COSC451: Artificial Intelligence
Lecture 13: A sensorimotor interpretation of clause syntax

Alistair Knott
Dept. of Computer Science, University of Otago
Recap

My example sentence: The man grabbed a cup.
Recap

My example sentence: The man grabbed a cup.

The proposal I’m making:
Recap

My example sentence: **The man grabbed a cup.**

The proposal I’m making:

1. The sensorimotor processes involved in ‘experiencing’ the action of grabbing a cup have the form of a sequence.
Recap

My example sentence: The man grabbed a cup.

The proposal I’m making:

1. The sensorimotor processes involved in ‘experiencing’ the action of grabbing a cup have the form of a sequence.
2. This sequence is initially retained in working memory as a sequence plan, which can then be covertly replayed.
Recap

My example sentence:  **The man grabbed a cup.**

The proposal I’m making:

1. The sensorimotor processes involved in ‘experiencing’ the action of grabbing a cup have the form of a sequence.
2. This sequence is initially retained in working memory as a sequence plan, which can then be covertly replayed.
3. The ‘deep’ syntactic structure of the sentence can be read as a description of the process of replaying the working memory sequence (to long-term memory).
Replay of the WM sequence: timecourse of signals

<table>
<thead>
<tr>
<th>Sustained signals</th>
<th>Transient signals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plan</strong> attend_agent / attend_cup / grasp</td>
<td><strong>Context signals</strong></td>
</tr>
<tr>
<td></td>
<td>Context signals</td>
</tr>
<tr>
<td>( plan_{\text{attend}<em>\text{agent}/\text{attend}</em>\text{cup}/\text{grasp}} )</td>
<td>( C_1 )</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>attend_agent</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>attend_cup</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>grasp</td>
</tr>
</tbody>
</table>
The LF of *The man grabbed a cup*

The verb and its arguments originate in the VP.
The LF of *The man grabbed a cup*

The subject raises to [Spec,IP] to get Case.

```
  IP
     Spec I'
       I   AgrP
             Spec Agr'
                      Agr VP
                                         Spec the man
                                             V' V
                                          grabbed a cup
```

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The LF of *The man grabbed a cup*

The subject raises to [Spec, IP] to get Case.

```
Spec
  the man
I'
I
AgrP
Spec
  Agr'
Agr
VP
Spec
  V'
V
grabbed
DP
a cup
```
The LF of *The man grabbed a cup*

The subject raises to [Spec,IP] to get Case.
The LF of *The man grabbed a cup*

The object raises to [Spec,AgrP] to get Case.
The LF of *The man grabbed a cup*

The object raises to \([\text{Spec}, \text{AgrP}]\) to get Case.

```
IP
 / \      /     /
Spec  I'   I     AgrP
 /      /   /
Spec  Agr'  V'  Spec
  /   /   /     /  
Agr  VP  V     DP
 /  /  / /
grabbed
```
The LF of *The man grabbed a cup*

The object raises to [Spec,AgrP] to get Case.
The LF of *The man grabbed a cup*

The verb raises successively to the Agr and I heads.
The LF of *The man grabbed a cup*

The verb raises successively to the Agr and I heads.
The LF of *The man grabbed a cup*

The verb raises successively to the Agr and I heads.

```
IP
  Spec
  the man
  I'
  AgrP
    I
    grabbed
    Spec
    a cup
    Agr'
    VP
      Agr
      Spec
      V
      Spec
      V
      DP
```
The LF of *The man grabbed a cup*

The verb raises successively to the Agr and I heads.
The LF of *The man grabbed a cup*

Moved elements leave traces.

```
IP
  Spec
    the man
  I'
    AgrP
      Spec
        a cup
      Agr'
    Agr
      VP
        Spec
          the man
        V
          V
            grabbed
          DP
            a cup
```
Outline of today’s lecture

- The idea of a SM characterisation of LF.
- Proposal: a SM interpretation of LF.
My hypothesis:

‘An LF structure describes a sensorimotor process.’
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‘An LF structure describes a sensorimotor process.’

