An embodied account of the syntactic domain of verbs

Alistair Knott

Department of Computer Science, University of Otago
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.

\[
S \rightarrow \text{subject} \rightarrow \text{VP} \rightarrow \text{V} \rightarrow \text{smile}
\]
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.

```
S
  VP
    V
      kiss
```
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.

\[ S \rightarrow \text{VP} \rightarrow \text{V} \rightarrow \text{put} \]
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It determines how many argument positions there are in the clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.

In some languages, the subject must agree with the verb:
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.

In some languages, the subject must agree with the verb:

John feeds[3/sing] the goats
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.

In some languages, the subject must agree with the verb:

The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.

In some languages (e.g. Hindi), the object must agree with the verb.

John banana bought[masc/plur]
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

It can transmit its agreement features to its arguments.

In some languages (e.g. Hindi), the object must agree with the verb.

John banana[masc/plur] bought[masc/plur]
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

Verbs can appear at different positions within a clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

Verbs can appear at different positions within a clause.

They appear ‘high’ in VSO languages (e.g. Māori):

Chased John the dog
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

Verbs can appear at different positions within a clause.
The syntactic domain of verbs

The main verb of a clause exerts influence over the whole clause.

Verbs can appear at different positions within a clause.

They appear ‘low’ in SVO/SOV languages:

John [chased the dog] (English)
John it [chased] (French)
Chomsky’s account of the syntactic domain of verbs
Chomsky’s account of the syntactic domain of verbs

Chomsky’s Minimalist model:
Chomsky’s account of the syntactic domain of verbs

Chomsky’s Minimalist model:

1. Sentences have a phonetic form (PF), but also a *logical form* (LF).
   - The LF of a sentence represents its semantic structure.
   - LF is relatively invariant across languages.
Chomsky’s account of the syntactic domain of verbs

Chomsky’s Minimalist model:

1. Sentences have a phonetic form (PF), but also a logical form (LF).
   - The LF of a sentence represents its semantic structure.
   - LF is relatively invariant across languages.

2. In the LF of a sentence, the main verb appears at *multiple positions.*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*

Is there any analogue of the verb's extended syntactic domain in the sensorimotor system?
Is there any analogue of the verb’s extended syntactic domain in the sensorimotor system?
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*

Is there any analogue of the verb's extended syntactic domain in the sensorimotor system?

Alistair Knott (Univ. Otago)
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*
The LF structure of *The man grabs a cup*

Is there any analogue of the verb's extended syntactic domain in the sensorimotor system?
The LF structure of *The man grabs a cup*

- **AgrSP**
  - man
  - AgrS'
- **AgrS**
  - grabs
- **AgrOP**
  - cup
  - AgrO'
- **AgrO**
  - grabs
- **VP**
  - man
  - V'
  - V
  - cup

Is there any analogue of the verb's extended syntactic domain in the sensorimotor system?

Alistair Knott (Univ. Otago)
The LF structure of *The man grabs a cup*

Is there any analogue of the verb’s extended syntactic domain in the sensorimotor system?
Embodied accounts of sentence semantics

Embodied linguists often claim that episodes are represented as *simulations* of sensorimotor (SM) experiences (see e.g. Glenberg and Robertson, 1999; Feldman and Narayanan, 2004; Barsalou, 2008).

In a book last year, I proposed that Minimalist LF structures can be interpreted as descriptions of simulated SM routines (Knott, 2012).
Embodied accounts of sentence semantics

Embodied linguists often claim that episodes are represented as simulations of sensorimotor (SM) experiences (see e.g. Glenberg and Robertson, 1999; Feldman and Narayanan, 2004; Barsalou, 2008).

In a book last year, I proposed that Minimalist LF structures can be interpreted as descriptions of simulated SM routines (Knott, 2012).

Episodes are experienced in canonical sequences of SM operations:

<table>
<thead>
<tr>
<th>Initial context</th>
<th>SM operation</th>
<th>Reafferent signal</th>
<th>New context</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>attend_man</td>
<td>man</td>
<td>C₂</td>
</tr>
<tr>
<td>C₂</td>
<td>attend_cup</td>
<td>cup</td>
<td>C₃</td>
</tr>
<tr>
<td>C₃</td>
<td>grab</td>
<td>man</td>
<td>C₄ / cup</td>
</tr>
</tbody>
</table>
Embodied accounts of sentence semantics

Embodied linguists often claim that episodes are represented as *simulations* of sensorimotor (SM) experiences (see e.g. Glenberg and Robertson, 1999; Feldman and Narayanan, 2004; Barsalou, 2008).

In a book last year, I proposed that *Minimalist LF structures can be interpreted as descriptions of simulated SM routines* (Knott, 2012).

Each XP in an LF denotes a single SM operation:

```
XP
spec   X'
   X   comp
```
Embodied accounts of sentence semantics

Embodied linguists often claim that episodes are represented as *simulations* of sensorimotor (SM) experiences (see e.g. Glenberg and Robertson, 1999; Feldman and Narayanan, 2004; Barsalou, 2008).

In a book last year, I proposed that *Minimalist LF structures can be interpreted as descriptions of simulated SM routines* (Knott, 2012).

Each XP in an LF denotes a single SM operation:
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

AgrSP
- man
  - AgrS'
    - AgrS
      - 3/sing
        - AgrOP
          - cup
            - AgrO'
              - AgrO
                - 3/sing
                  - VP
                    - man
                      - V'
                        - V
                          - grab
                            - cup
A right-branching LF structure describes a simulated sequence of SM operations.

