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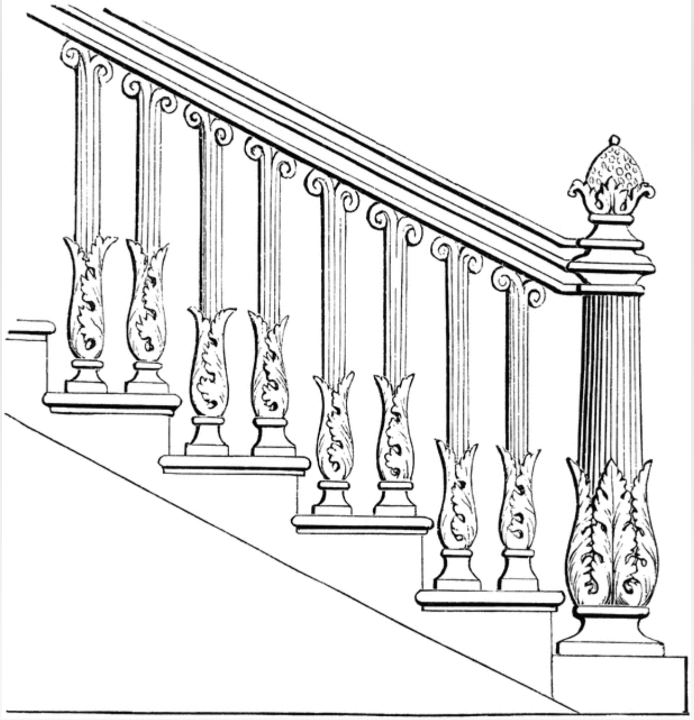
From Balustrades to Pierre Vinken:

Looking for Syntax in Transformer Self-Attentions

Charles University, Prague
Faculty of Mathematics and Physics
Institute of Formal and Applied Linguistics

BlackboxNLP Workshop, Firenze, 1 August 2019

From balustrades to Pierre Vinken



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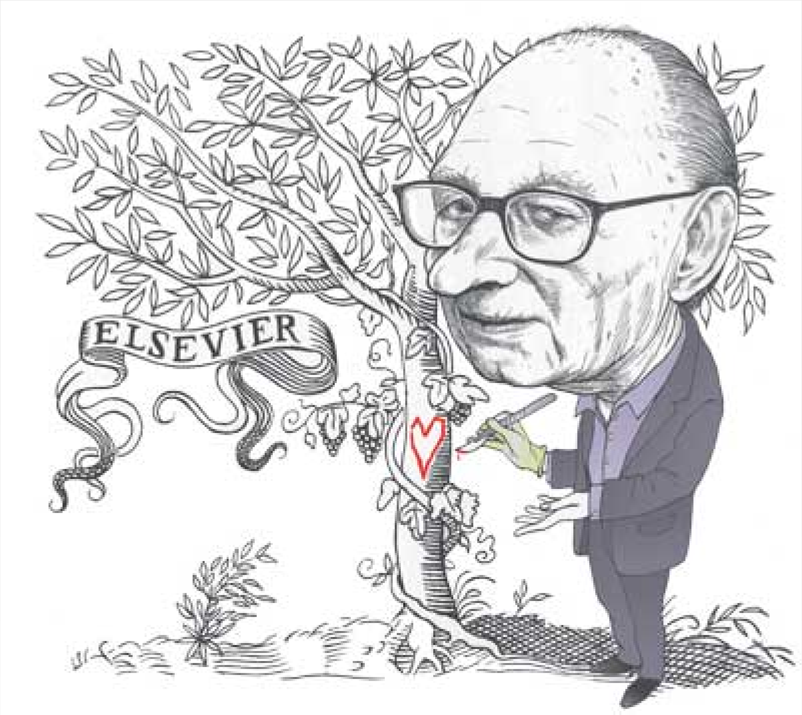
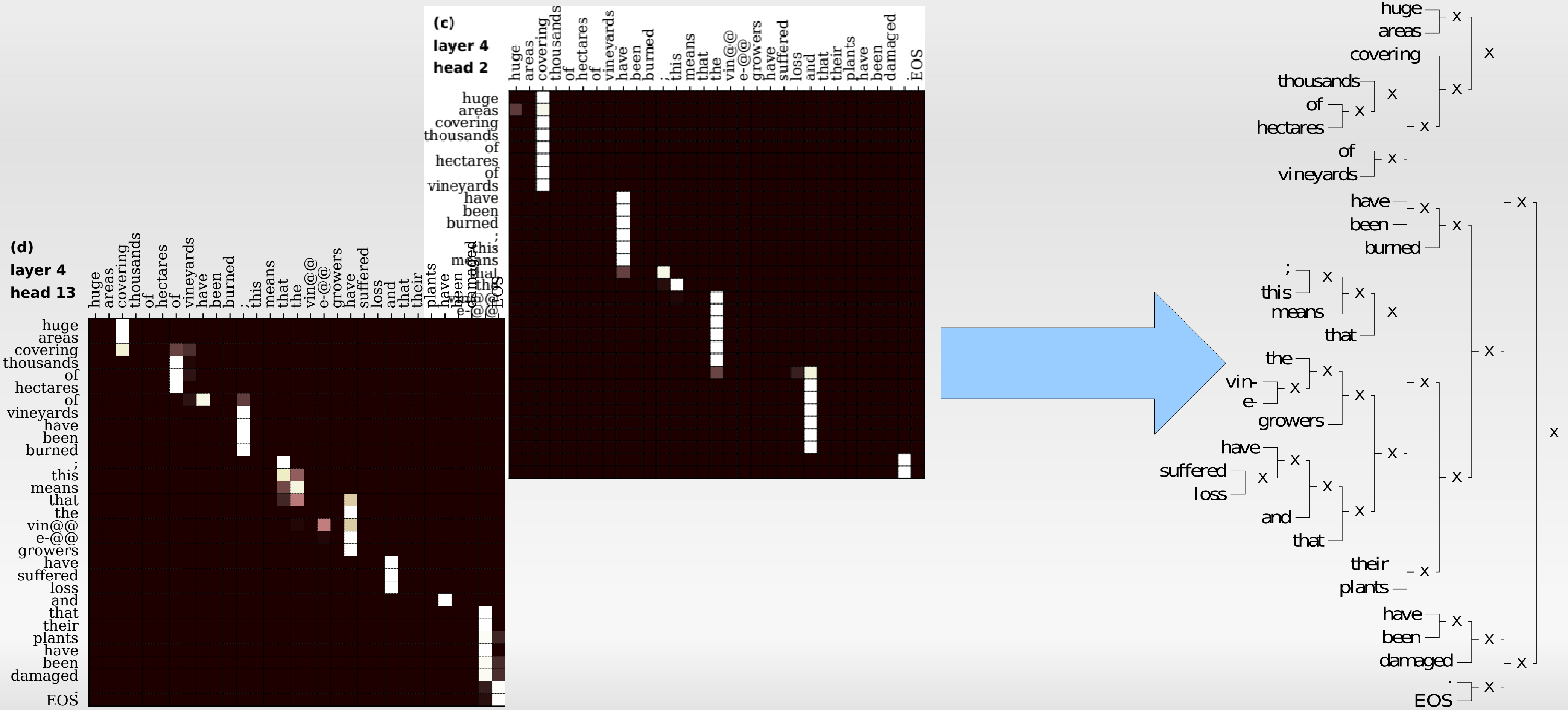


by Jan Hein van Dierendonck

Transformer self-attentions → syntactic trees



Observation

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- Common pattern in Transformer NMT self-attention heads