What does that mean?
My hypothesis:

‘An LF structure describes a sensorimotor process.’

What does that mean?

Consider the LF structure of The man grabbed a cup.
What is this, for a syntactician?

- It’s a structure from which the ‘meaning’ of the sentence can be extracted.
My hypothesis:

‘An LF structure describes a sensorimotor process.’

What does that mean?

Consider the LF structure of *The man grabbed a cup*.

What is this, for a syntactician?

- It’s also a description of how the mechanism which generates *all sentences* generated *this particular sentence*. 
My hypothesis:

‘An LF structure describes a sensorimotor process.’

What does that mean?

Consider the LF structure of *The man grabbed a cup*.

What is this, for a syntactician?

- It also expresses a hypothesis about ‘universal grammar’: the idea that at the level of LF, all languages are the same.
The idea of a SM characterisation of LF

My hypothesis:

‘An LF structure describes a sensorimotor process.’

What does that mean?

Consider the SM model of the cup-grabbing episode.

What does this provide?

- A model of how the episode is experienced.
  (Key idea: it’s a sequence.)
The idea of a SM characterisation of LF

My hypothesis:

‘An LF structure describes a sensorimotor process.’

What does that mean?

Consider the SM model of the cup-grabbing episode.

What does this provide?

- A model of how the episode is retained in WM.
  (Key idea: it’s stored as a ‘replayable’ sequence plan.)
The idea of a SM characterisation of LF

My hypothesis (more precisely):

‘An LF structure describes the process of replaying a sequence plan stored in WM.’
The idea of a SM characterisation of LF

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‘An LF structure describes the process of replaying a sequence plan stored in WM.’

What has that process got to do with sentence meaning?
The idea of a SM characterisation of LF

My hypothesis (more precisely):

‘An LF structure describes the process of replaying a sequence plan stored in WM.’

What has that process got to do with sentence meaning?

Proposal:

- We ‘entertain the meaning’ of the sentence *The man grabbed a cup* by rehearsing its associated SM sequence.
The idea of a SM characterisation of LF

My hypothesis (more precisely):

‘An LF structure describes the process of replaying a sequence plan stored in WM.’

What has that process got to do with a description of the generative mechanism?
The idea of a SM characterisation of LF

My hypothesis (more precisely):

‘An LF structure describes the process of replaying a sequence plan stored in WM.’

What has that process got to do with a description of the generative mechanism?

Proposal:

- The SM system (and the world) place constraints on the SM sequences which can be experienced.
- These constraints define the generative mechanism.
The idea of a SM characterisation of LF

My hypothesis (more precisely):

‘An LF structure describes the process of replaying a sequence plan stored in WM.’

What has that process got to do with universal grammar?
Universal grammar revisited

Linguists tend to think of the ‘generative mechanism’ as a Fodorian module.

But that’s not the only way to think about it.

- My proposal: the generative mechanism overlaps with SM mechanisms.
- Linguistic universals are then explained by the fact that we all have the same SM mechanisms.
The idea of a SM characterisation of LF

Reading LF as the trace of a replayed sequence

Timecourse of SM signals during the replayed cup-grabbing episode:

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>Planned action signals</td>
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</tr>
<tr>
<td>( \text{plan}<em>{\text{attend}</em>\text{agent}/\text{attend}_\text{cup}/\text{grasp}} )</td>
<td>( C_1 )</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>( \downarrow )</td>
</tr>
<tr>
<td>( \text{plan}<em>{\text{attend}</em>\text{agent}/\text{attend}_\text{cup}/\text{grasp}} )</td>
<td>( C_2 )</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>( \downarrow )</td>
</tr>
<tr>
<td>( \text{plan}<em>{\text{attend}</em>\text{agent}/\text{attend}_\text{cup}/\text{grasp}} )</td>
<td>( C_3 )</td>
</tr>
<tr>
<td>( \downarrow )</td>
<td>( \downarrow )</td>
</tr>
<tr>
<td>( \text{plan}<em>{\text{attend}</em>\text{agent}/\text{attend}_\text{cup}/\text{grasp}} )</td>
<td>( C_4 )</td>
</tr>
</tbody>
</table>
Proposal:

