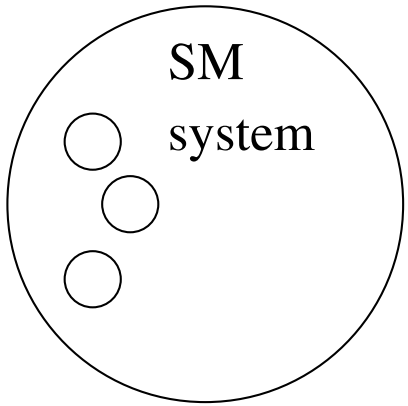

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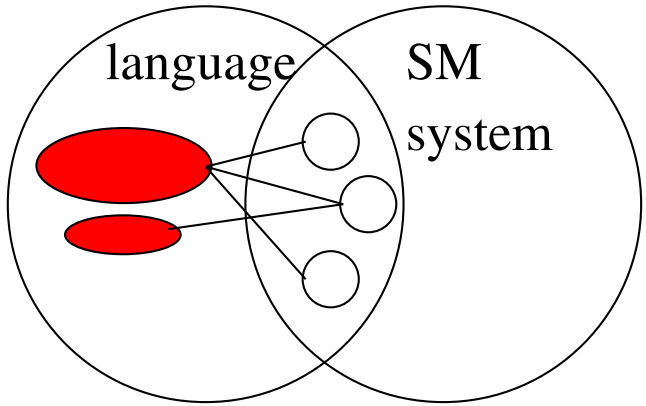

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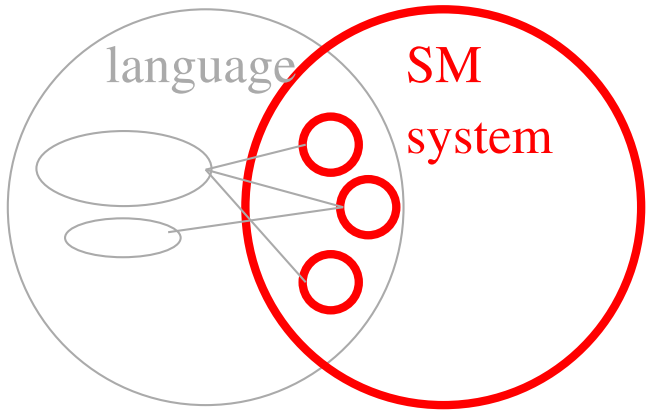
(2) We can use the *modern SM system* to approximate the platform from which language evolved.



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This would be particularly good news for language evolution researchers.

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Perhaps surprisingly, the syntactic framework we are drawn towards is some form of Chomskyan generative grammar.

- Sentences have a ‘surface’ structure and an ‘underlying’ structure.
- It’s the *underlying* structure which can be interpreted as a description of SM processing.

Method

Take a simple example episode: **a man grabs a cup**.

Develop two models:

- A **syntactic model** of the (underlying) structure of sentences reporting this episode in different languages, according to some variety of Chomskyan syntax.
- A **sensorimotor model** of the processes which allow the episode to be perceived or executed, according to current psychology/ neuroscience.

Question: do these models overlap?

I argue that there are formal similarities between the syntactic and sensorimotor models, which are strong enough to require explanation.

A syntactic model of *The man grabbed a cup*

I assume a version of Minimalism (Chomsky, 1995).

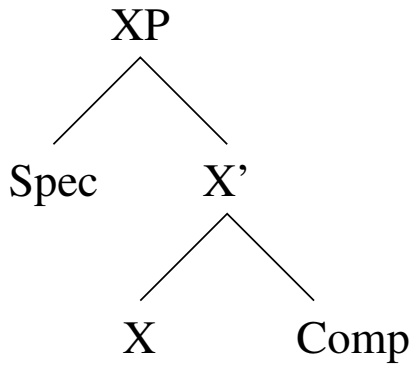
In Minimalism, a sentence needs to be described at two different syntactic levels:

- Phonetic form (PF) represents the surface form of the sentence.
- Logical form (LF) is 'the level of syntactic representation which interfaces with the semantic system'.

I'll assume that all translations of *The man grabbed a cup* have the same LF.

The building blocks of syntactic structures

The basic unit of phrase structure is the X-bar schema.

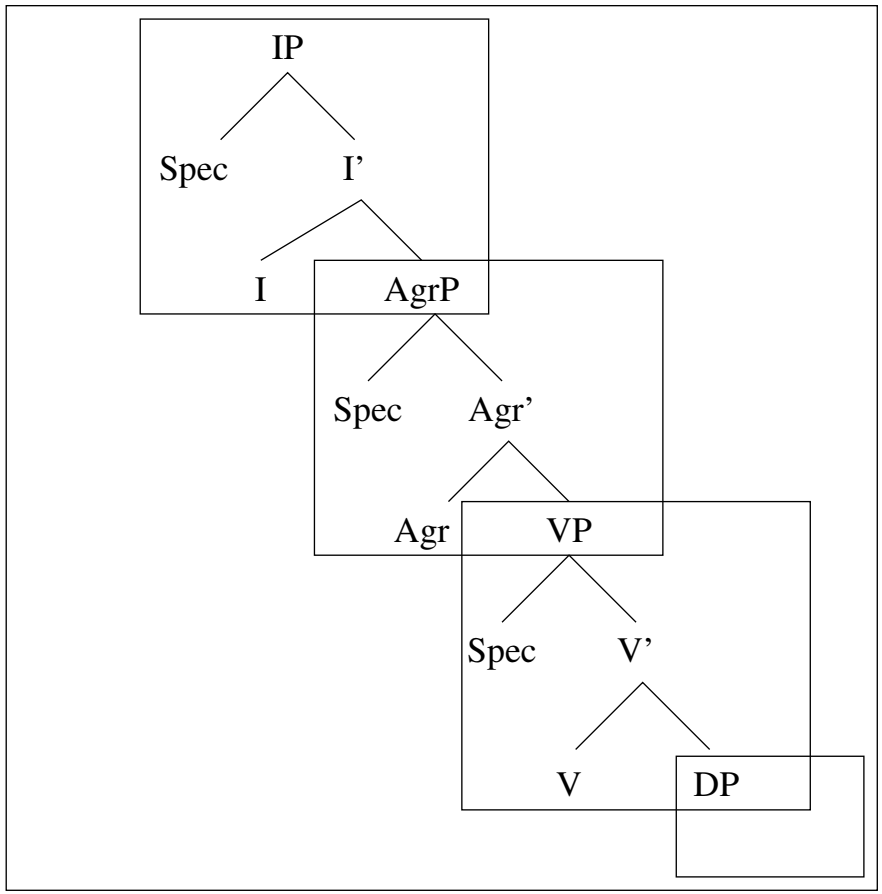


Each word in a sentence contributes an XP structure.

- The head of the structure (X) is the word itself.
- The structure also has slots for a specifier (Spec) and a complement (Comp).
- These slots can (recursively) be occupied by other XPs.

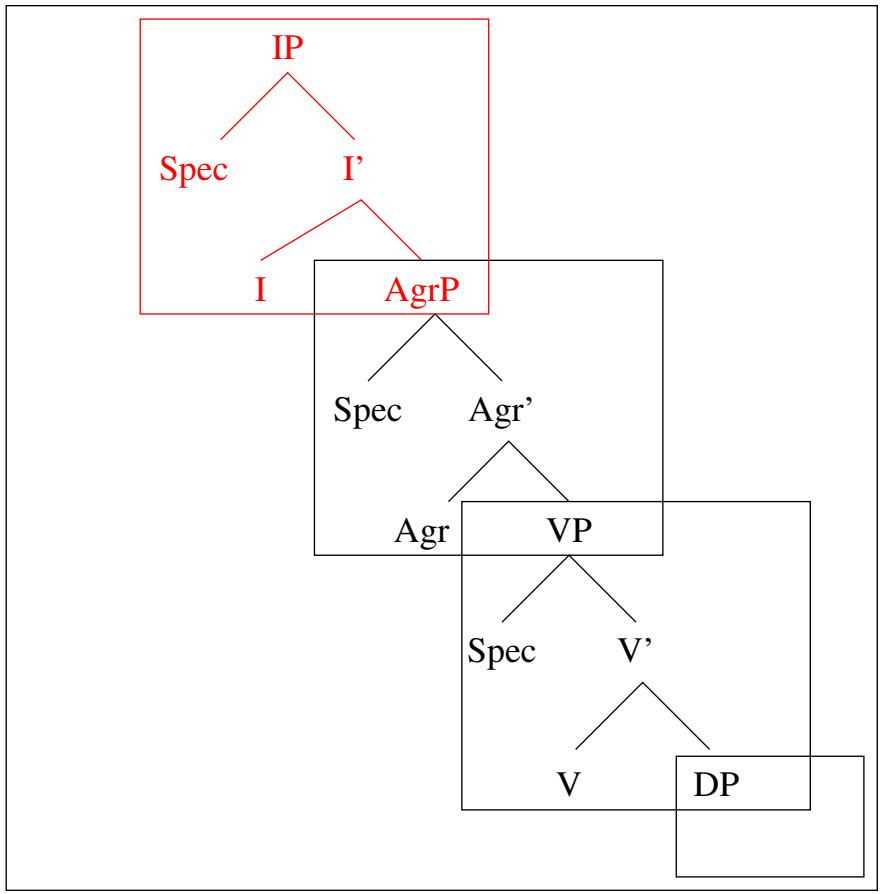
LF structure of *The man grabbed a cup*

The LF of our sentence is a right-branching pattern of XPs.



LF structure of *The man grabbed a cup*

IP is associated with the subject.



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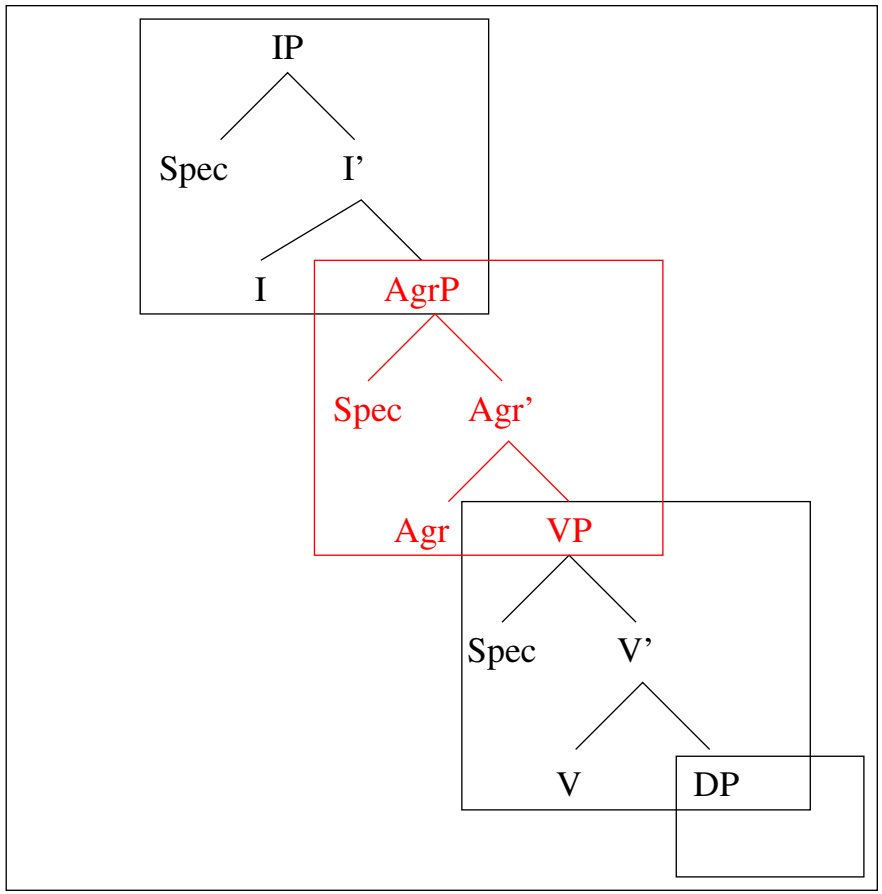
AgrP is associated with the object.



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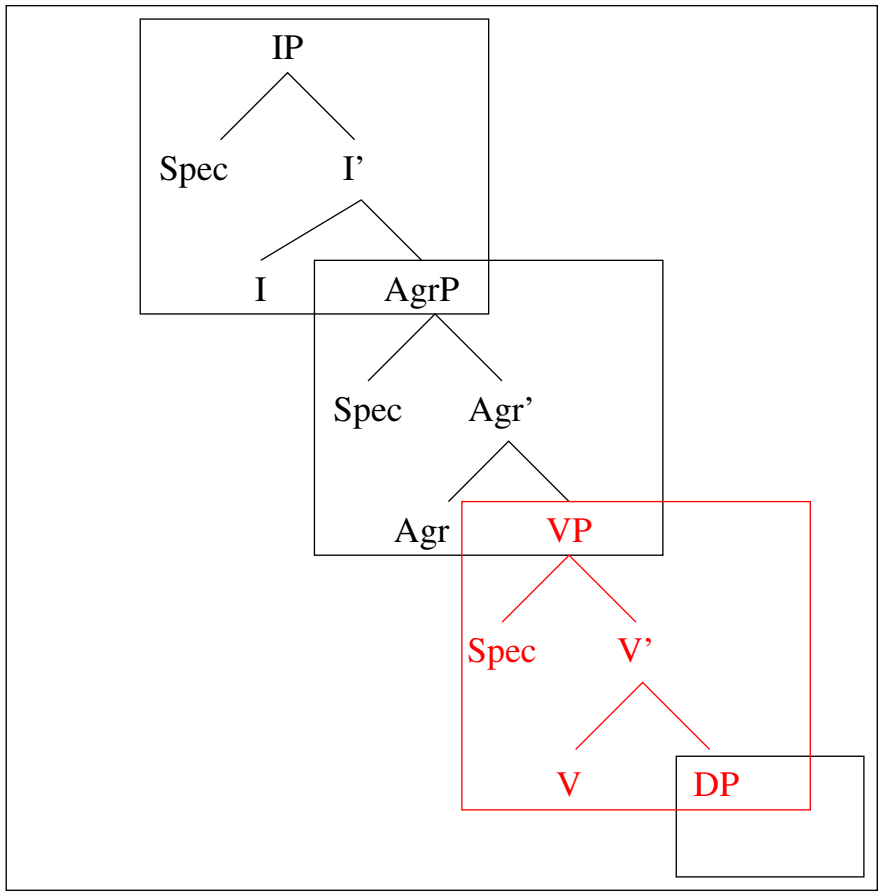
AgrP is associated with the verb.



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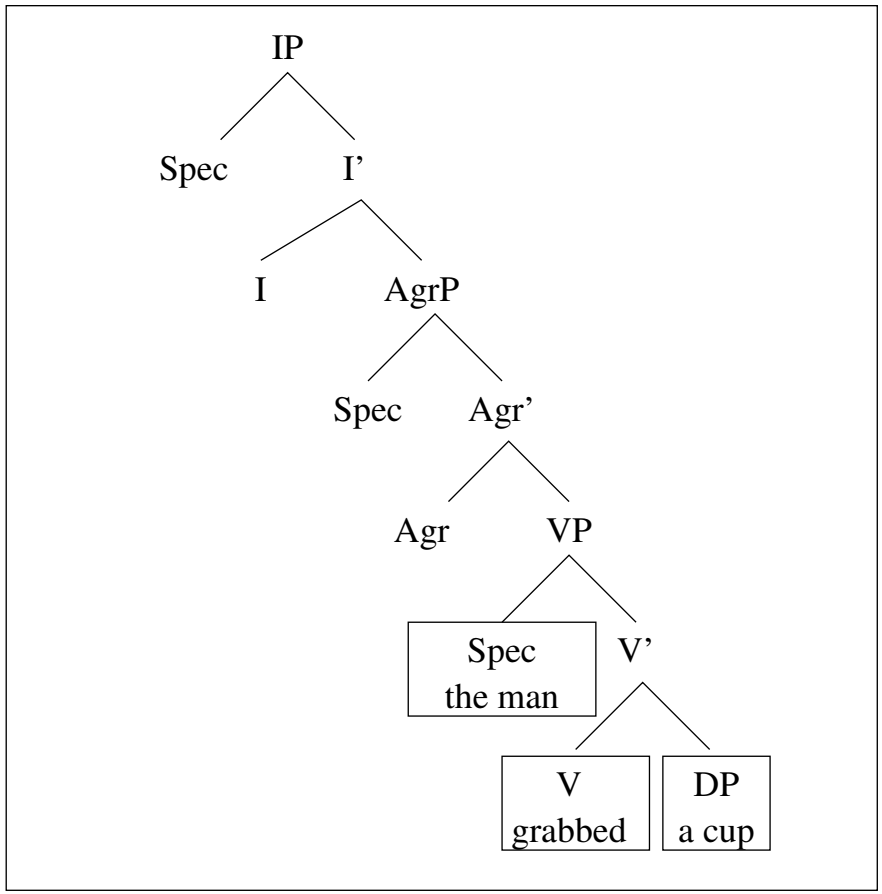
VP is headed by the verb, and introduces the subject and object.