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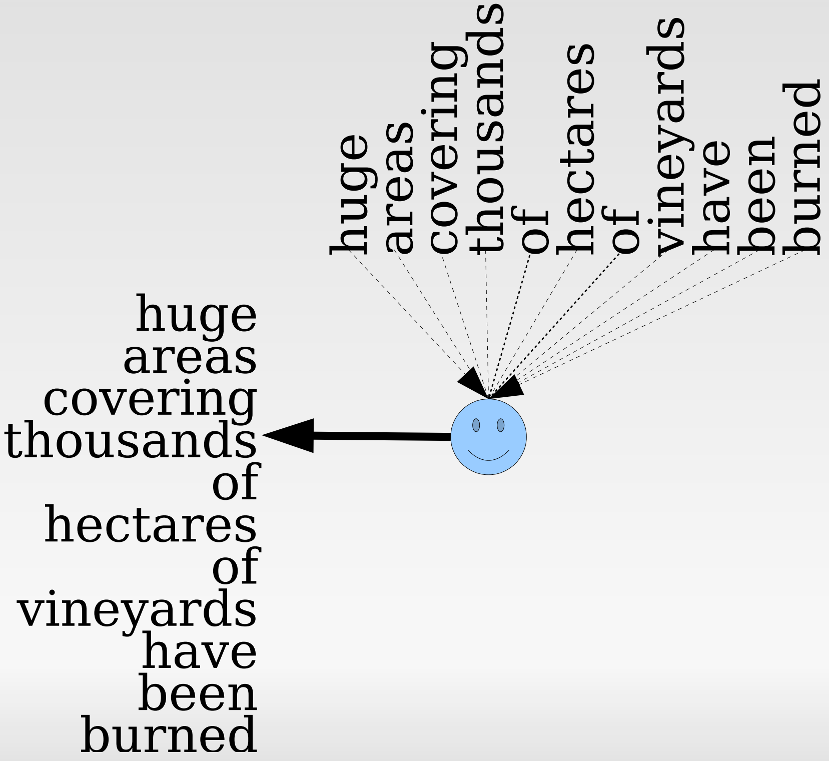

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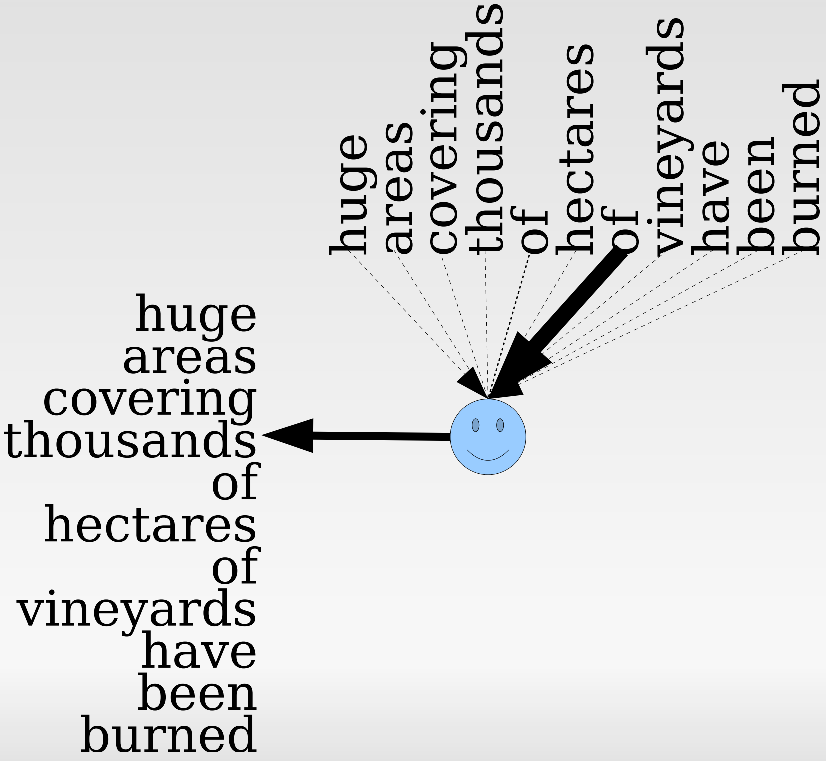

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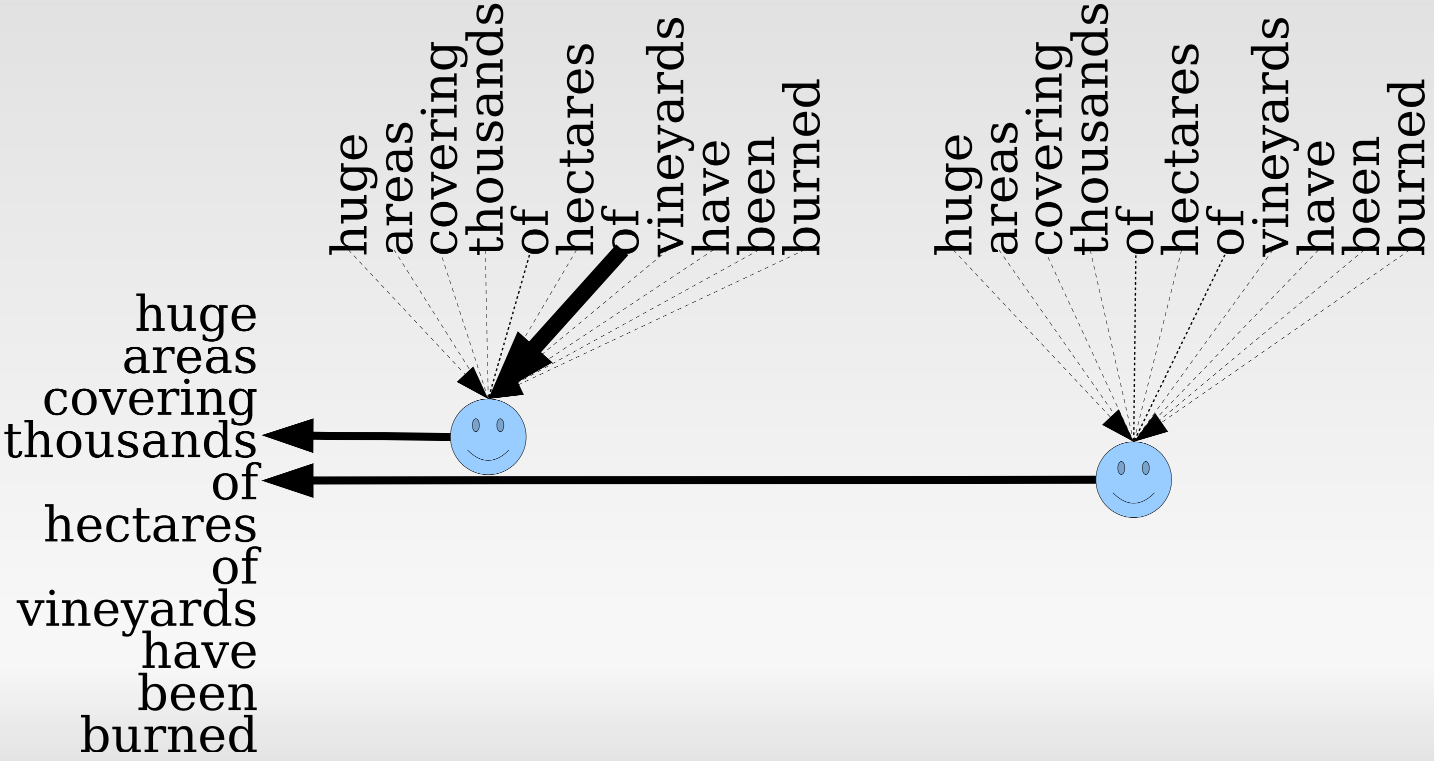