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

A list of operations involves:
- Attention to man
- Attention to cup
- Grasp monitoring routine

The diagram illustrates the sequence of operations:
1. AgrSP ← C1
2. AgrSP → AgrS'
   - AgrS
     - AgrOP
       - AgrO'
         - VP
           - V'
             - cup
           - man
             - V
               - grab
         - 3/sing
       - cup
     - man
       - 3/sing
   - man
     - attention to man
   - AgrS
     - AgrS'
       - attention to cup

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.

Alistair Knott (Univ. Otago)
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

AgrSP ← C1
man
AgrS'
AgrS
AgrOP ← C2
3/sing
cup
AgrO'
AgrO
VP
man
3/sing
cup
grab
V

Attention to man
Attention to cup
Grasp monitoring routine
Attend-to-man
Attend-to-cup

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

AgrSP  \[\text{C1}\]
\[\text{man}\]
AgrS'
AgrS
AgrOP  \[\text{C2}\]
\[\text{cup}\]
AgrO'
AgrO
VP
V'
man
\[\text{3/sing}\]
grab
\[\text{3/sing}\]
cup

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
A right-branching LF structure describes a simulated sequence of SM operations.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

AgrSP → C1
AgrS'         attention to man
   man

AgrS → 3/sing
AgrOP ← C2
AgrO'         attention to cup
   cup

AgrO → 3/sing
VP ← C3
   man
   V'          grasp monitoring routine
      V
      cup

man

3/sing
grab

'cup'
attend-to-cup

'man'
attend-to-man

grasp monitoring routine
A right-branching LF structure describes a simulated sequence of SM operations.
SM interpretation of an LF structure

A right-branching LF structure describes a simulated sequence of SM operations.

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

Why can the verb and its inflections appear at every head position?

If LF encodes a simulated sequence, the SM operations in this sequence must be active throughout the simulation.
SM interpretation of an LF structure

Why can the verb and its inflections appear at every head position?

If LF encodes a simulated sequence, the SM operations in this sequence must be active *throughout the simulation.*
How are SM routines simulated?

My model of simulation starts from the premise that episodes are apprehended in canonical sequences of SM operations.
How are SM routines simulated?

My model of simulation starts from the premise that episodes are apprehended in canonical sequences of SM operations.

Proposal: episodes are stored in working memory as prepared sequences of discrete SM operations.

- Since they’re prepared SM sequences, they’re naturally replayable.
How are SM routines simulated?

My model of simulation starts from the premise that episodes are apprehended in canonical sequences of SM operations.

Proposal: episodes are stored in working memory as prepared sequences of discrete SM operations.

- Since they’re prepared SM sequences, they’re naturally replayable.

We know a lot about how sequences of attentional/motor operations are stored in the brain.

- For more, come to Takac and Knott, 2:30 Thurs!
Averbeck et al. (2002) trained monkeys to draw simple linear shapes.

- Drawing each shape involved a sequence of motor movements.
- There was a delay before the monkey began to draw.

- PFC cells were recorded during the delay and drawing periods.
Prefrontal representations of prepared SM sequences

Different PFC cells were sensitive to different movements.

These PFC cells were active in parallel.
Why do verbs have an extended syntactic domain?

A model of sentence generation (Takac et al., Cognition 2012):

A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words. Heads of XPs (verbs and agreement inflections) ‘report’ SM operations. Verbs and their inflections are read from representations of SM operations as they are planned, in prefrontal cortex, where they are active in parallel. They can therefore be pronounced at any stage during replay.

Processing of verbs and inflections activates prefrontal cortex (Shapiro & Caramazza, 2003; Cappeletti et al., 2008; Shapiro et al., 2012)
Why do verbs have an extended syntactic domain?

A model of sentence generation (Takac et al., Cognition 2012):

A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words. Heads of XPs (verbs and agreement inflections) ‘report’ SM operations. Verbs and their inflections are read from representations of SM operations as they are planned, in prefrontal cortex, where they are active in parallel. They can therefore be pronounced at any stage during replay.

Processing of verbs and inflections activates prefrontal cortex (Shapiro & Caramazza, 2003; Cappeletti et al., 2008; Shapiro et al., 2012).
Why do verbs have an extended syntactic domain?

A model of sentence generation (Takac et al., Cognition 2012):

- A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words.
A model of sentence generation (Takac et al., Cognition 2012):

- A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words.
- Heads of XPs (verbs and agreement inflections) ‘report’ SM operations.
Why do verbs have an extended syntactic domain?

A model of sentence generation (Takac et al., Cognition 2012):

- A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words.
- Heads of XPs (verbs and agreement inflections) ‘report’ SM operations.
- Verbs and their inflections are read from representations of SM operations as they are planned, in prefrontal cortex, where they are active in parallel. They can therefore be pronounced at any stage during replay.
Why do verbs have an extended syntactic domain?

A model of sentence generation (Takac *et al.*, Cognition 2012):

- A sentence is generated by replaying a SM sequence in a special mode where SM signals can trigger surface words.
- Heads of XPs (verbs and agreement inflections) ‘report’ SM operations.
- Verbs and their inflections are read from representations of SM operations as they are planned, in prefrontal cortex, where they are active in parallel. They can therefore be pronounced at any stage during replay.

Processing of verbs and inflections activates prefrontal cortex (Shapiro & Caramazza, 2003; Cappeletti *et al.*, 2008; Shapiro *et al.*, 2012)
If sentence meanings are simulated SM routines, maybe the verb’s extended syntactic domain is because verbs denote SM operations as they are planned, in prefrontal cortex, where they are tonically active.