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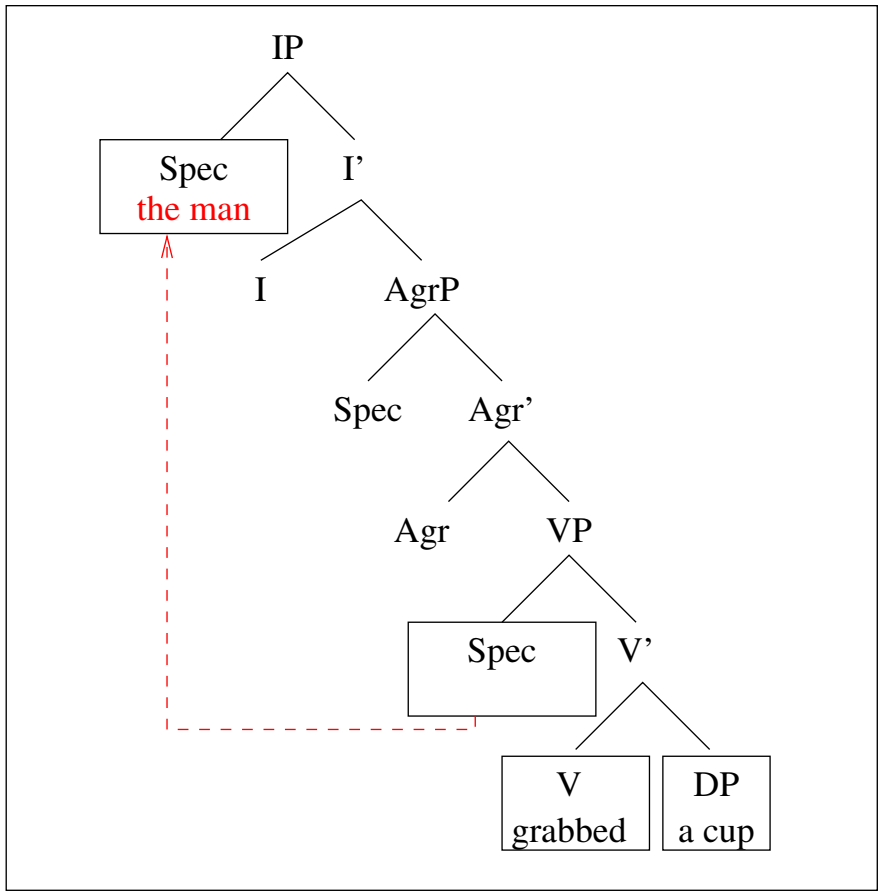
The subject raises to [Spec,IP] to get Case (assigned by I)



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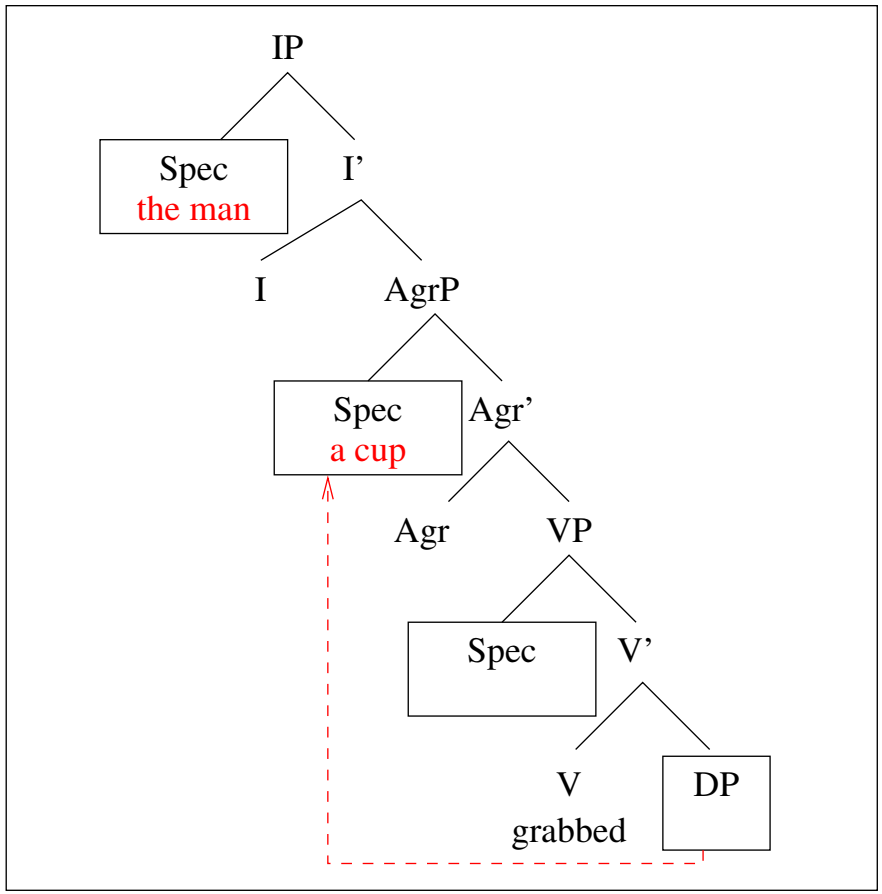
The object raises to [Spec,AgrP] to get Case (assigned by Agr)



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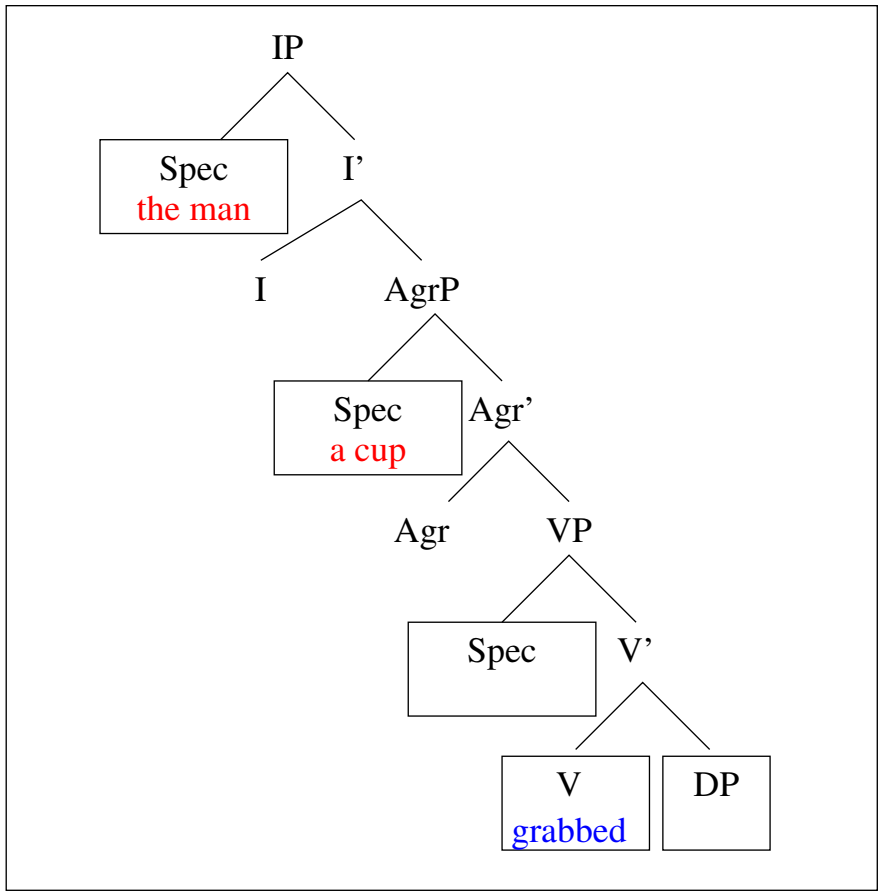

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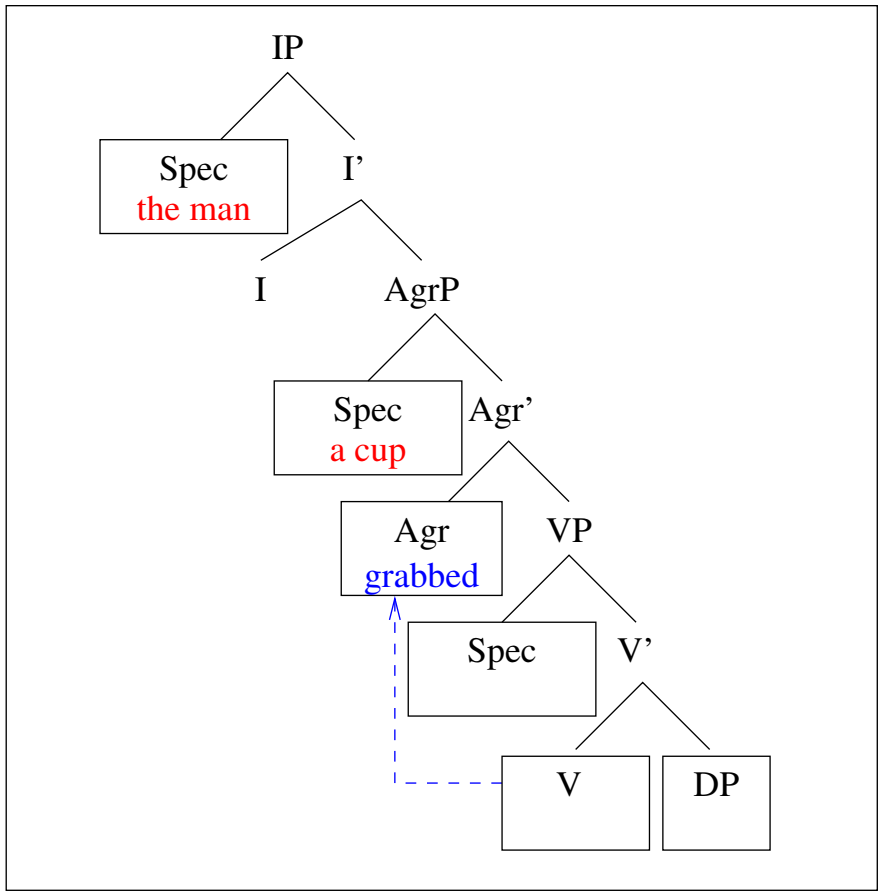

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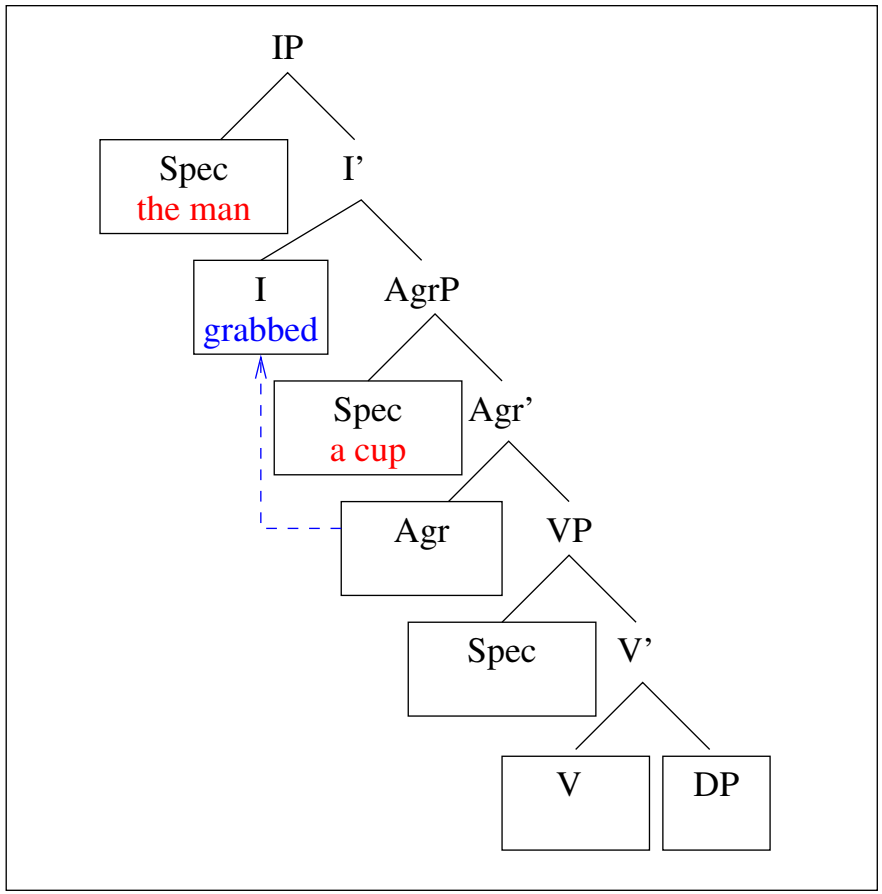

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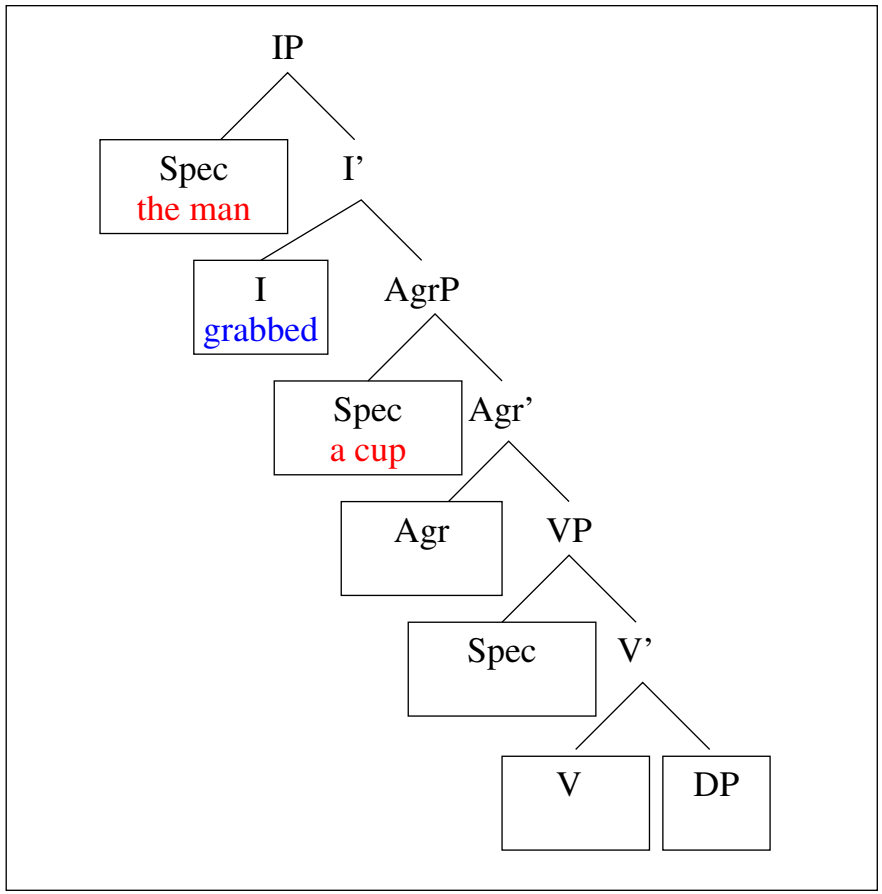

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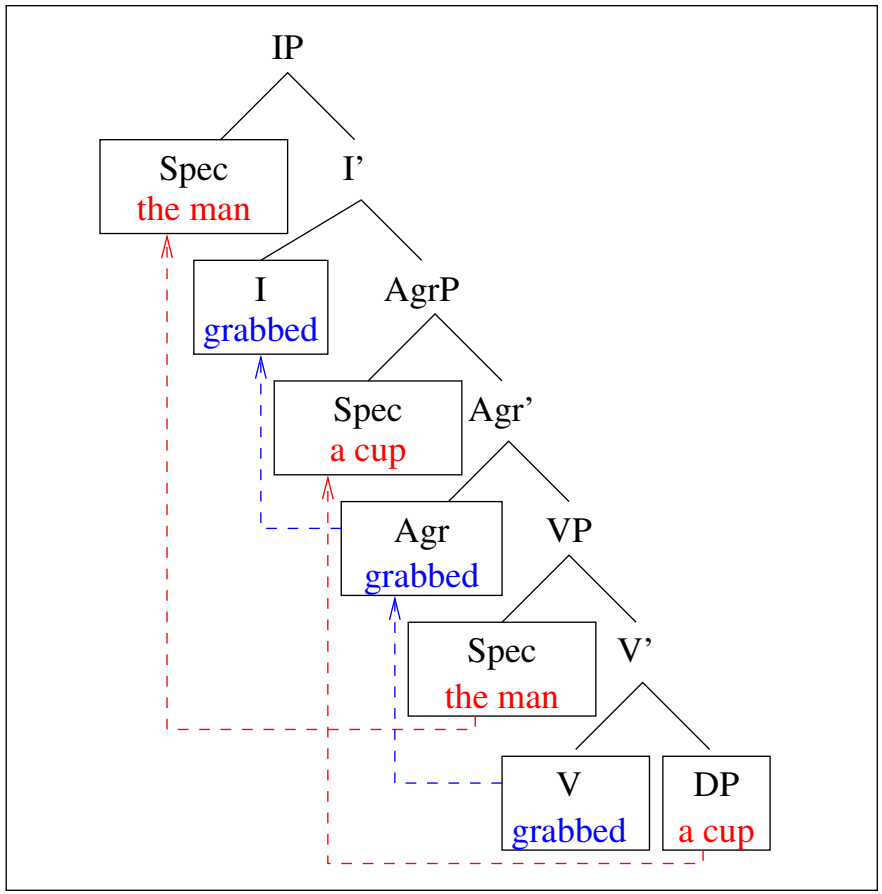
Languages have different conventions about when to pronounce the different elements of LF.