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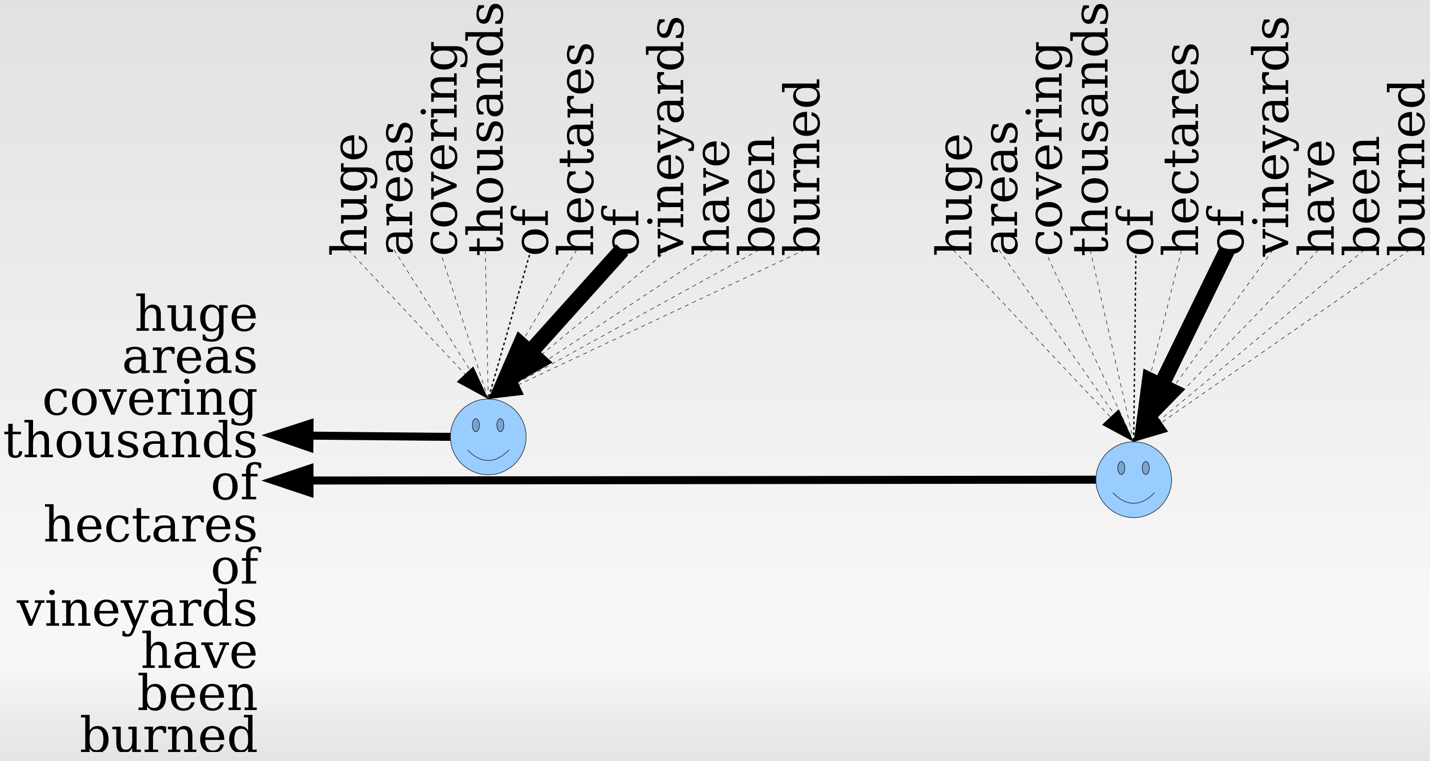

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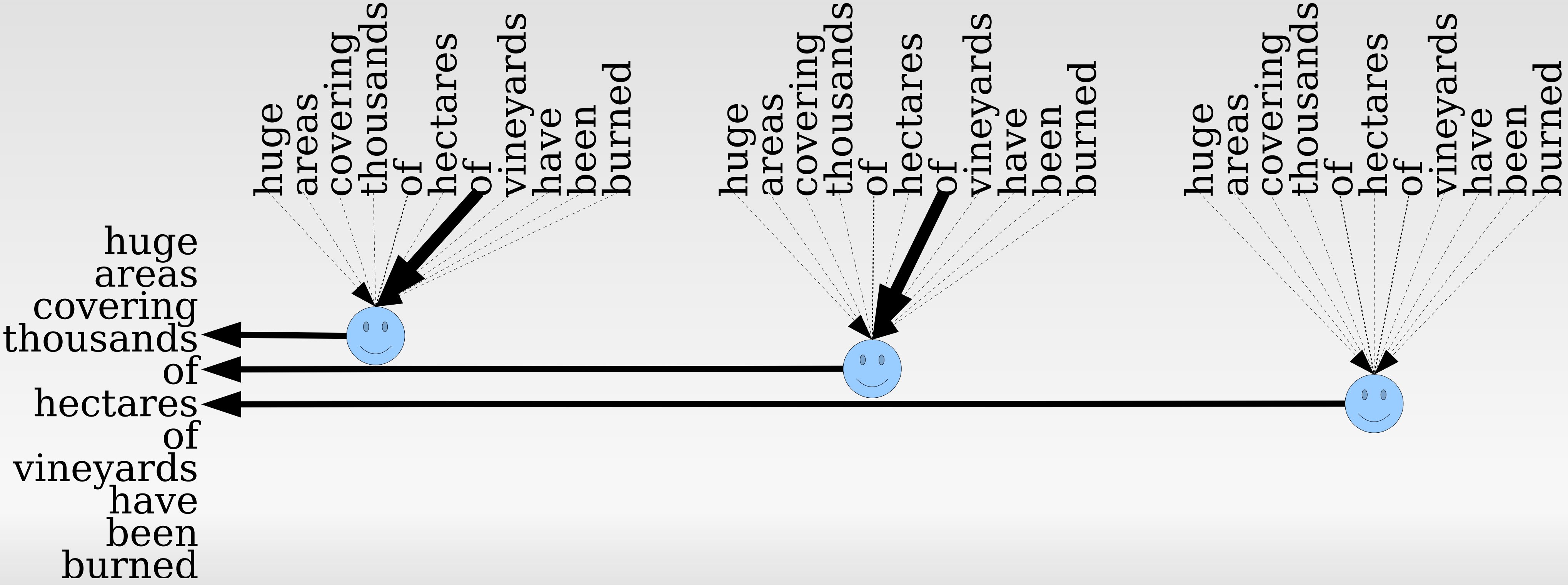

