Modeling garden path effects without explicit hierarchical syntax

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Introduction

Syntactically ambiguous sentences can lead to misinterpretations, causing slower reading than unambiguous sentences at disambiguation point (garden path effect).

- Can models without explicit hierarchical syntax predict garden path effects?
- Can word predictability alone explain magnitude of garden path effects?

Linking Hypothesis

Smith & Levy (2013): 1 bit surprisal = 3.75 ms reading time

\[
surprisal(w_i) = -\log_2 P(w_i | w_1, \ldots w_{i-1})
\]

Grammar-Based Language Models

Top-Down Beam Refined Grammar

<table>
<thead>
<tr>
<th>Parser</th>
<th>Beam</th>
<th>Refined Grammar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-Down [4]</td>
<td>( \gamma = 10^{-11} )</td>
<td>0 PTB</td>
</tr>
<tr>
<td>Left-Corner [7]</td>
<td>( K = 5000 )</td>
<td>5 PTB</td>
</tr>
<tr>
<td>Left-Corner</td>
<td>( K = 5000 )</td>
<td>Categorial Grammar [3]</td>
</tr>
</tbody>
</table>

Table 1: Model specs. All were trained on the Wall Street Journal corpus.

Neural Network Language Models

<table>
<thead>
<tr>
<th>LSTM</th>
<th>LSTM</th>
<th>LSTM</th>
<th>LSTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Street Journal</td>
<td>2</td>
<td>1500</td>
<td>0.65</td>
</tr>
<tr>
<td>Wikipedia (2M words)</td>
<td>2</td>
<td>1500</td>
<td>0.65</td>
</tr>
<tr>
<td>Wikipedia (90M words) [2]</td>
<td>2</td>
<td>650</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Table 2: Model specs. The Units column indicates the number of units in each layer and the size of the word embeddings.

NP/S Garden Paths

(1) The employees understood the contract \( \text{would be changed} \) soon to accommodate all parties.

<table>
<thead>
<tr>
<th>Ambiguous</th>
<th>Disambiguation</th>
</tr>
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Grammar-Based Models

Neural Network Models

NP/Z Garden Paths

(1) Even though the girl phoned the instructor \( \text{was very upset} \) with her for missing a lesson.

(2) Even though the girl phoned, the instructor \( \text{was very upset} \) with her for missing a lesson.

Grammar-Based Models

Neural Network Models

Timecourse Predictions

- NN predictions comparable to grammar predictions
- All models correctly predict garden-path effect
- Models severely underestimate size of NP/Z effect
- Therefore, surprisal likely not enough
- NP/Z repair mechanism may be needed

Conclusions

References

[5] Nathaniel J. Smith and Roger Levy. The effect of word predictability on reading time is longer than that of Grodner et al. because Sturt et al. presented text region-by-region, so subjects were more strongly encouraged to adopt the incorrect interpretation prior to the disambiguation region.