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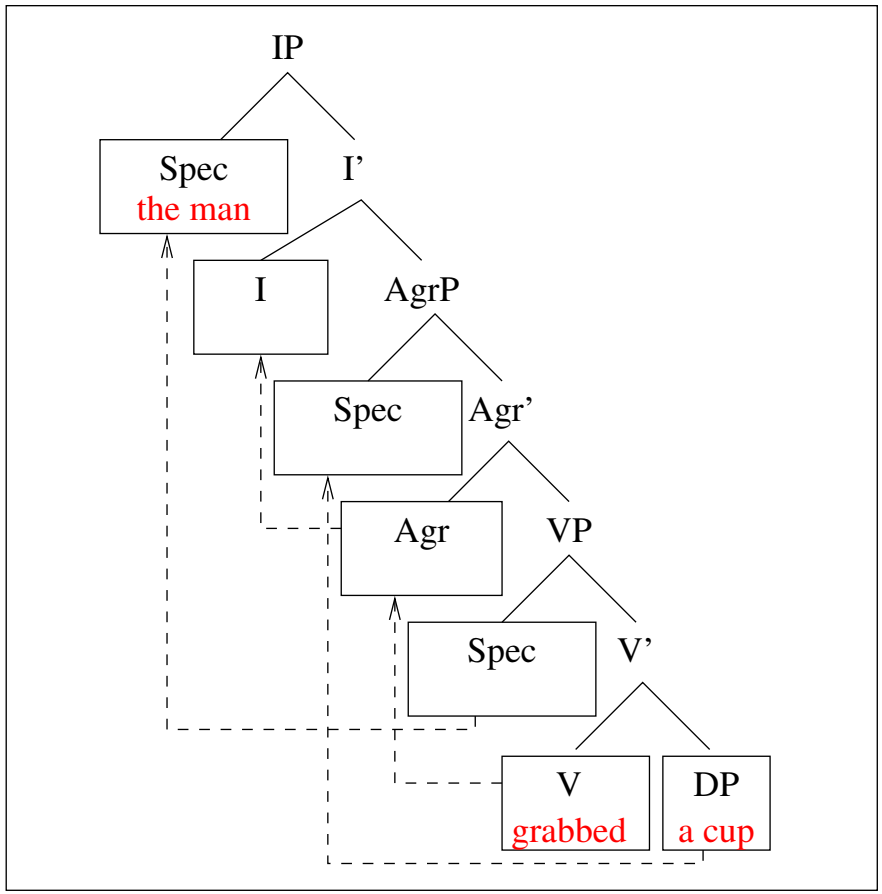

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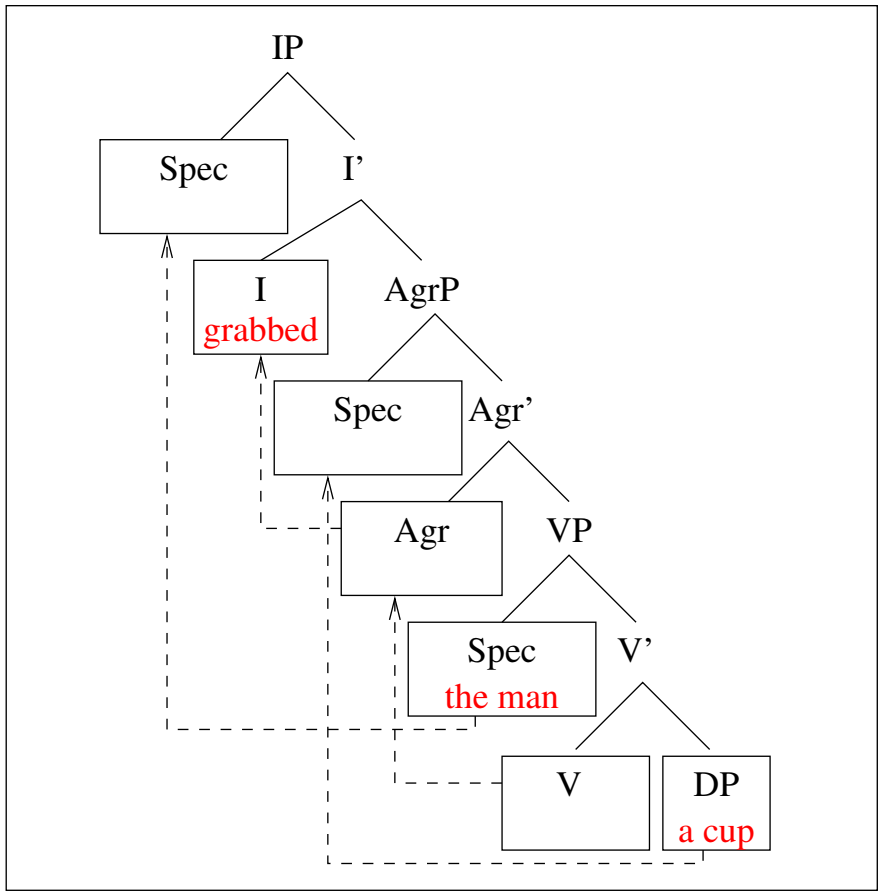
Māori PF looks like this:



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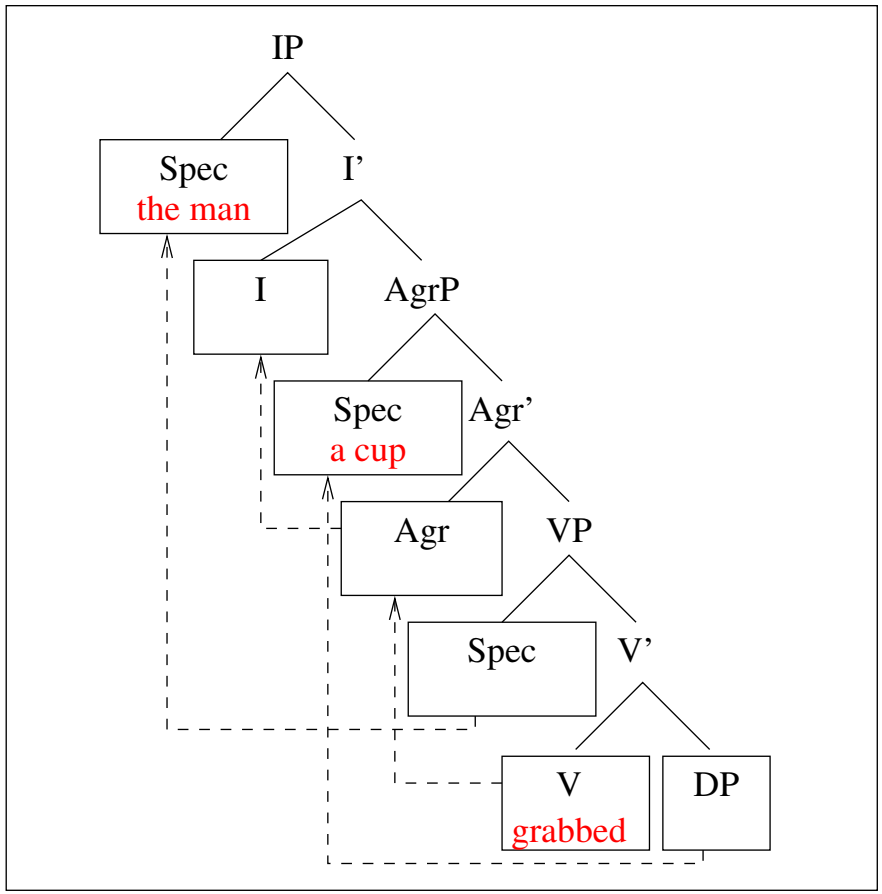
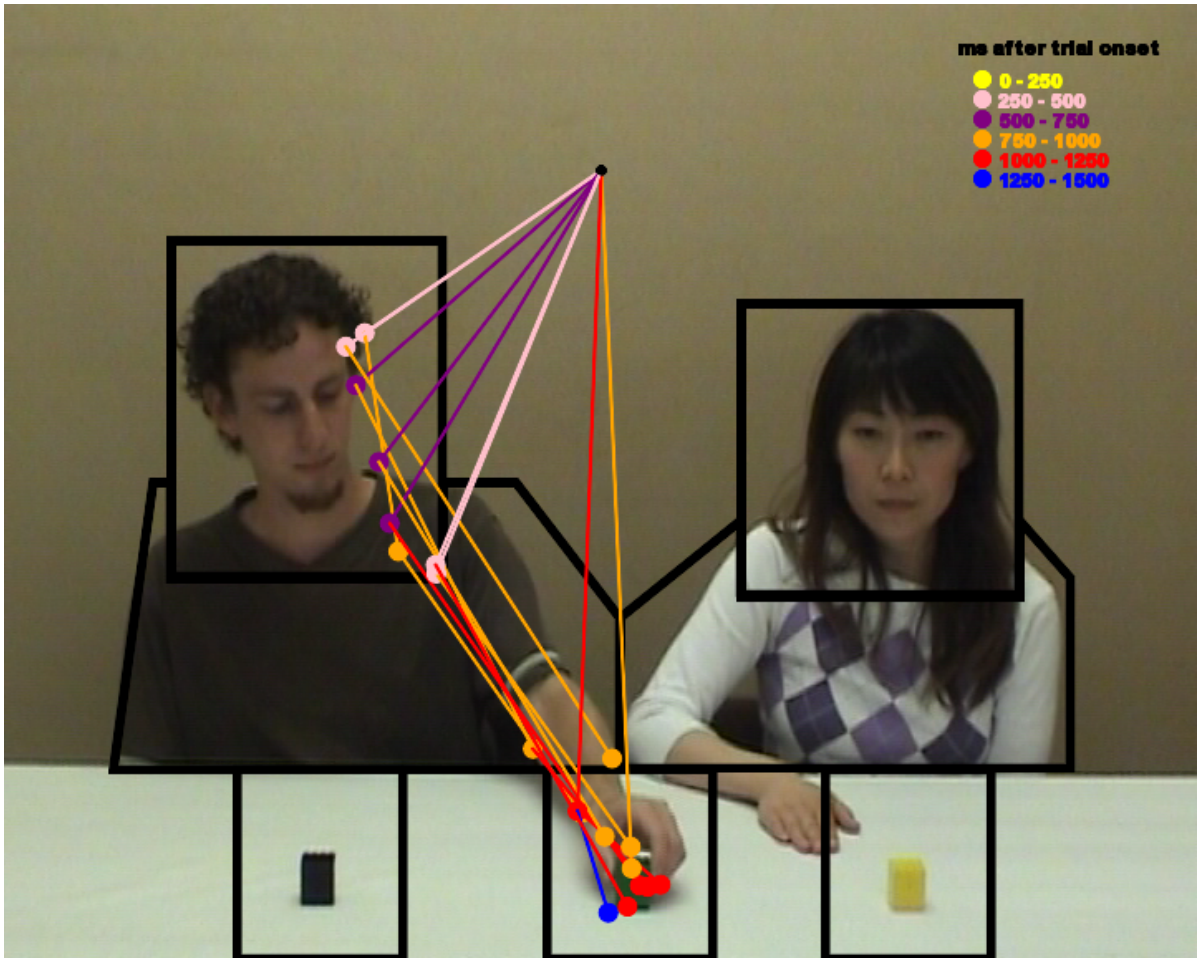


A sensorimotor model of reach-to-grasp actions

1. I argue that the processes involved in perceiving or executing a reach-to-grasp action have a strong *sequential structure*:

- The observer must first attend to the agent
- and then attend to the target
- and only then dynamically monintor the action to completion.

Some evidence from an eye-tracking study



(Webb *et al.* 'Eye movements during transitive action observation have sequential structure', Acta Psychologica 2010)

A sensorimotor model of reach-to-grasp actions

2. I argue that both agent and target are *reattended to* when the action is experienced.

- During action monitoring, the agent is reattended to *as a dynamic entity*.
- At the end of the action, the target is reattended to *as a motor state*.

I suggest that these actions of reattention are crucial for the development of cross-modal object representations.

SM signals during experience of a reach-to-grasp

Context	Action signals	Reafferent signals
C1	*attend_agent*	*attending_to_agent*
C2	*attend_cup*	*attending_to_cup*
C3	*grasp*	*attending_to_agent*
C4		*attending_to_cup*

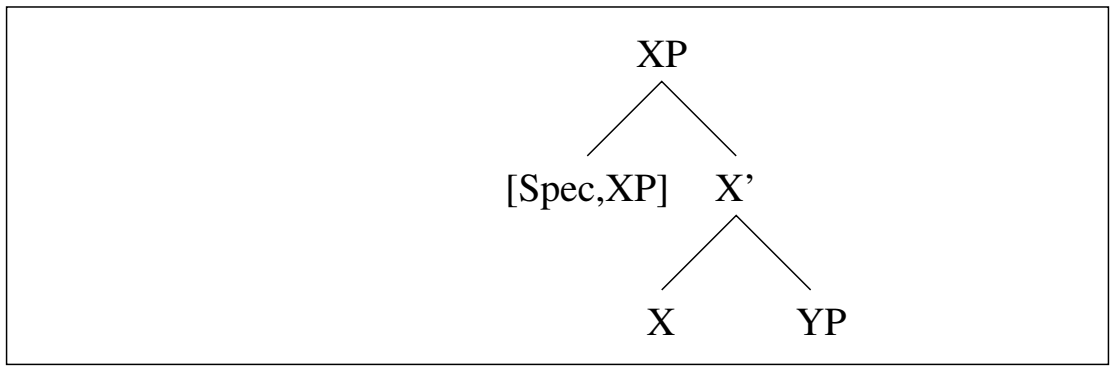
A SM characterisation of LF

My proposal (roughly):

> *The LF of 'The man grabbed a cup' describes the sequence of SM operations/states evoked during experience of a cup-grabbing event.*

SM interpretation of an XP schema

I express this proposal by giving a general SM interpretation of an XP schema.



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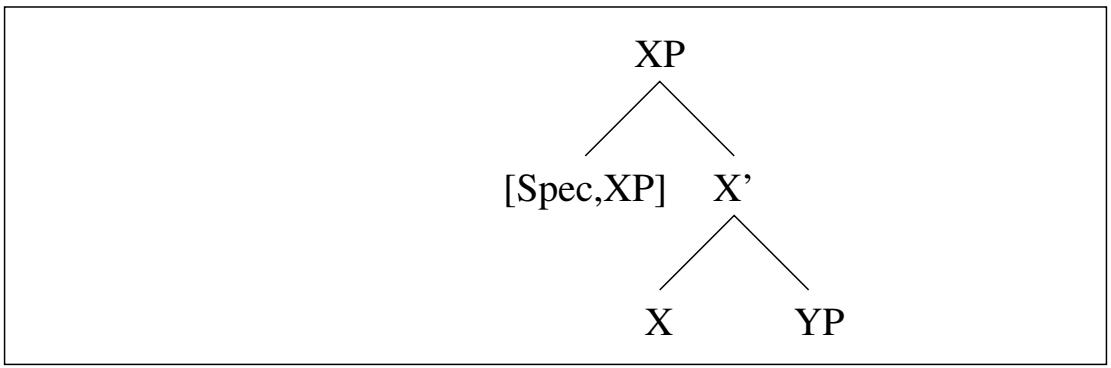

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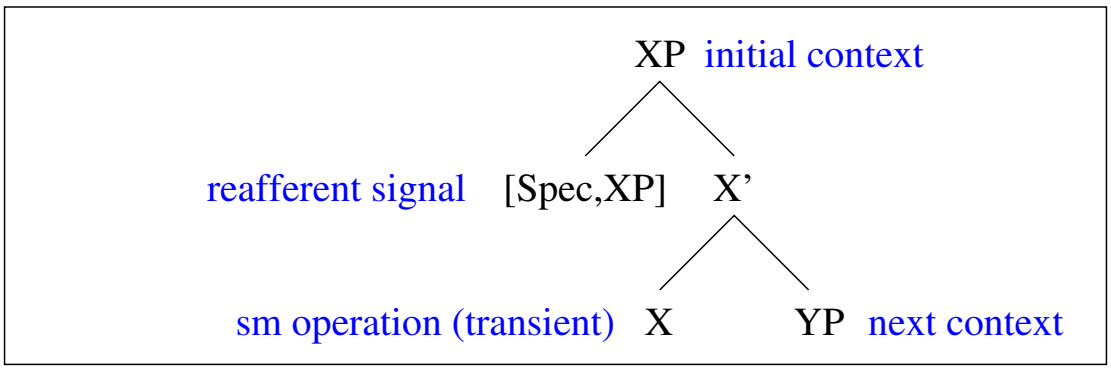
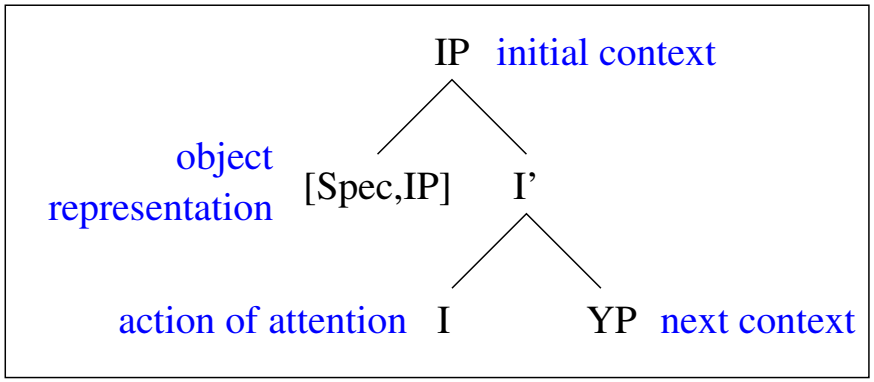
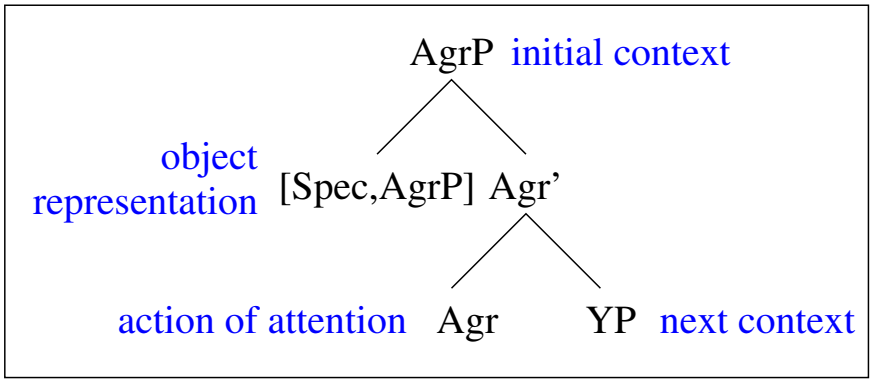
- Each item in the XP schema has a SM interpretation.