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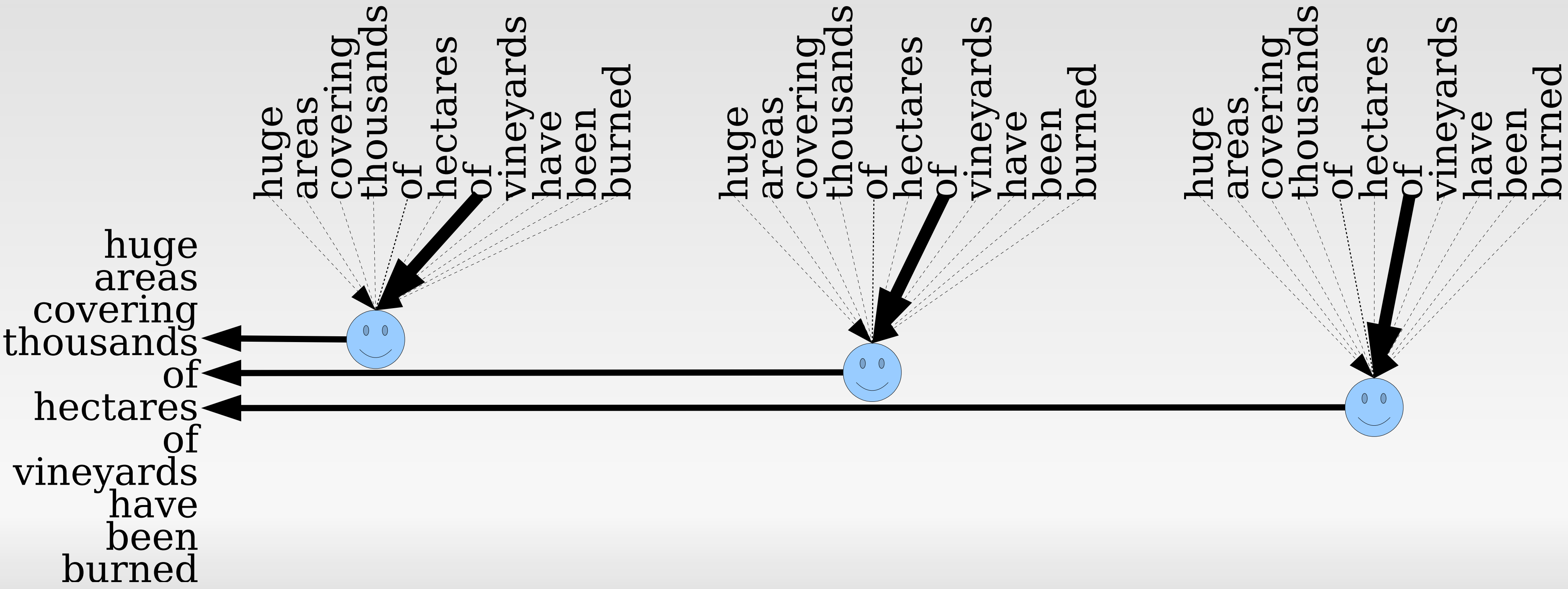

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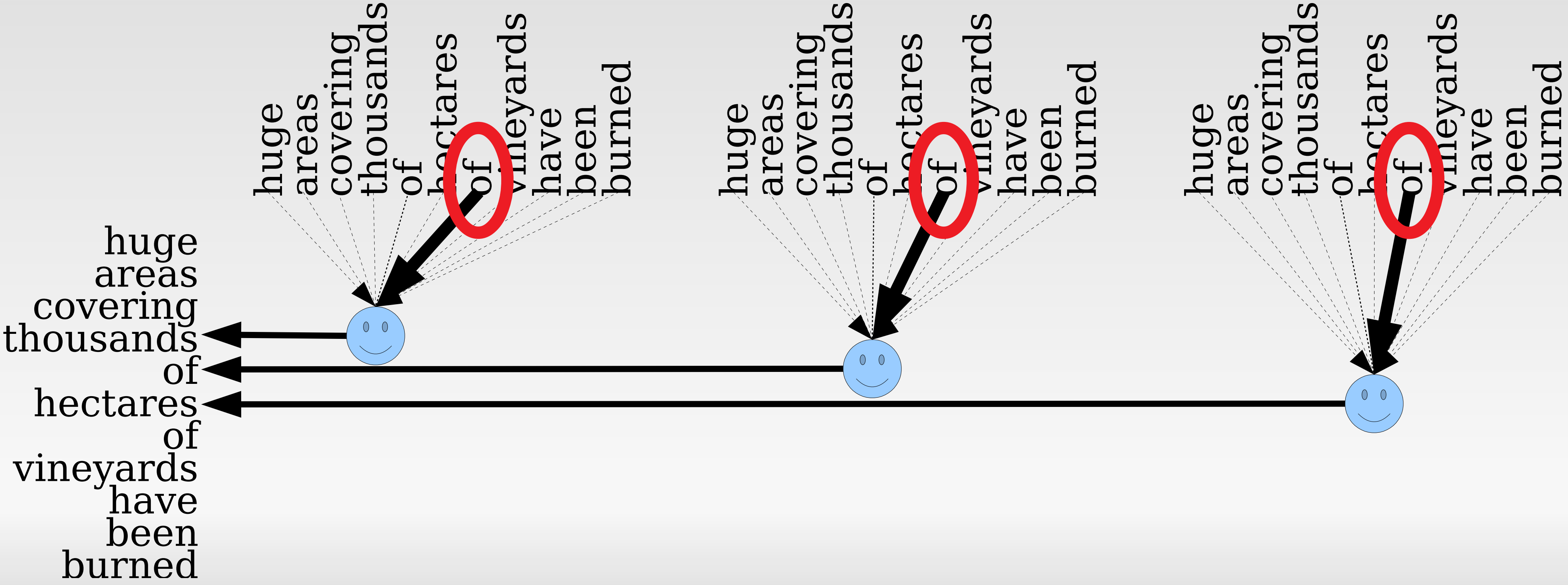