An XP schema describes a single iteration within a replayed SM sequence.
Proposal:

*An XP schema describes a single iteration within a replayed SM sequence.*

Each item in the XP schema has a SM interpretation.
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*An XP schema describes a single iteration within a replayed SM sequence.*

Each item in the XP schema has a SM interpretation.
Right-branching structures 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 *successive iterations* in the sequence.
Right-branching structures 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 *successive iterations* in the sequence.
SM interpretation of a transitive clause

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

\[
\begin{align*}
\text{VP} & \quad \text{Agr'} \quad \text{Spec a cup} \\
\text{Agr} & \quad \text{Spec the man} \\
\text{I'} & \quad \text{I} \quad \text{grabbed} \\
\text{IP} &
\end{align*}
\]

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SM interpretation of a transitive clause

The four LF projections map onto the four stages of the SM sequence.
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![Diagram showing SM interpretation of a transitive clause]
The four LF projections map onto the four stages of the SM sequence.
SM interpretation of a transitive clause

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A SM interpretation of LF phrase structure
SM interpretation of a transitive clause

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A SM interpretation of LF phrase structure

SM interpretation of a transitive clause

DP raising reflects operations of re-attention to agent and patient.
SM interpretation of a transitive clause

DP raising reflects operations of *re-attention to agent and patient.*
SM interpretation of a transitive clause

DP raising reflects operations of *re-attention to agent and patient.*
V-Agr-I raising reflects *tonically active planned action signals*.
V-Agr-I raising reflects *tonically active planned action signals.*
This model makes some concrete proposals about the semantic contributions of different types of lexical/morphological item.

- A verb stem like *grab* contributes a (planned) motor operation.
- An agreement inflection like ‘first person singular’ contributes a (planned) attentional operation.
- A DP contributes the reafferent sensory consequence of an attentional or motor operation. [First approximation.]

Do these make sense?
Some assumptions

These proposals can be thought of as hypotheses about connections between SM/WM areas and surface linguistic forms.

<table>
<thead>
<tr>
<th>Planned motor operations</th>
<th>Planned attentional operations</th>
<th>(Pre)motor operations</th>
<th>Attentional operations</th>
<th>Reafferent sensory consequences of attentional operations</th>
<th>Reafferent sensory consequences of motor operations</th>
<th>Context representations</th>
</tr>
</thead>
</table>

Idea: these are the basic interfaces which evolution happened to find.
Some assumptions

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<table>
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<tr>
<th>VERBS</th>
<th>NUMBER /PERSON inflections</th>
</tr>
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<tbody>
<tr>
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<td>Planned attentional operations</td>
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Some assumptions

These proposals can be thought of as hypotheses about connections between SM/WM areas and surface linguistic forms.

![Diagram showing connections between planned motor operations, planned attentional operations, (Pre)motor operations, attentional operations, reafferent sensory consequences of attentional operations, reafferent sensory consequences of motor operations, and context representations.](image-url)
Some assumptions

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![Diagram of connections between verbal and noun categories and operations involving attention and motor functions.](image)
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[Diagram showing connections between planned attentional operations, (pre)motor operations, attentional operations, reafferent sensory consequences of attentional operations, reafferent sensory consequences of motor operations, and context representations.]

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### Outline of the rest of the course

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>L15</td>
<td>How ‘surface language’ is represented in the brain: neural and</td>
</tr>
<tr>
<td></td>
<td>developmental models of language</td>
</tr>
<tr>
<td>L16</td>
<td>A neural network for learning words</td>
</tr>
<tr>
<td>L17</td>
<td>A neural network for learning clause syntax (the LF-PF mapping)</td>
</tr>
<tr>
<td>L18</td>
<td>SM and syntactic representations of objects</td>
</tr>
<tr>
<td>L19</td>
<td>SM and syntactic representations of predicates and quantified</td>
</tr>
<tr>
<td></td>
<td>propositions</td>
</tr>
<tr>
<td>L20</td>
<td>Revision</td>
</tr>
</tbody>
</table>