XPs denoting attentional operations

IP and AgrP denote attentional operations, and their reafferent consequences.



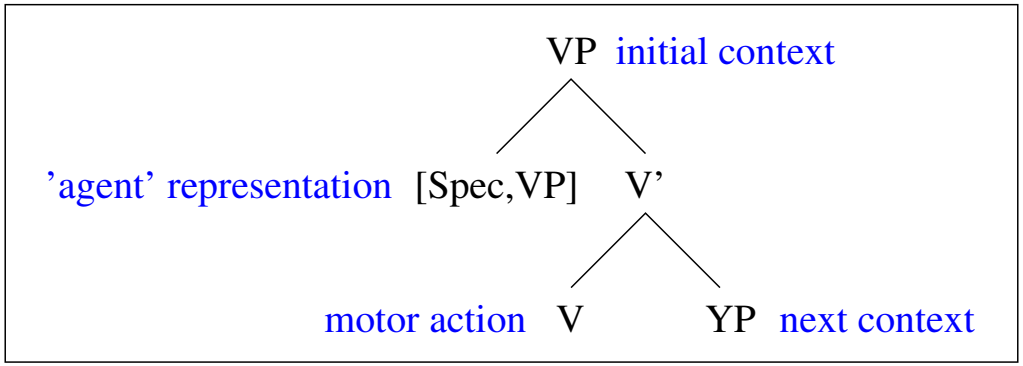


In these XPs:

- The head (which 'checks' a piece of verb morphology) denotes an action of attention.
- The specifier (the position occupied by a DP) denotes the sensory representation of an object.

XPs denoting motor operations

VP denotes a motor operation, and its reafferent consequences.

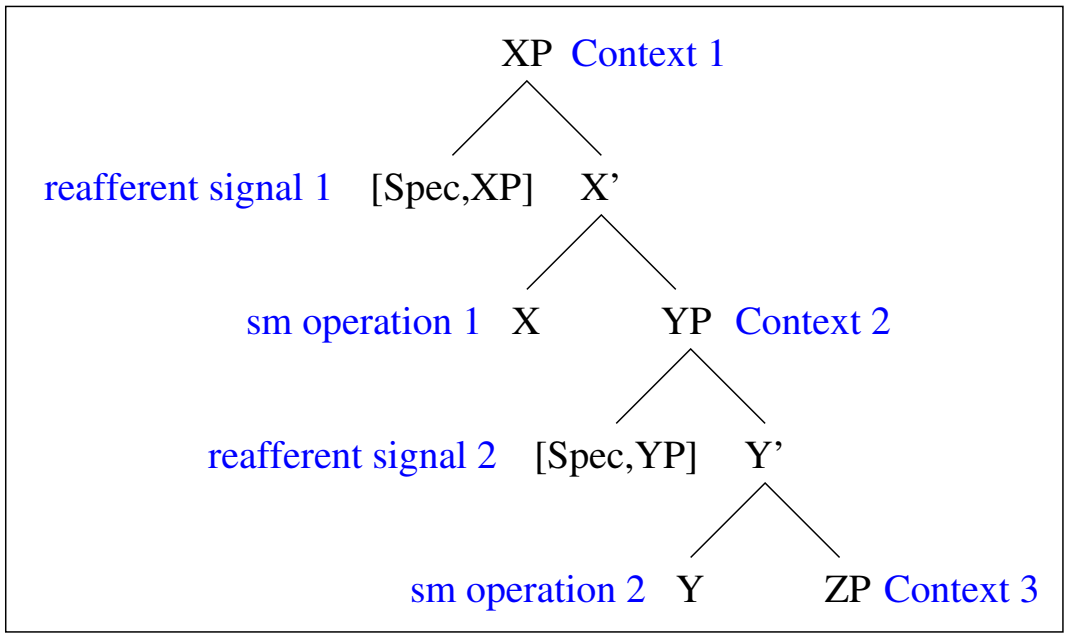


- The V head denotes a motor programme.
- The specifier of VP denotes the sensory representation of an agent.

A right-branching structure of X-bar schemas

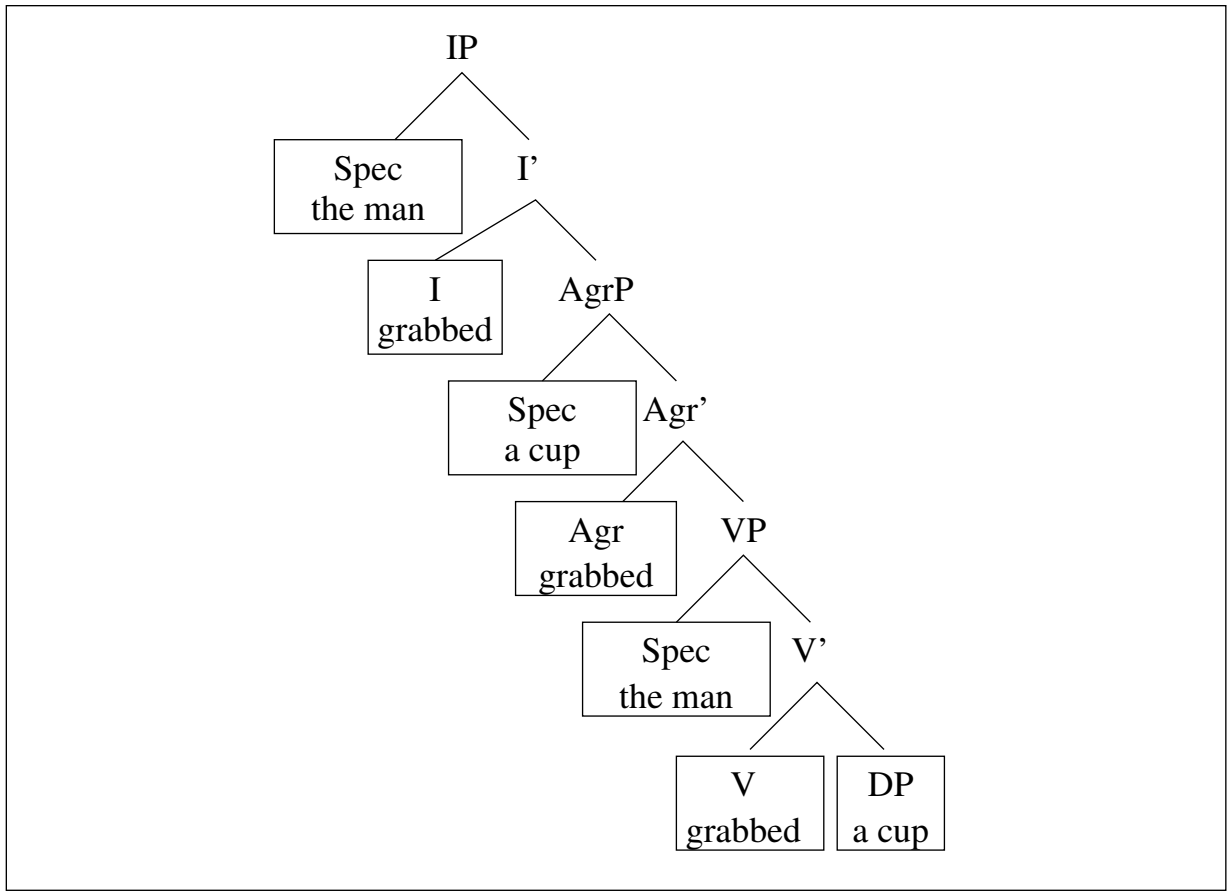
In a right-branching X-bar structure, the next context of one XP is the initial context of its complement XP.

So a right-branching structure of XPs describes a *sequence* of sensorimotor operations.



SM interpretation of the LF of *The man grabbed a cup*

The four LF projections map onto the four stages of the SM sequence.



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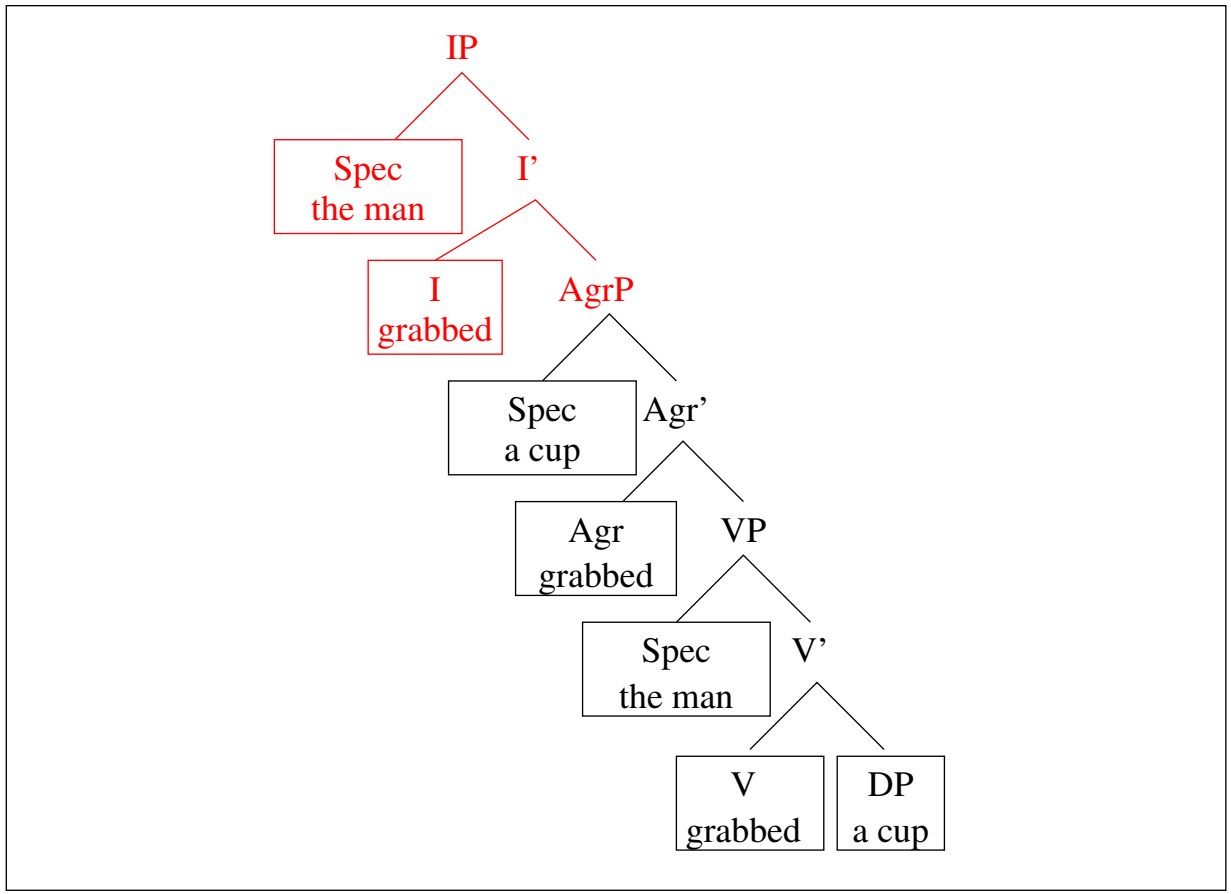

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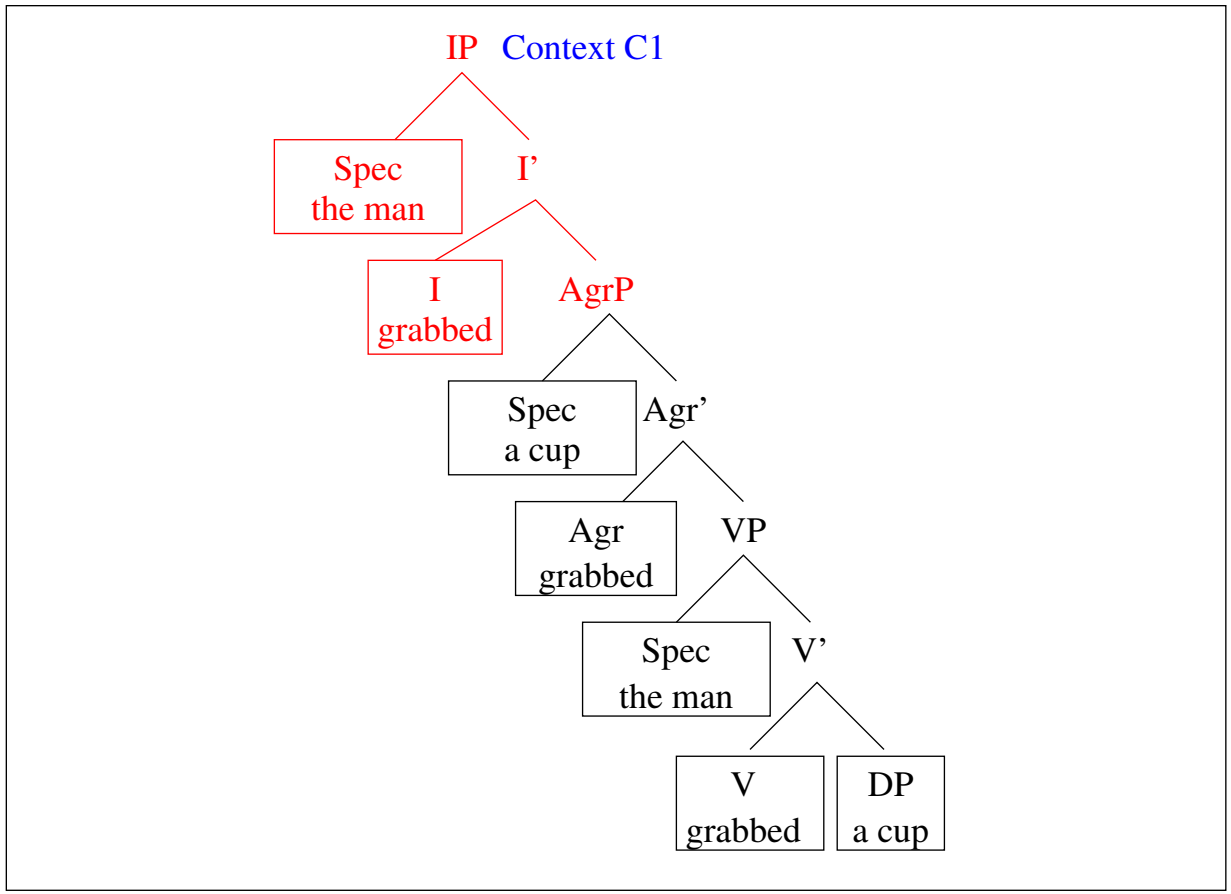