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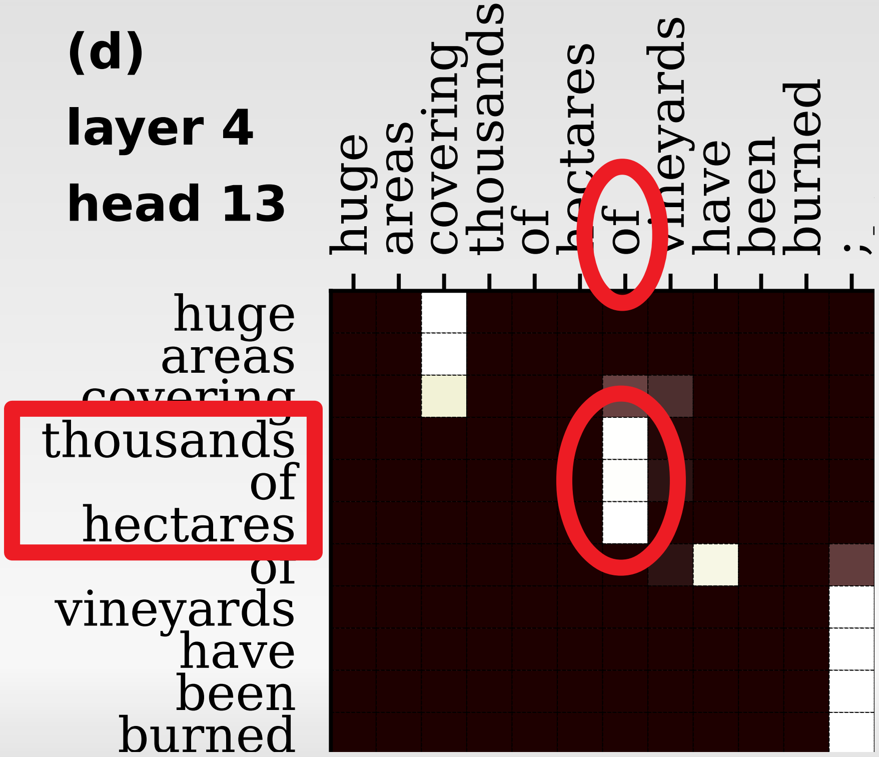

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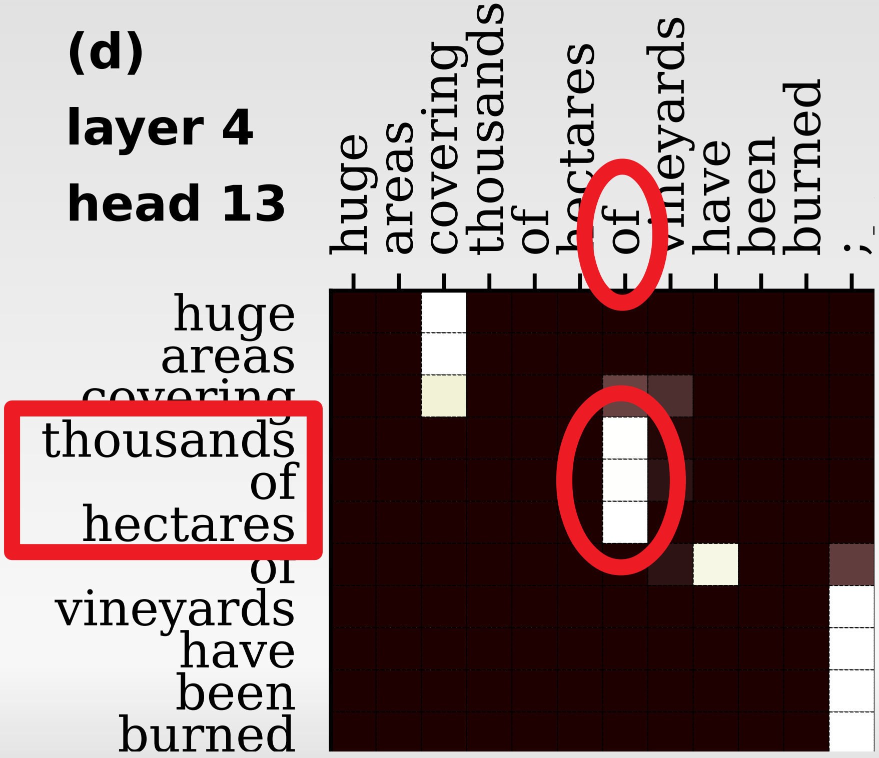
- Common pattern in Transformer NMT self-attention heads
  - “balusters”



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- Common pattern in Transformer NMT self-attention heads
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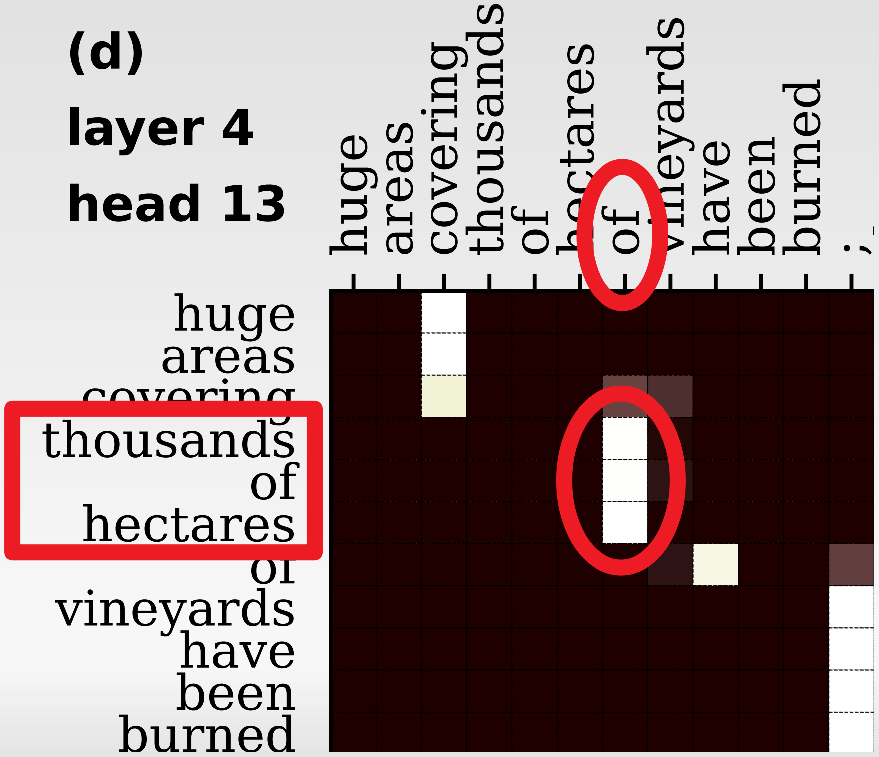
- Resemble syntactic phrases



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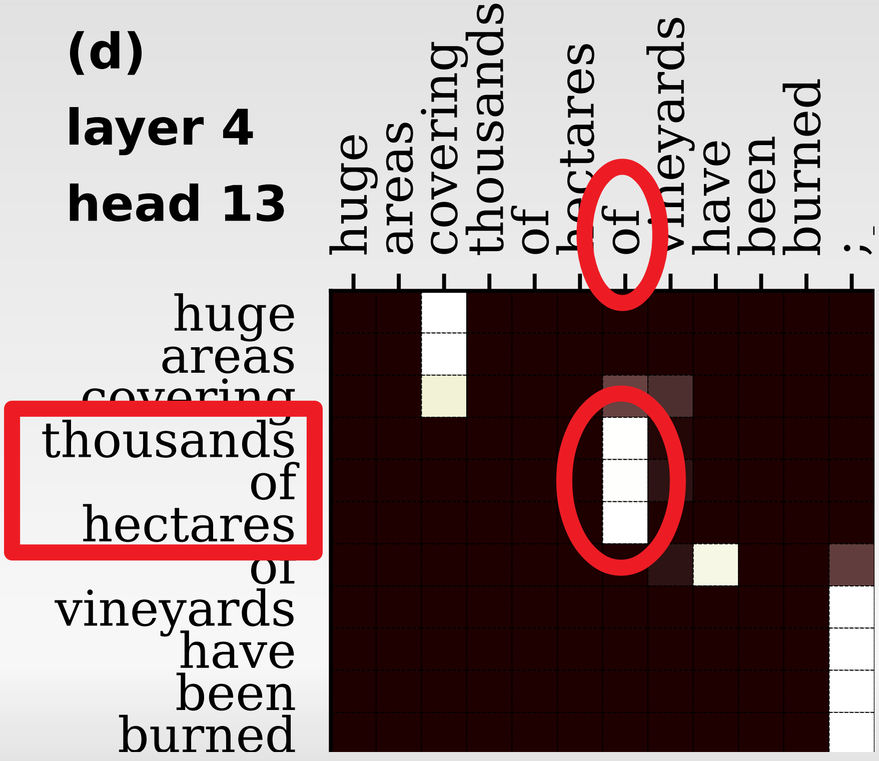
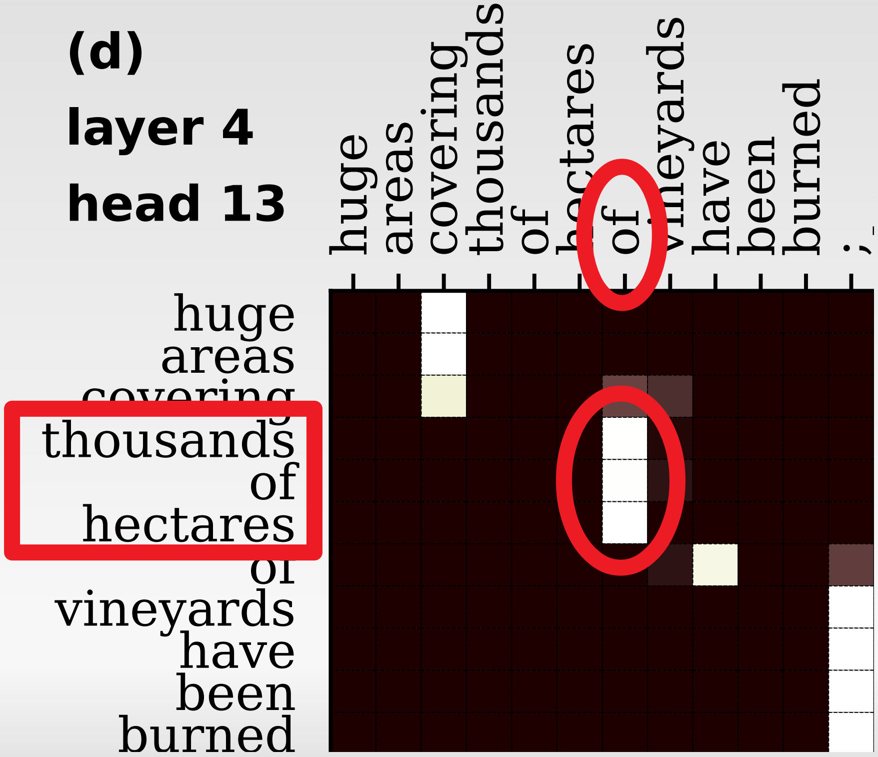


Observation

- Common pattern in Transformer NMT self-attention heads
  - “balusters”
- Resemble syntactic phrases
  - To what extent?
    → That’s our research question!



Approach

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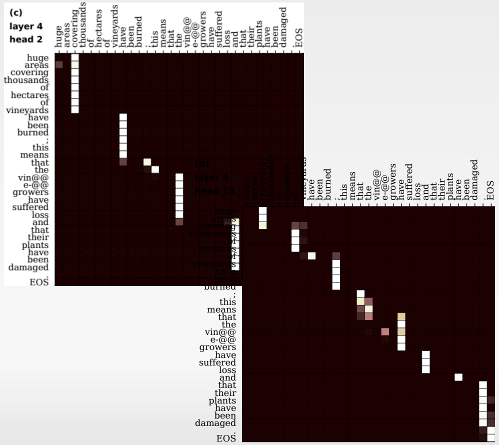
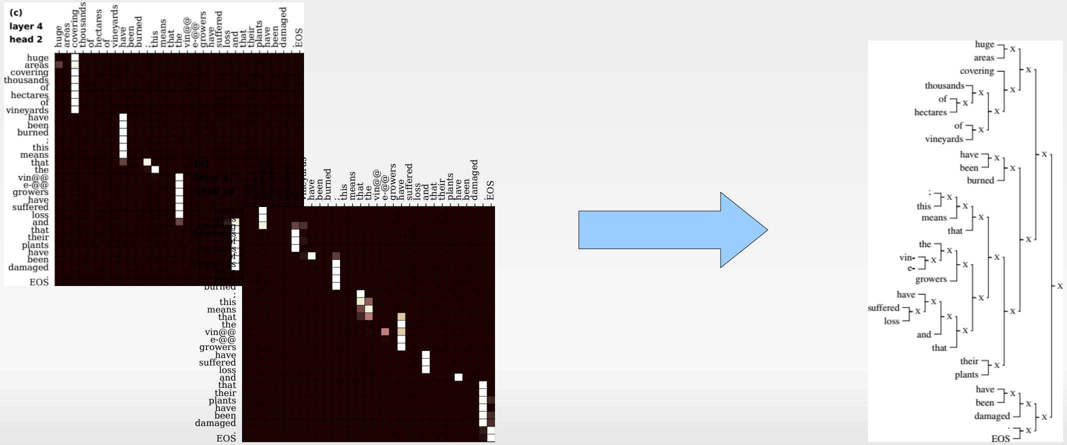
1. Balusters → phrase candidates