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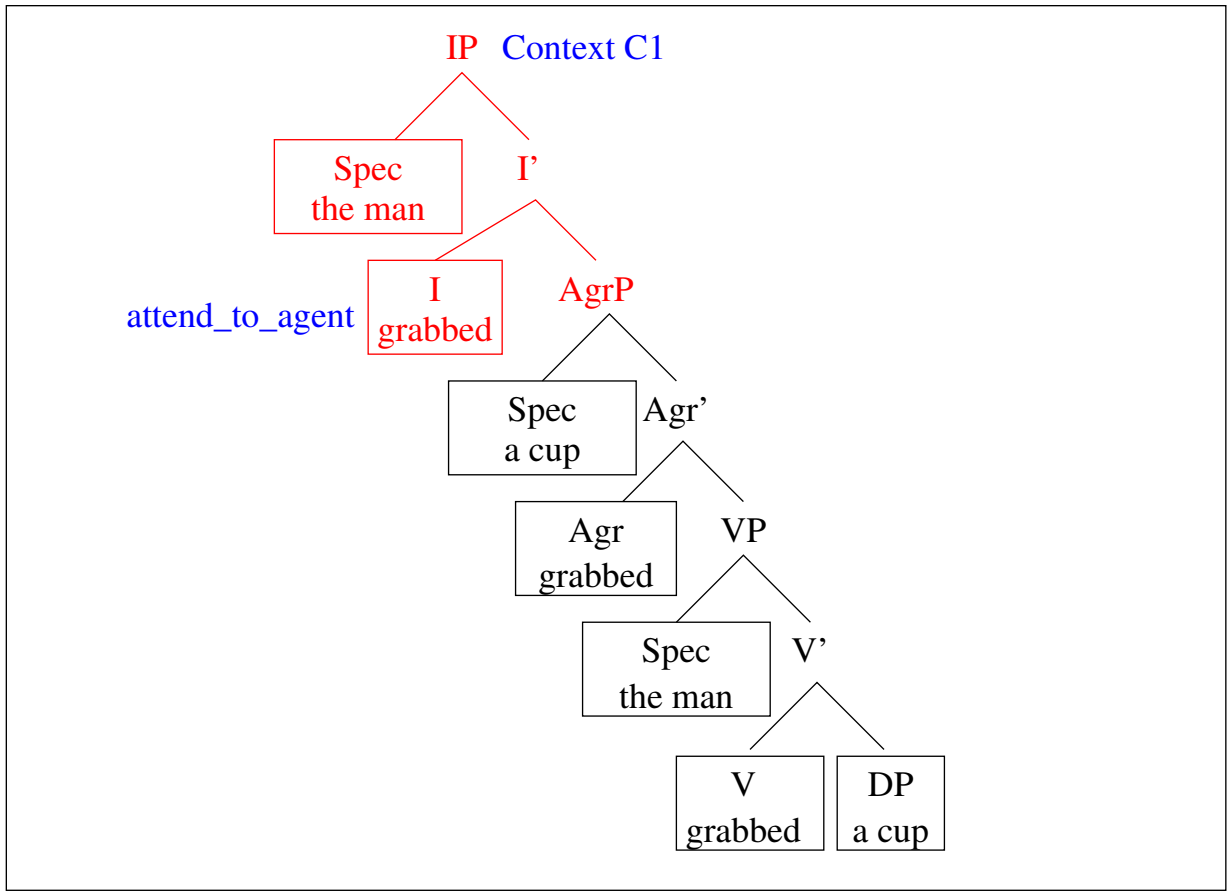

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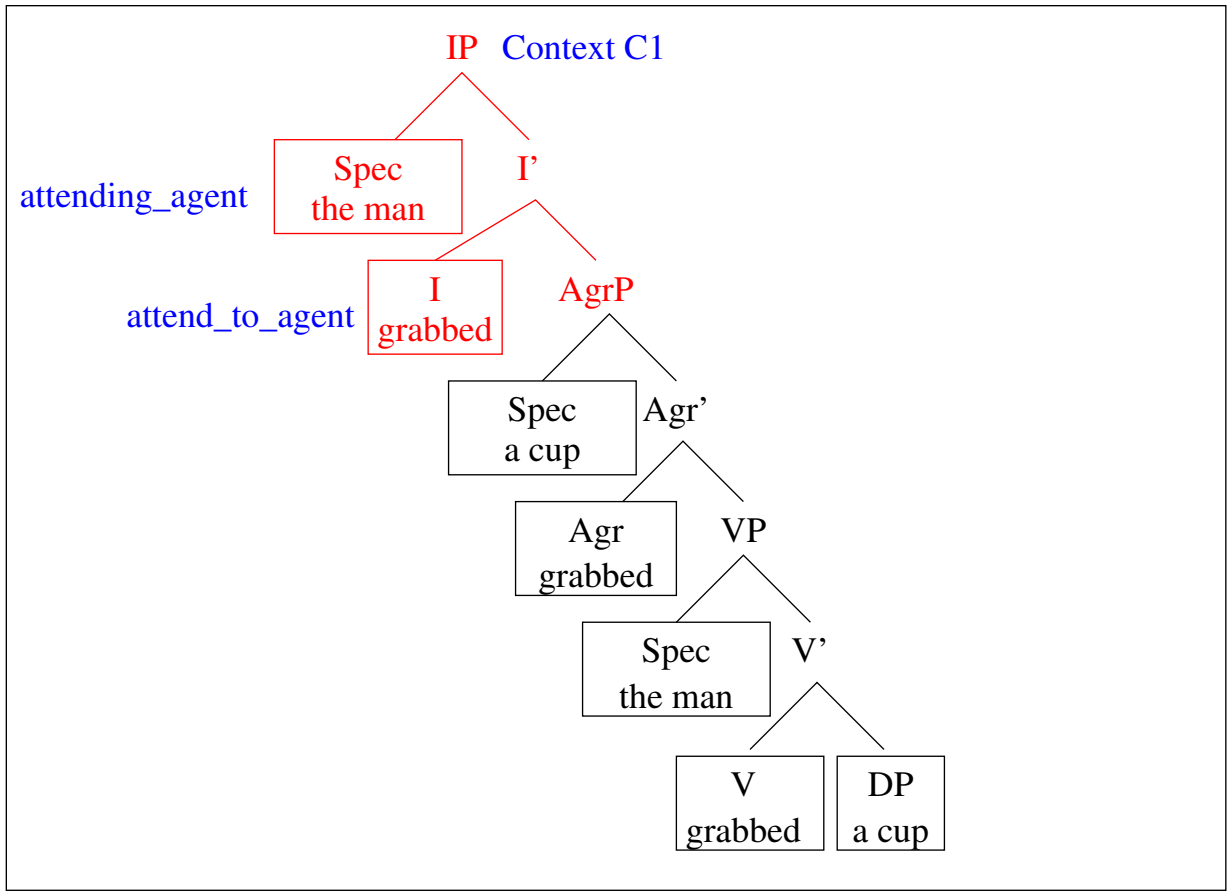

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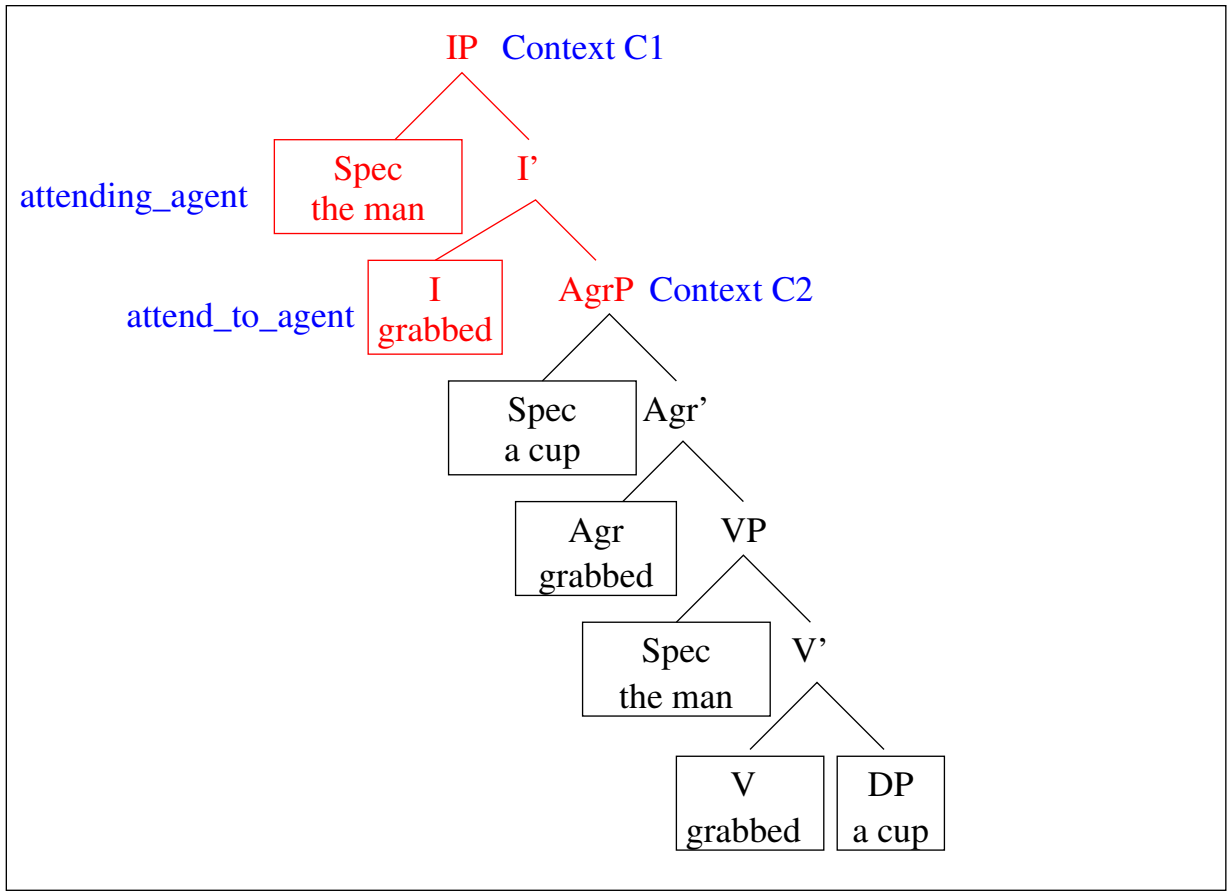

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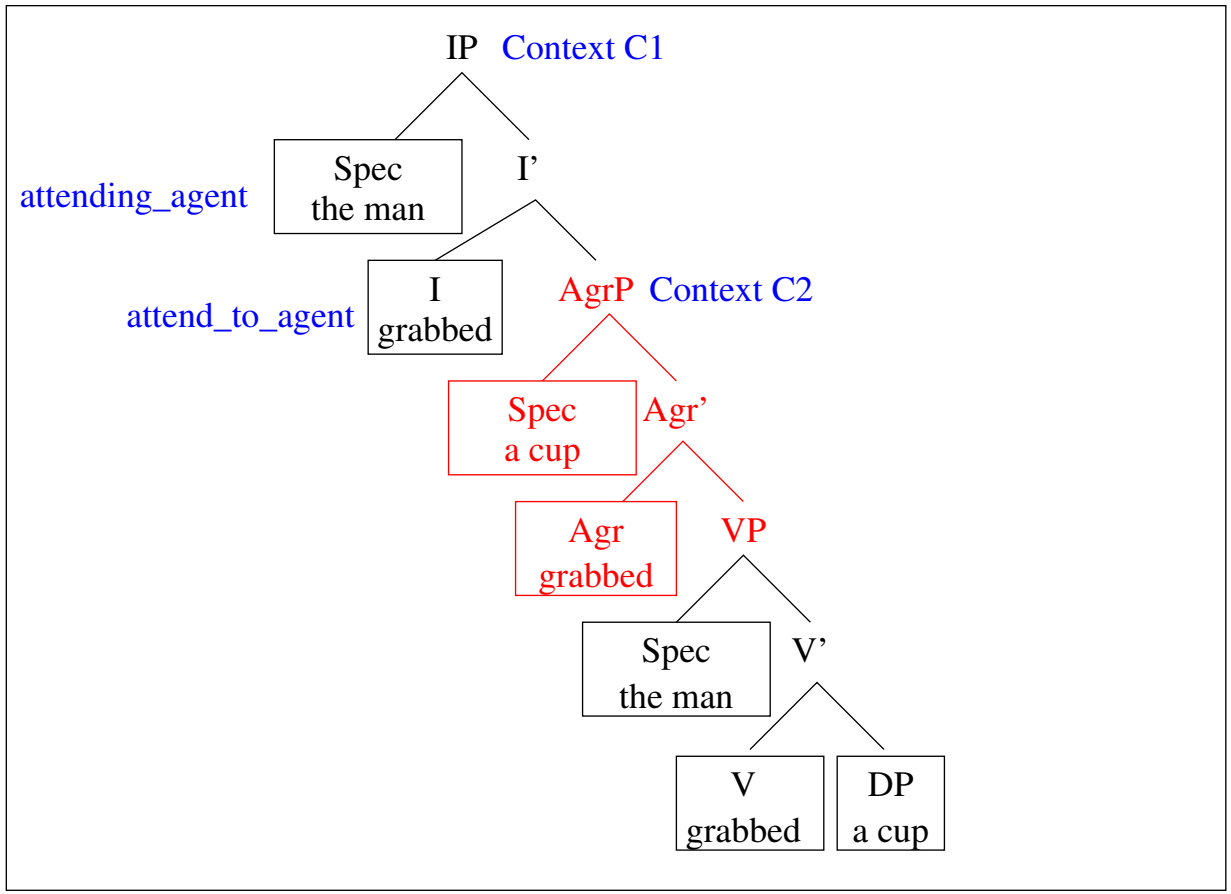

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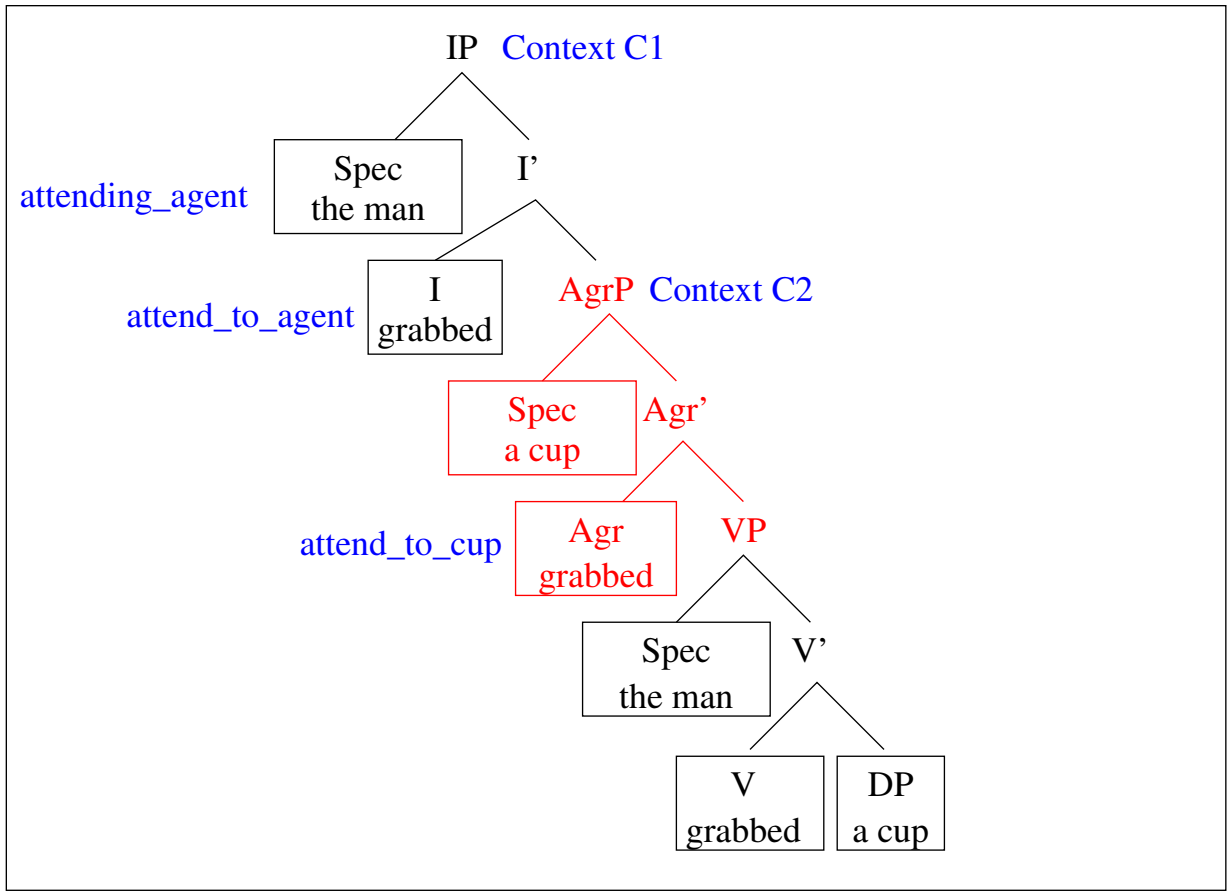