Approach

1. Balusters → phrase candidates
2. Phrase candidates → constituency tree
   - Linguistically uninformed algorithm


(c)
layer 4
head 2
huge areas covering thousands of hectares of vineyards have been burned ; this means that the vin@@ e-@@ growers have suffered loss and that their plants have been damaged . EOS
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EOS
x

Approach

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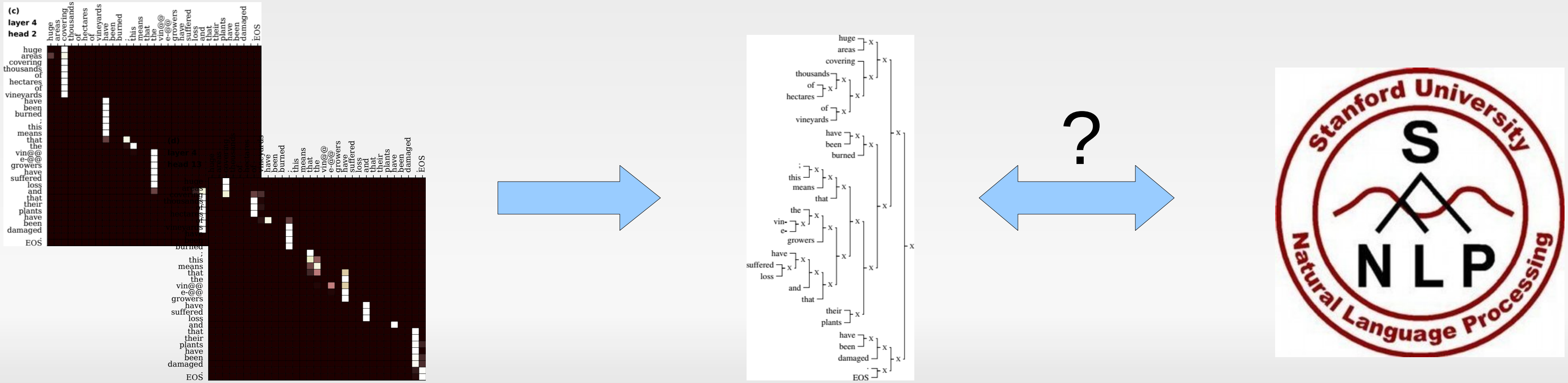
3. Compare to standard syntactic trees



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1. Balusters → phrase candidates
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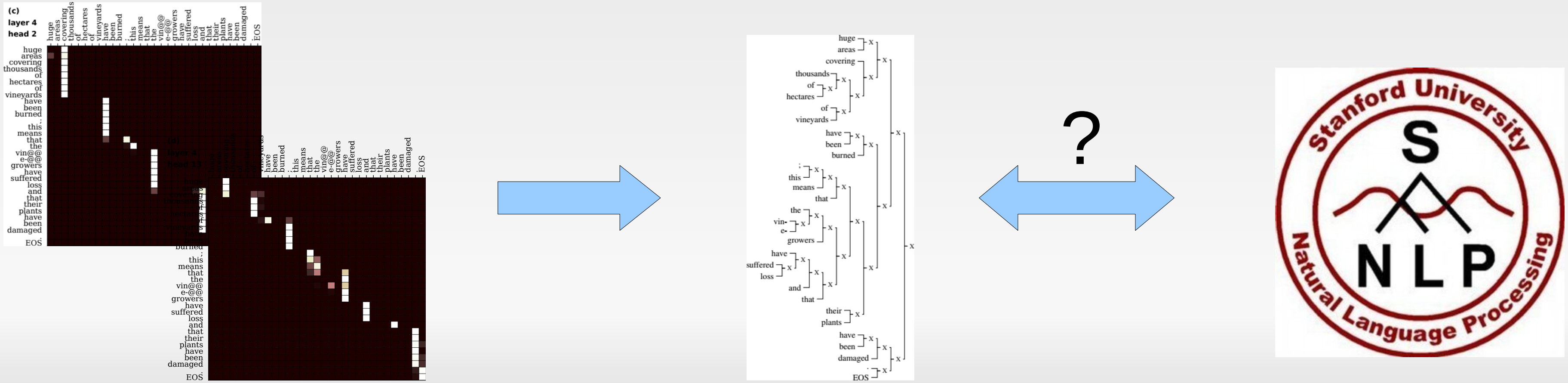
3. Compare to standard syntactic trees: ~40%; baseline ~30%



Experiment setup

- Balusters: Transformer NMT system
  - Encoder: 6 layers x 16 heads

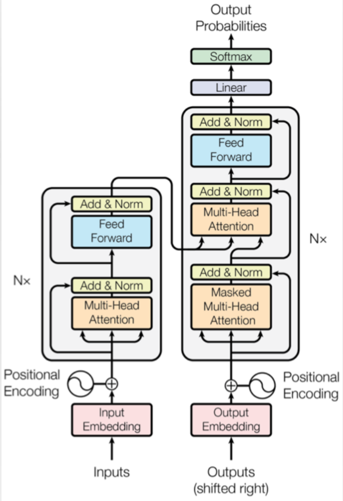


Figure 1: The Transformer - model architecture.

Experiment setup

- Balusters: Transformer NMT system
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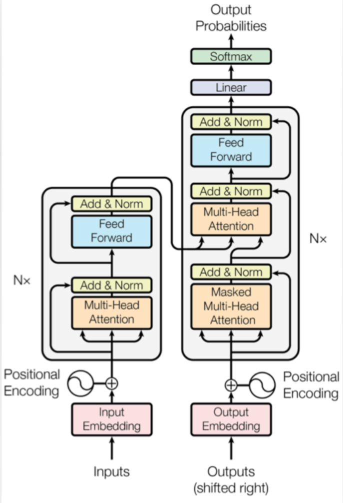
  - Europarl: French ↔ English, German ↔ English, French ↔ German



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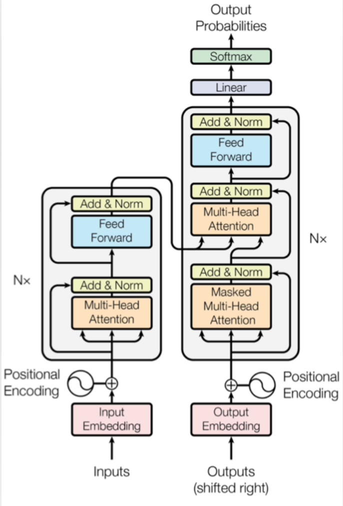
European Parliament

- Standard syntactic trees: Stanford parser
  - Penn Treebank, French Treebank, Negra Corpus
  - Only for evaluation