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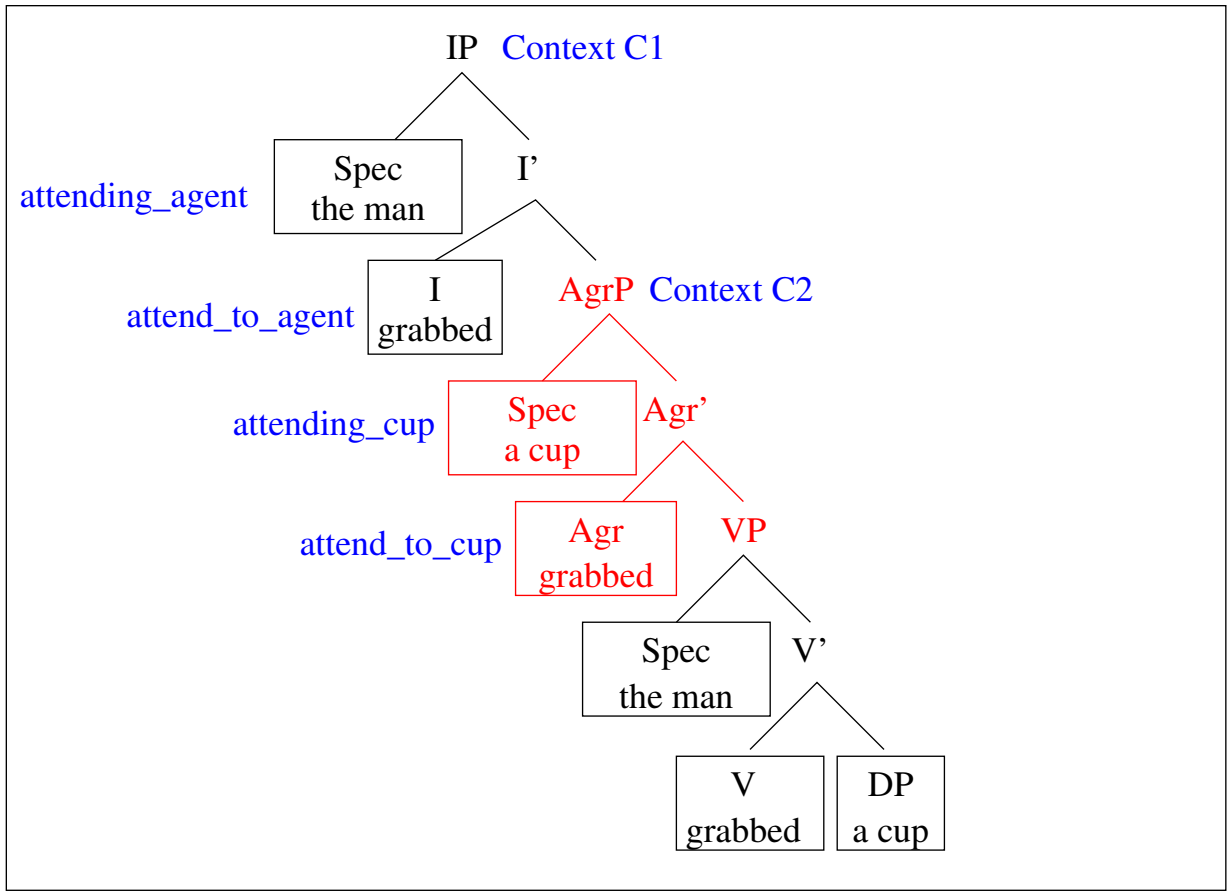

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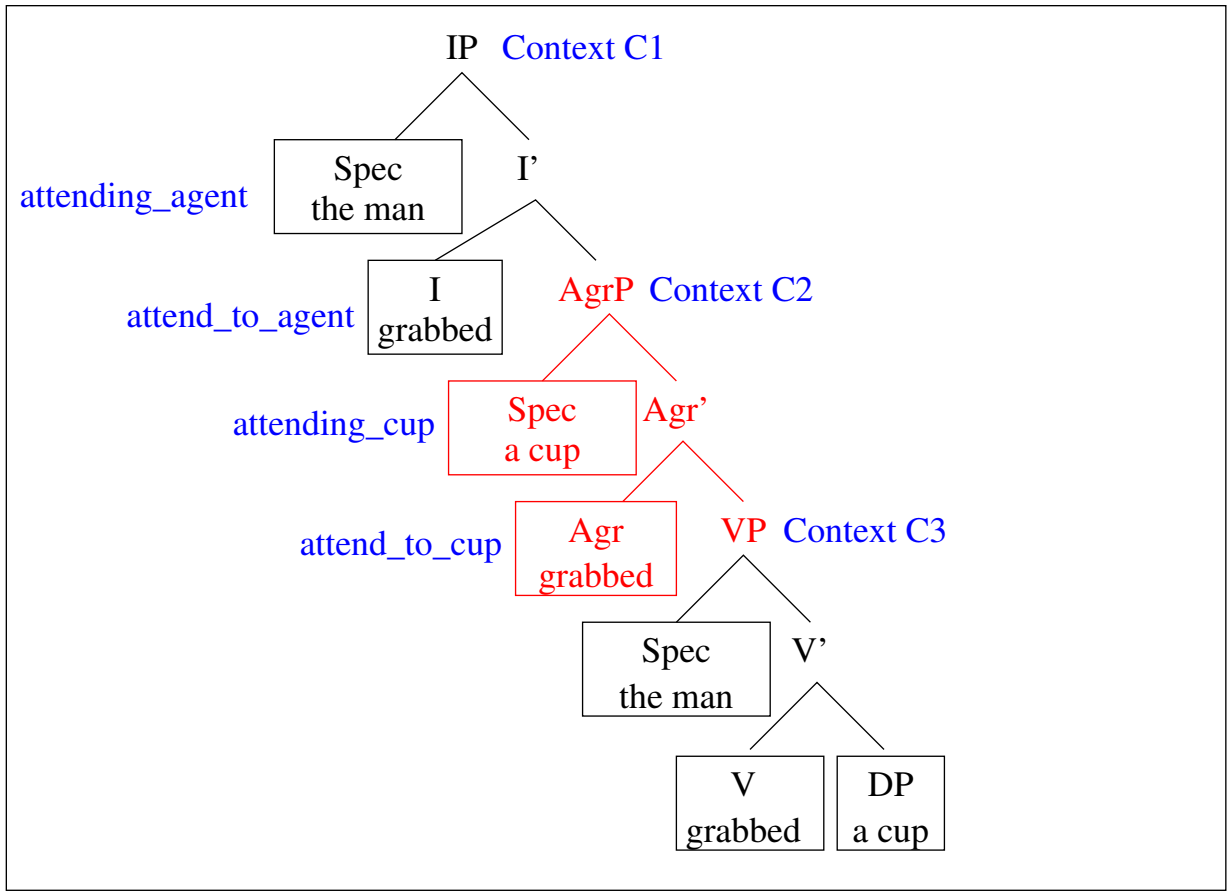

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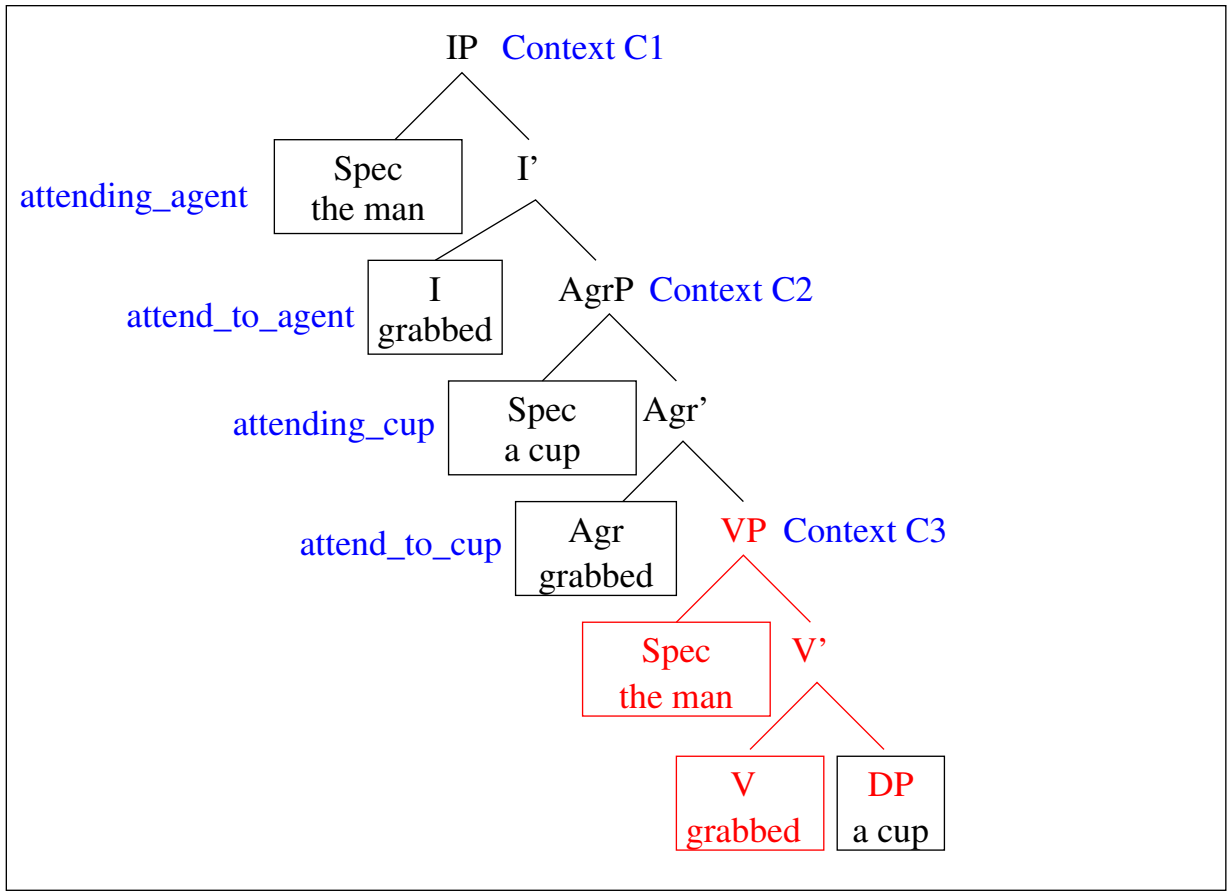

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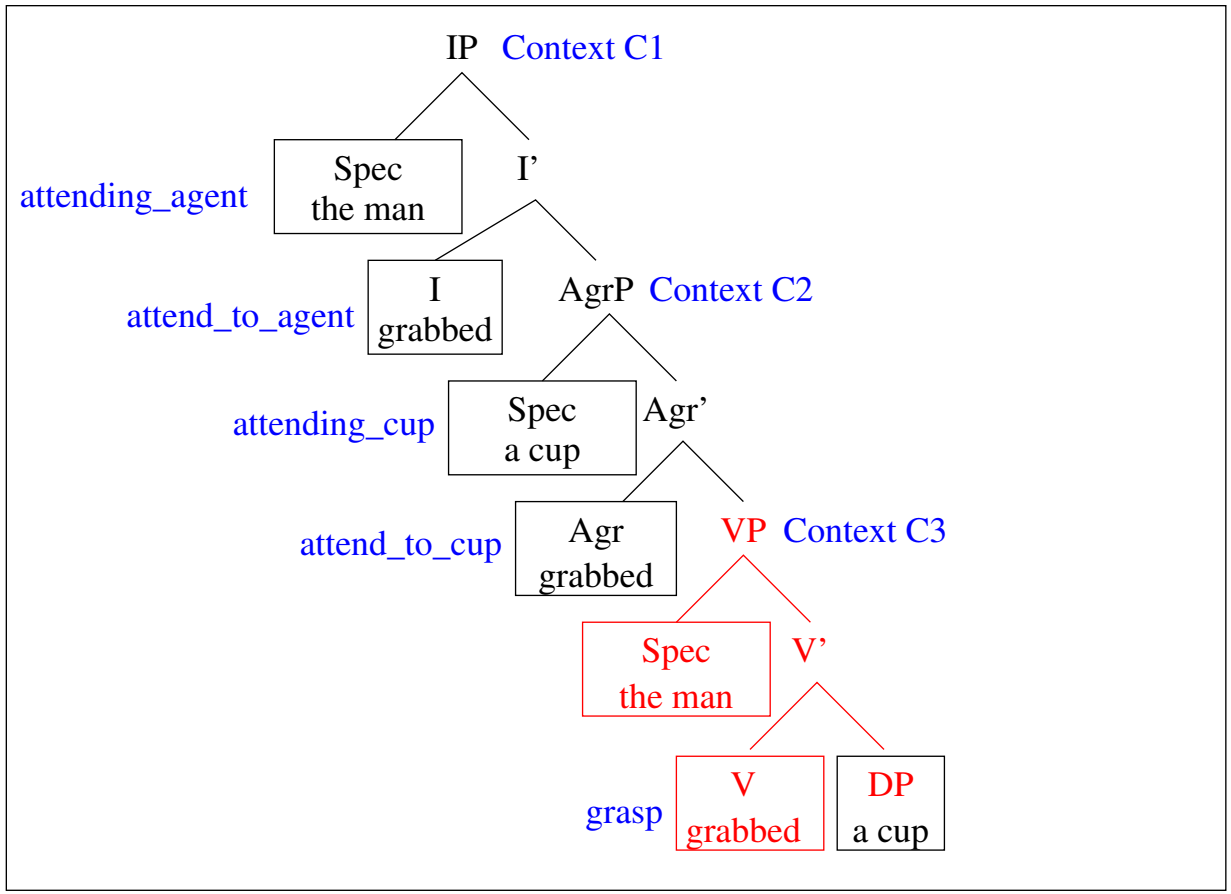

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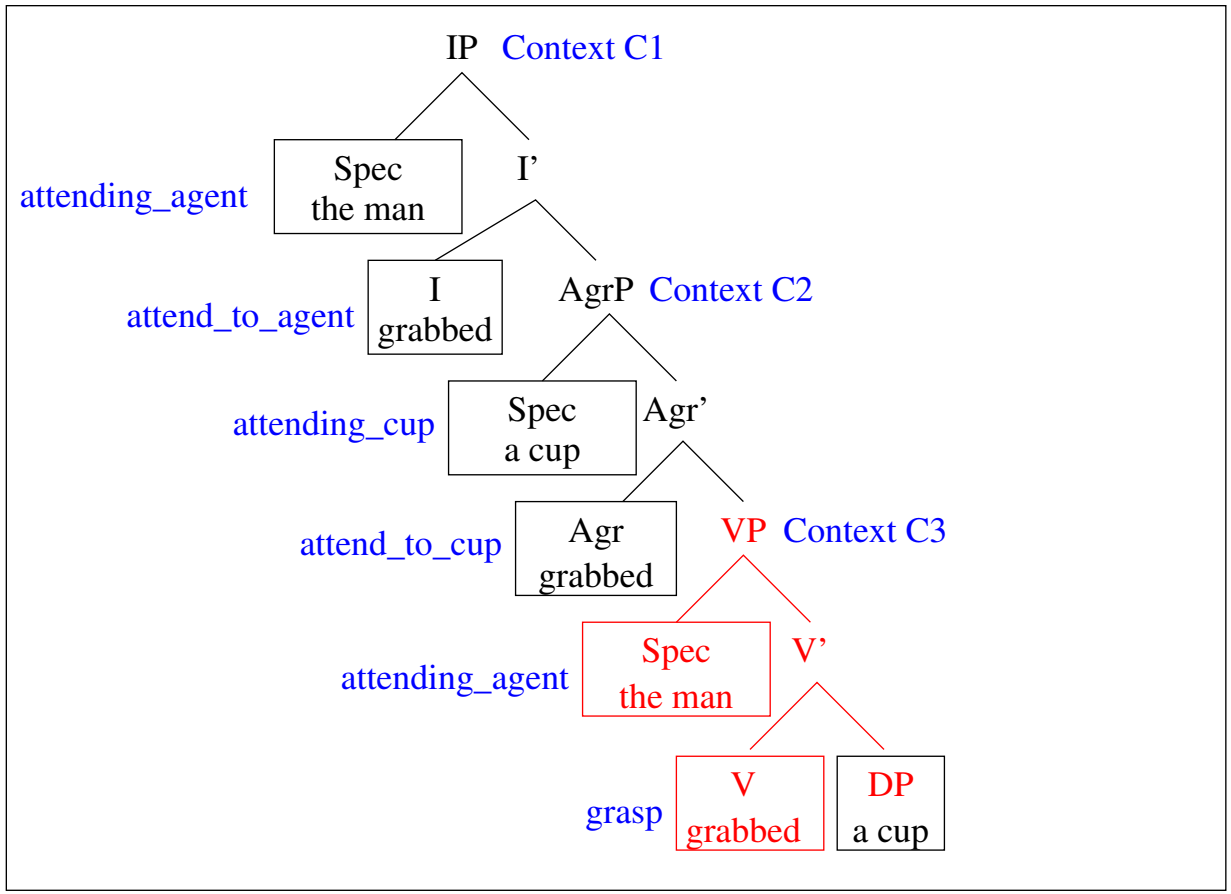

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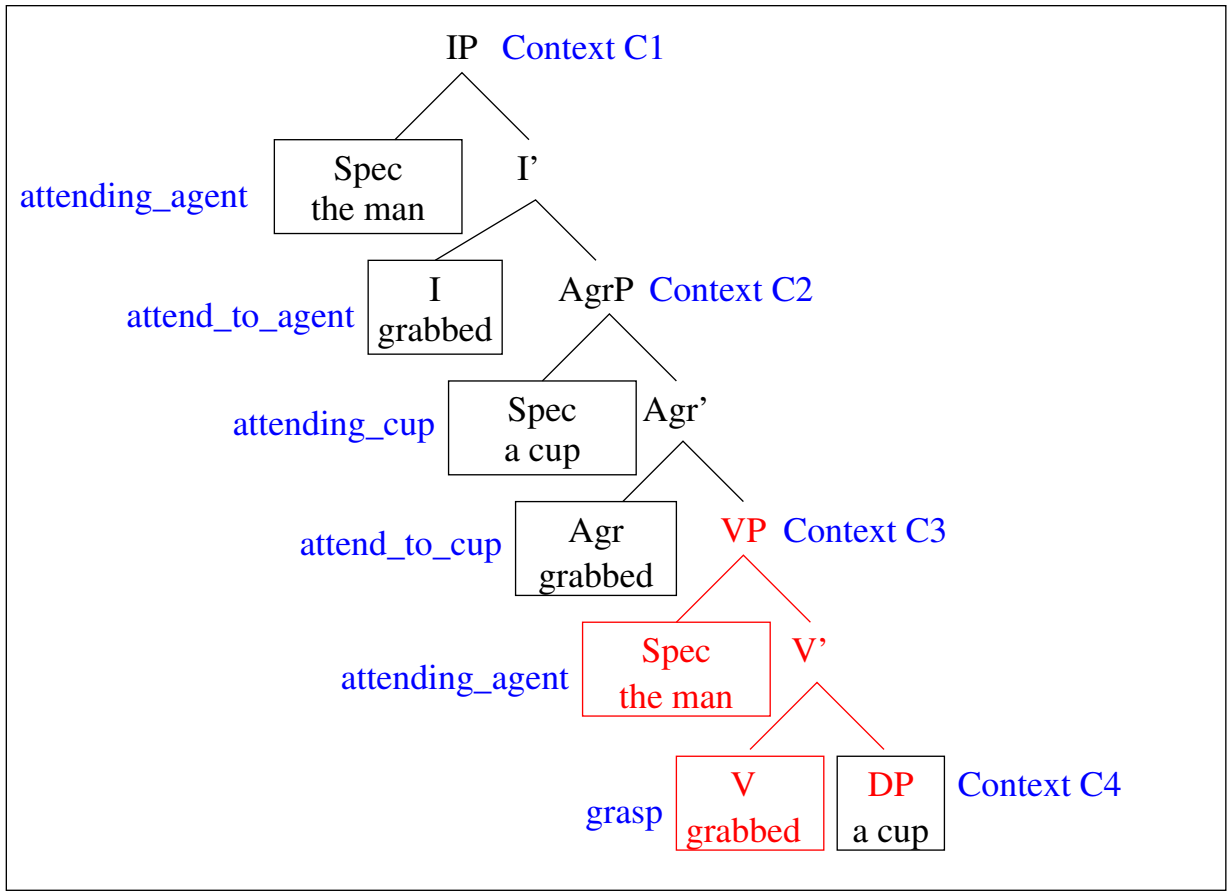

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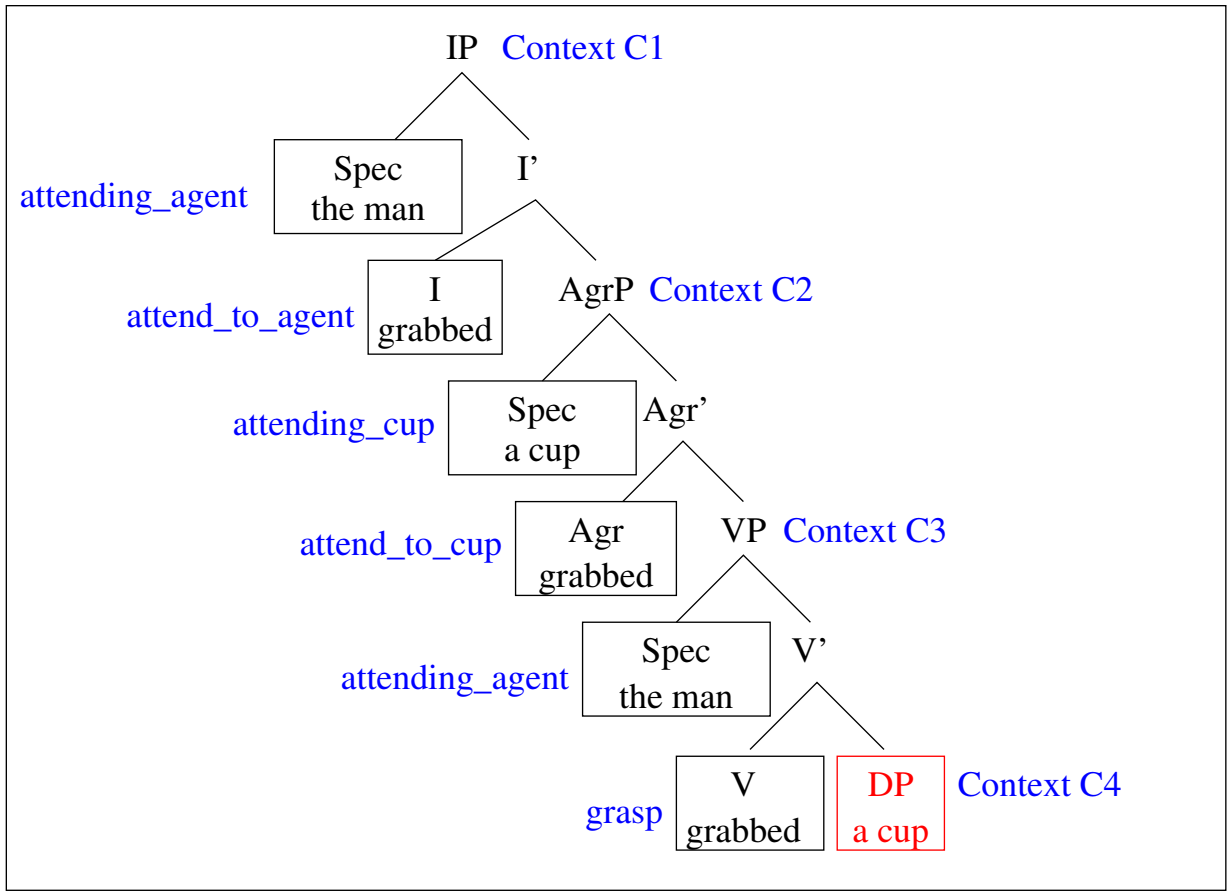

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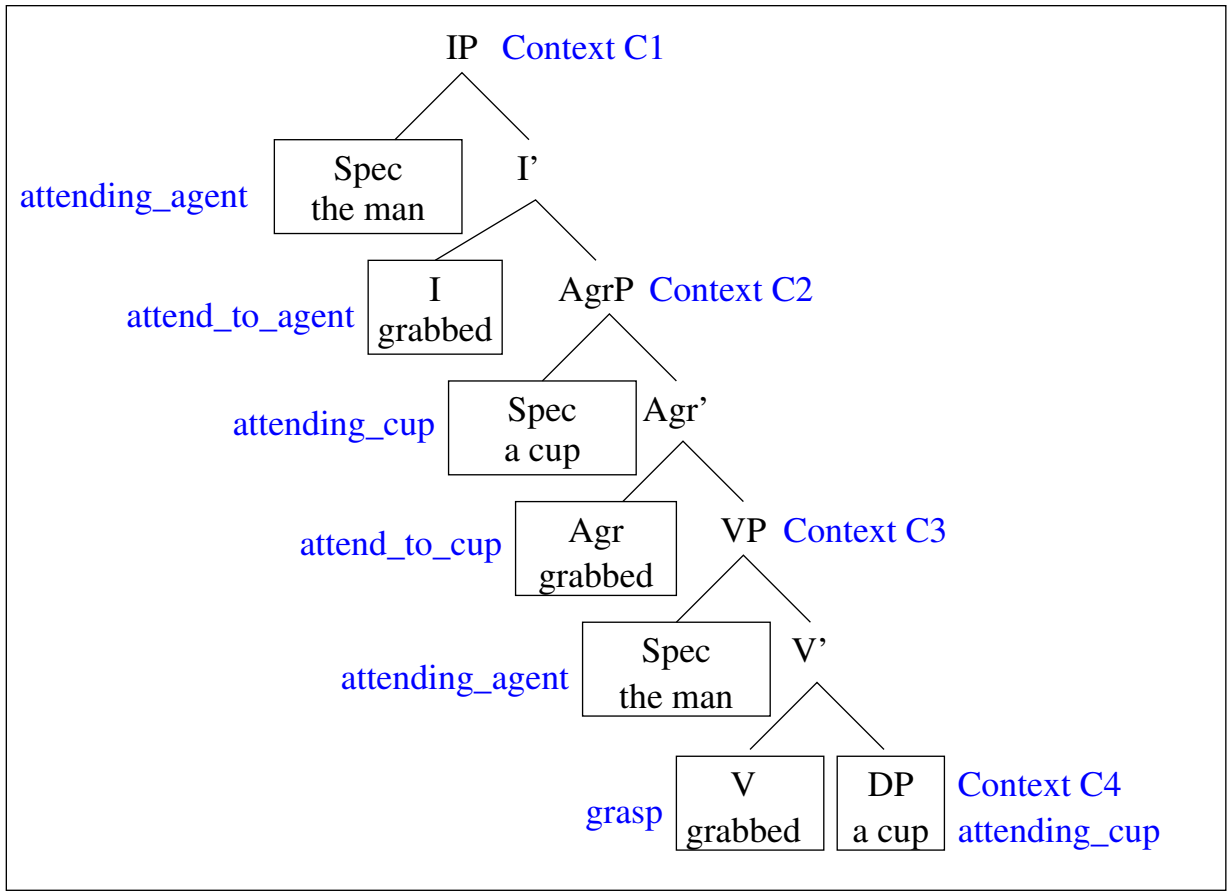
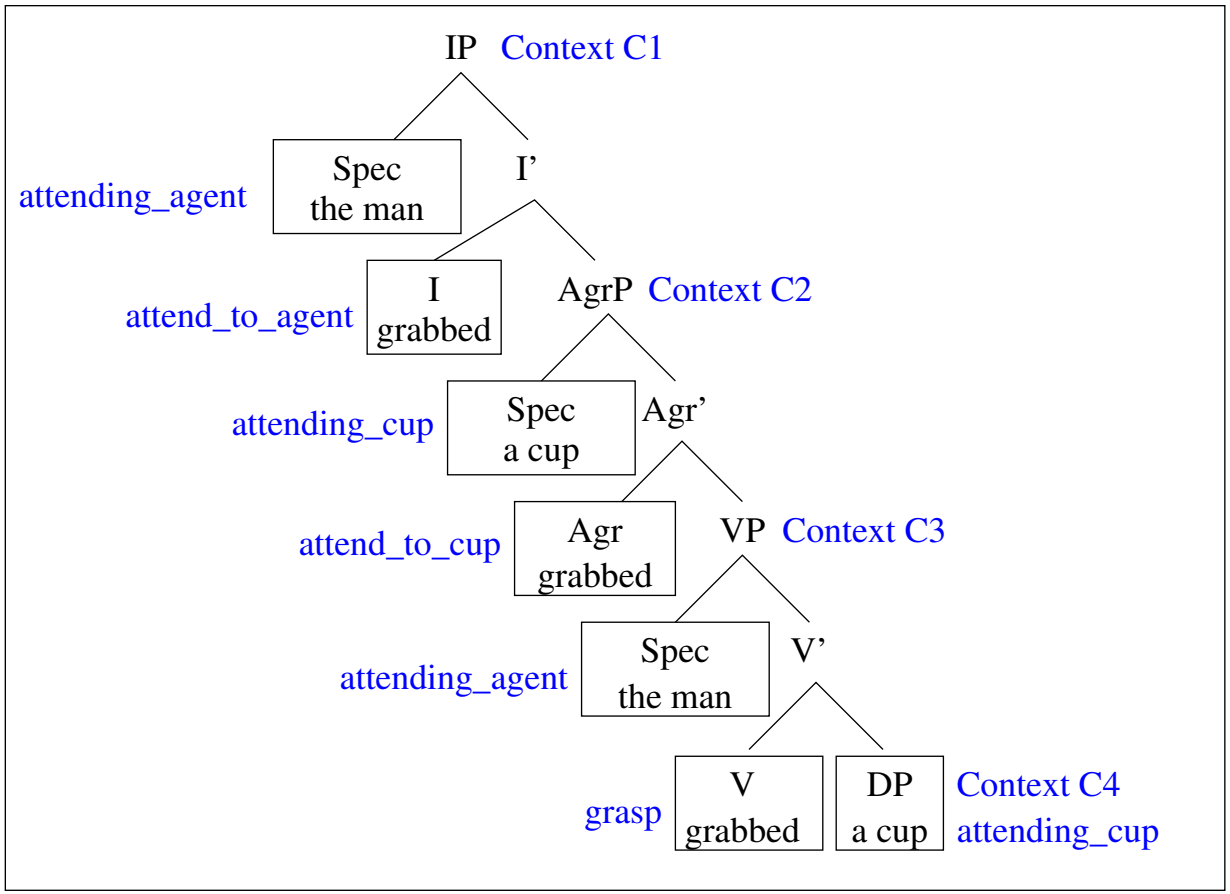


SM interpretation of the LF of *The man grabbed a cup*

So: what's the SM characterisation of movement?



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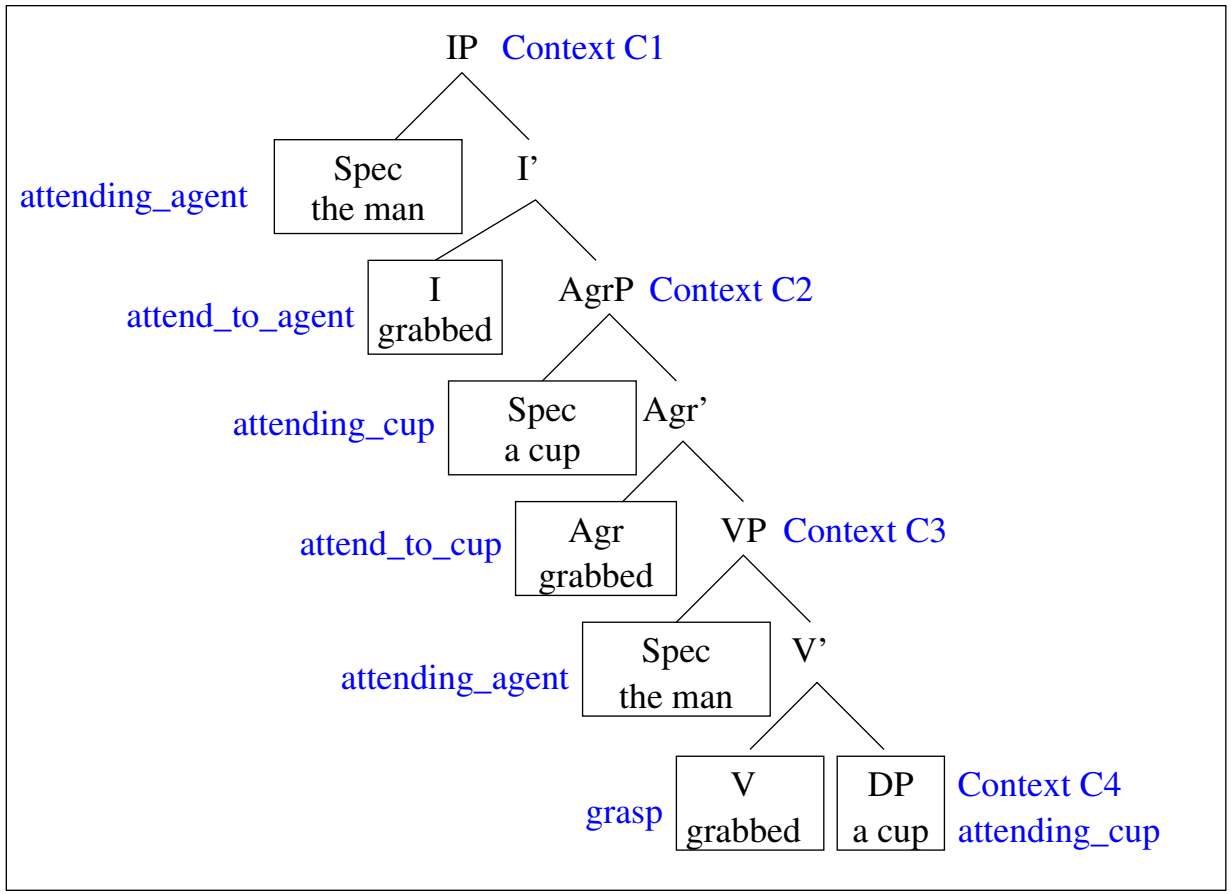

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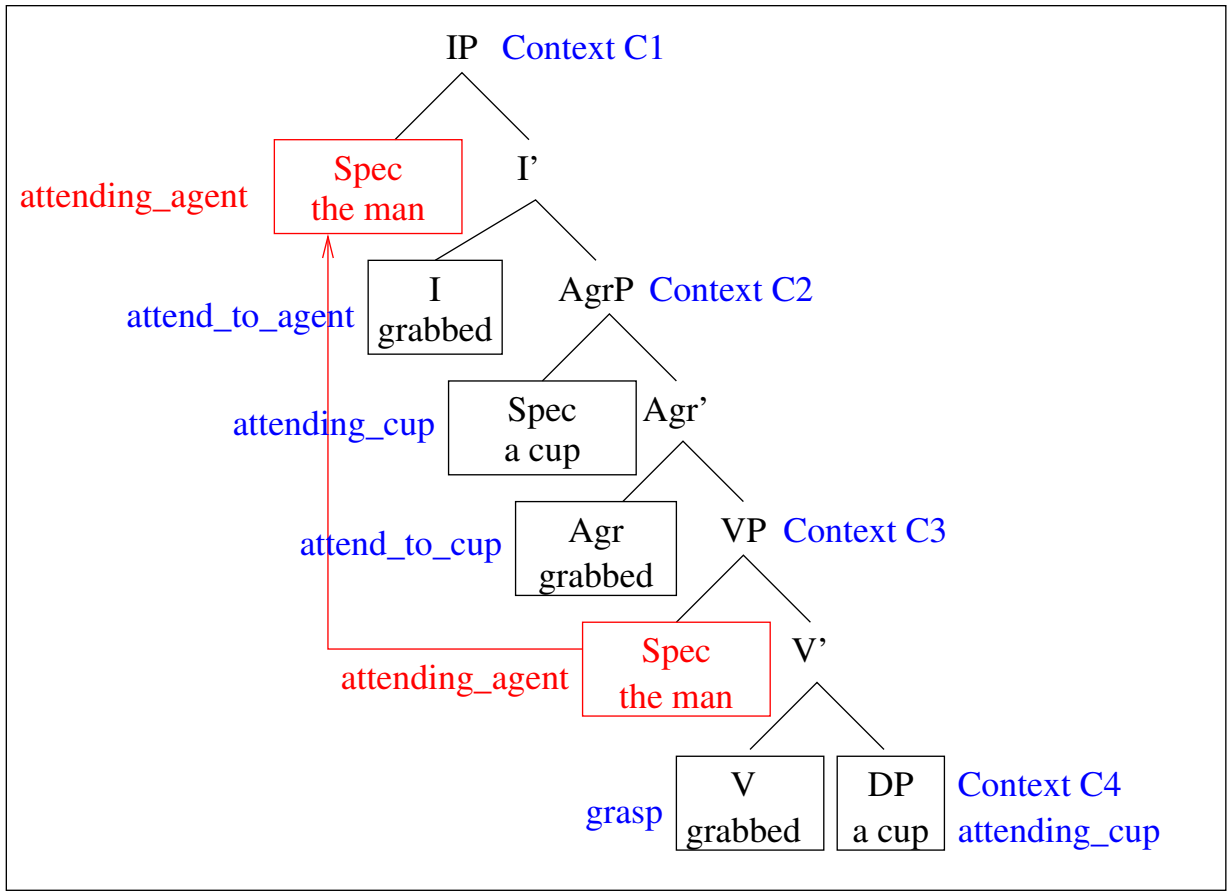

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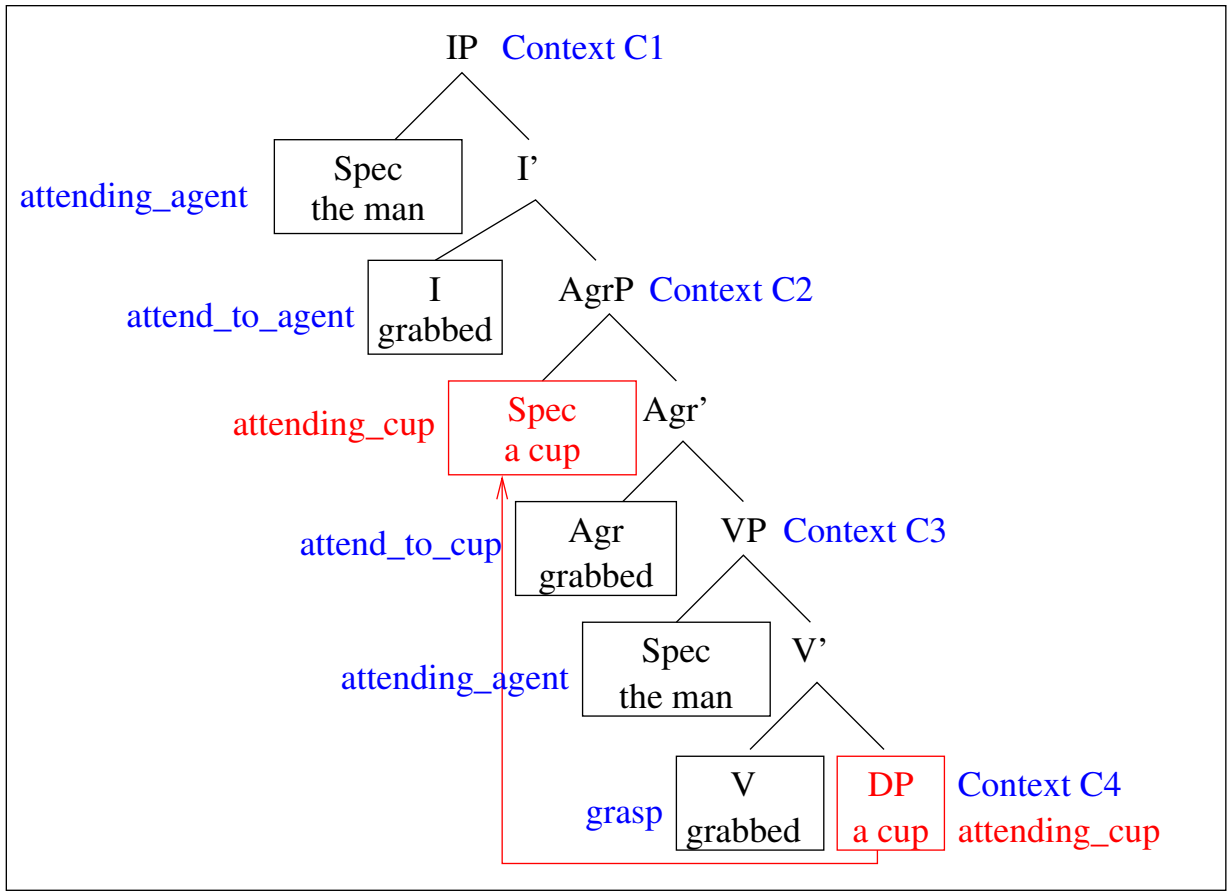

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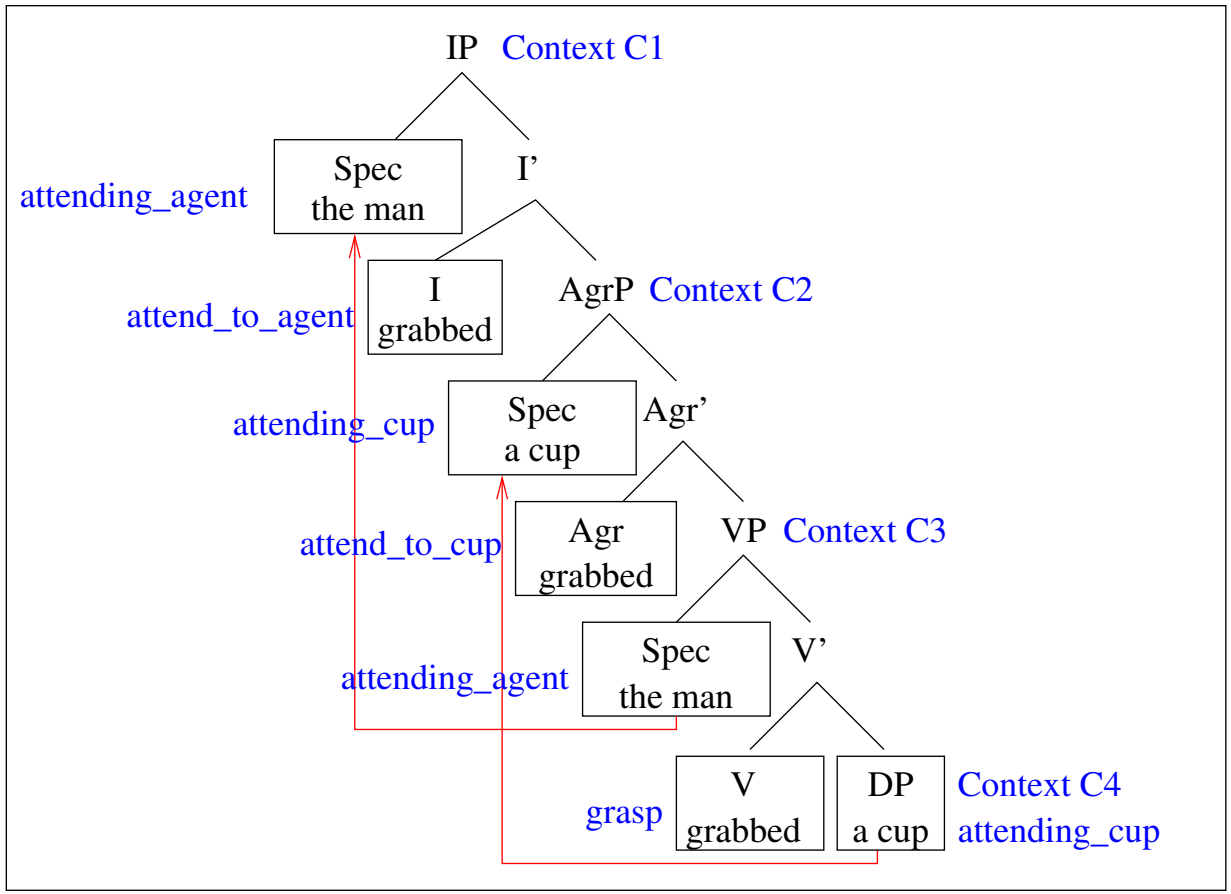
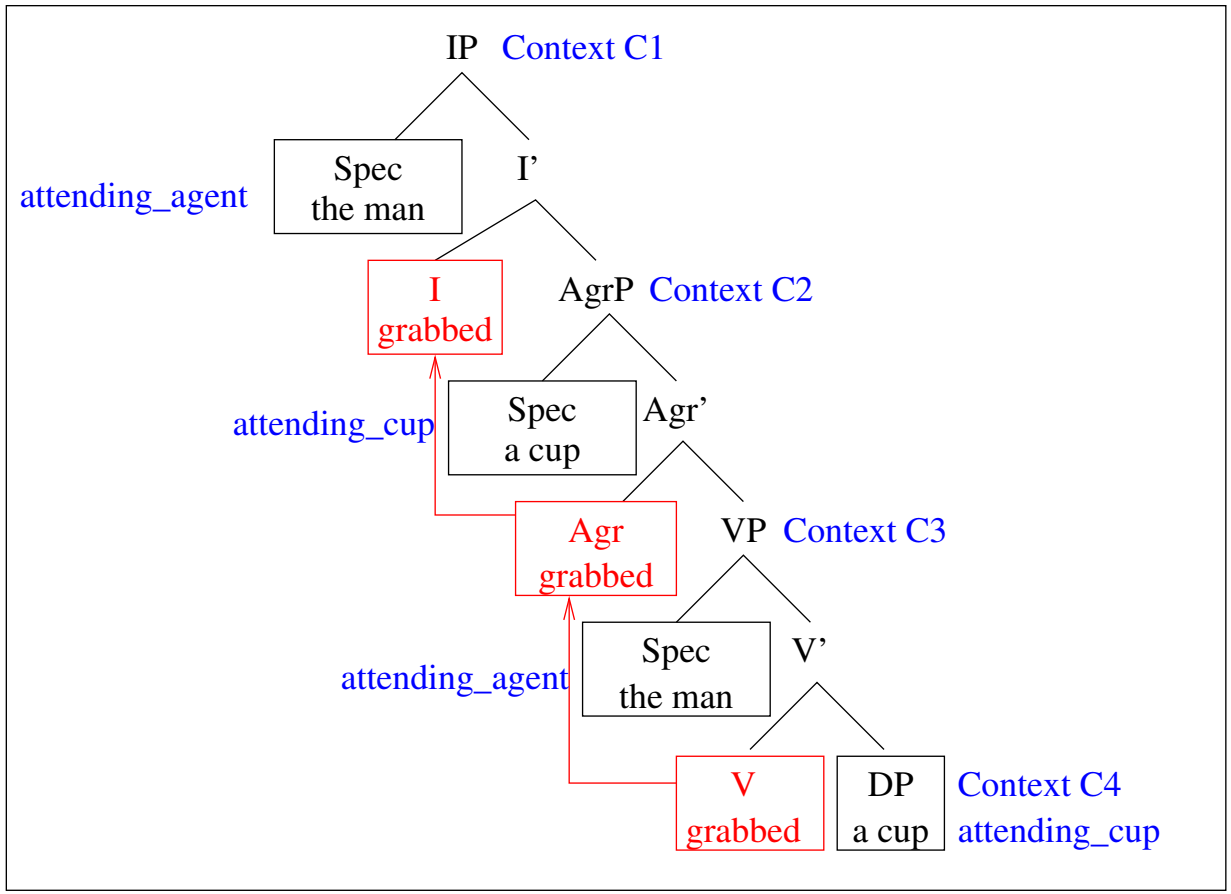
SM interpretation of 'DPs must raise to check Case':
Objects must be attended to before being involved in action monitoring.



SM interpretation of the LF of *The man grabbed a cup*

There's a neat SM interpretation of V-Agr-I raising too.



Language processing and syntactic development

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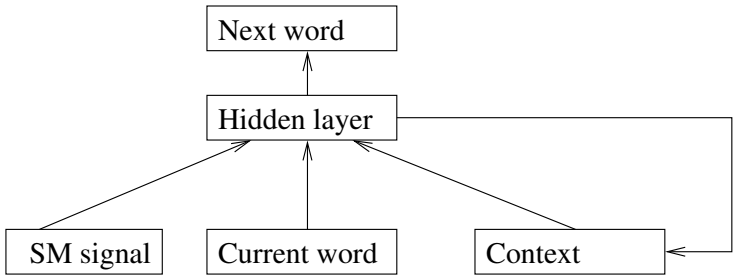
And of syntactic development:

- The agent learns which SM signals to 'read out' as words, and which to suppress.

Language processing and syntactic development

I have developed a neural network model of this generation/learning mechanism, which can handle idioms as well as productive syntactic constructions. (Joint work with Martin Takac and Lubica Benuskova.)



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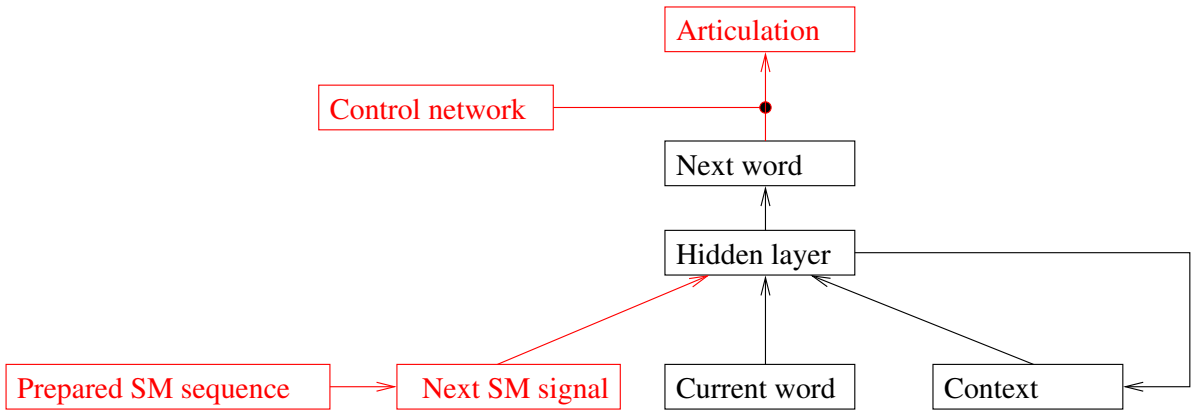

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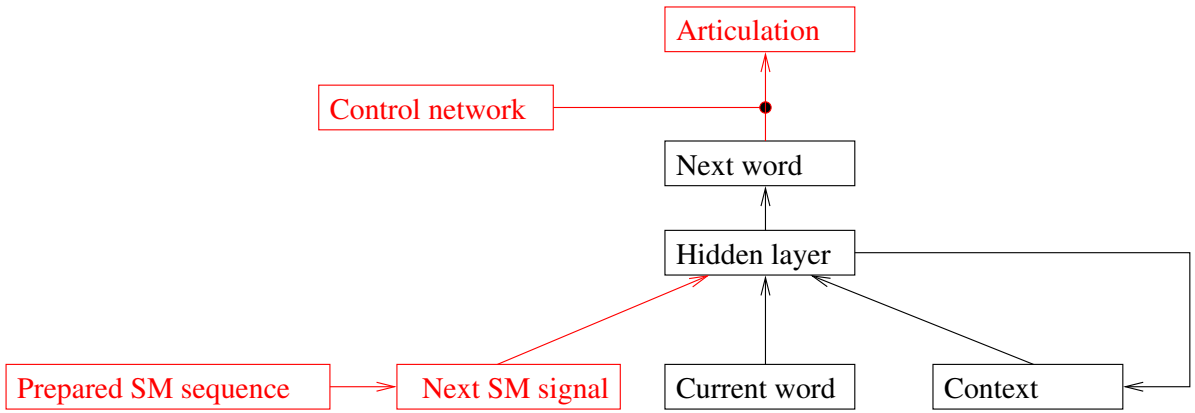

The model should look familiar to connectionist linguists. But it can also be interpreted by Minimalist linguists as a model of how speakers learn to set 'UG parameters' governing word order.

Beyond grabbing cups

I've just finished a book, called *Sensorimotor cognition and natural language syntax*, which goes into detail about all the models just described. (See my publications webpage.)

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The book also extends the SM interpretation of LF to several other constructions:

- The internal structure of noun phrases
- Predicative clauses
- Quantification
- Relative clauses.

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- A circuit evolves for mapping static SM signals to overt behaviours, allowing the production of simple word sequences.
- A new circuit evolves, co-opting the simple language circuit and the SM sequence rehearsal mechanism, which generates word sequences *from SM sequences*.