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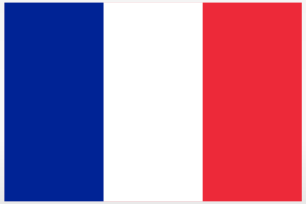
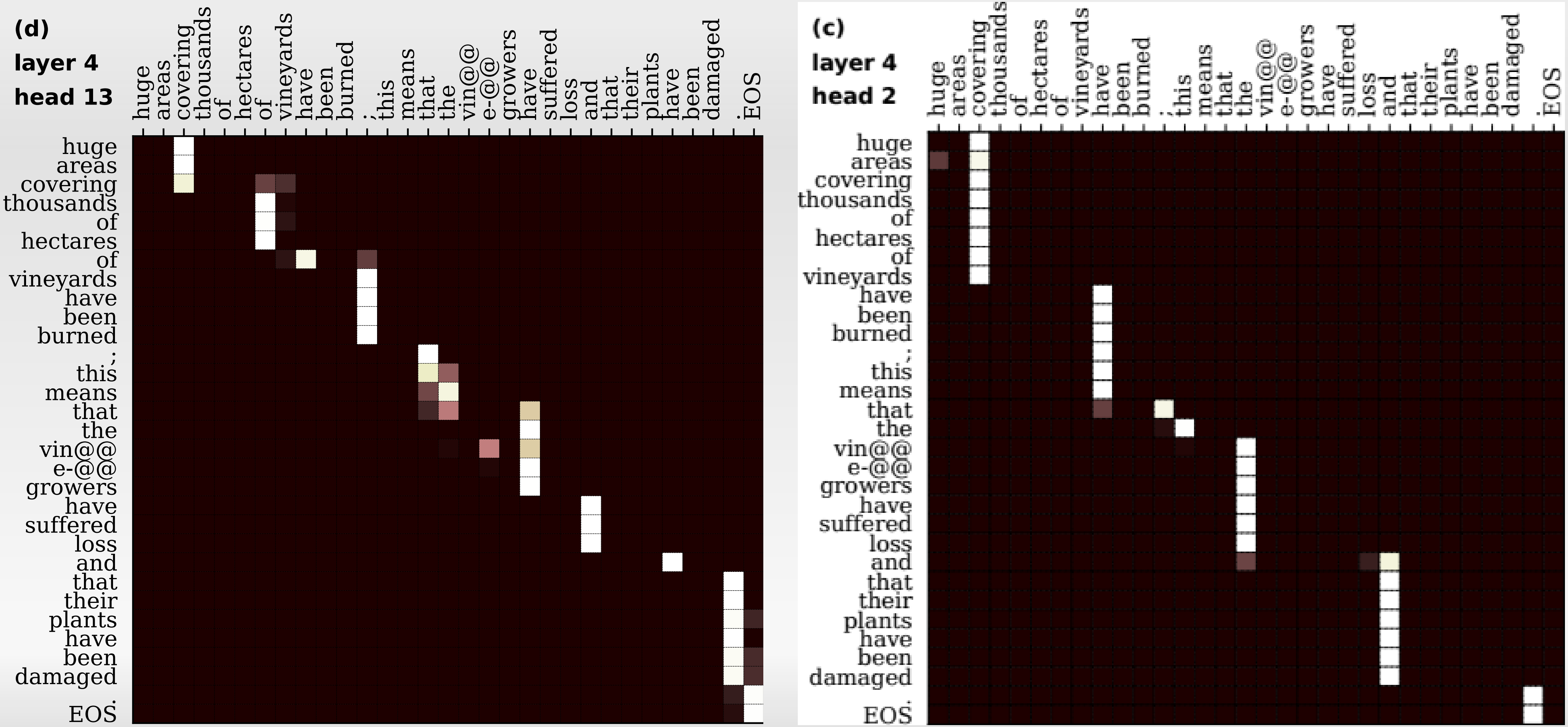
Stanford University S NLP Natural Language Processing



Balustrades (~70% of the attention heads)



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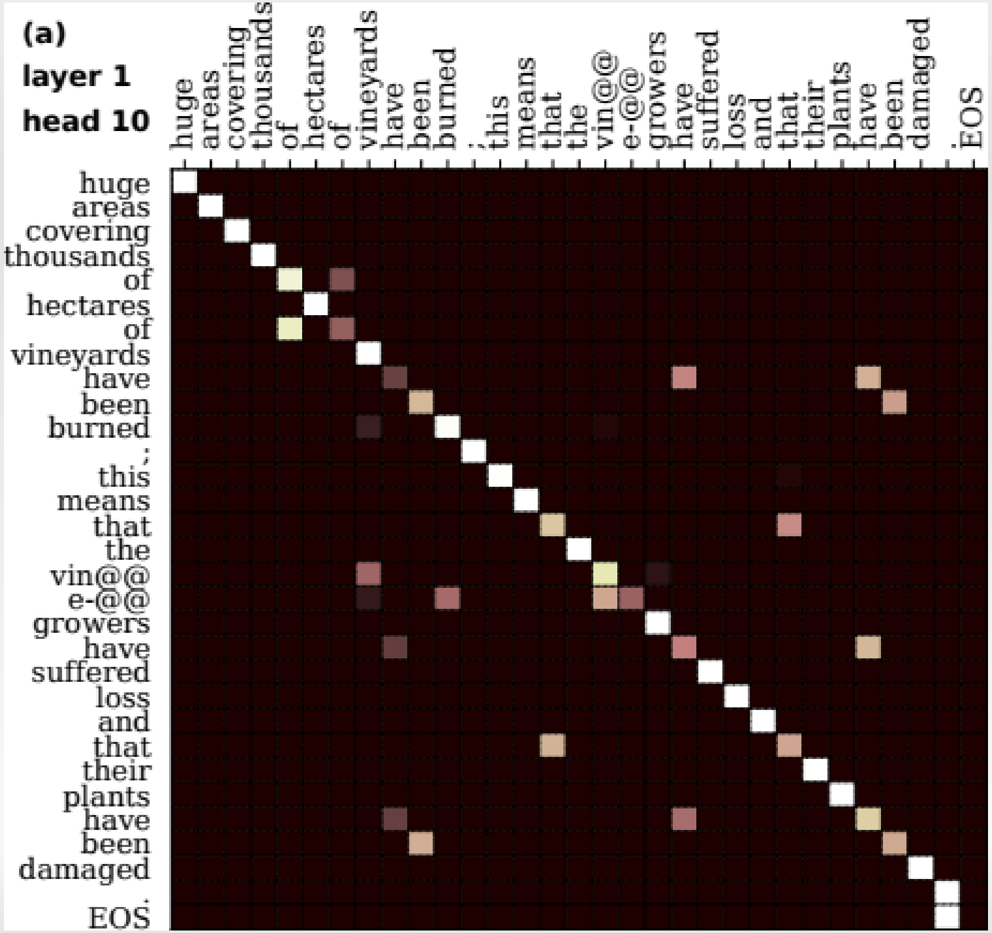
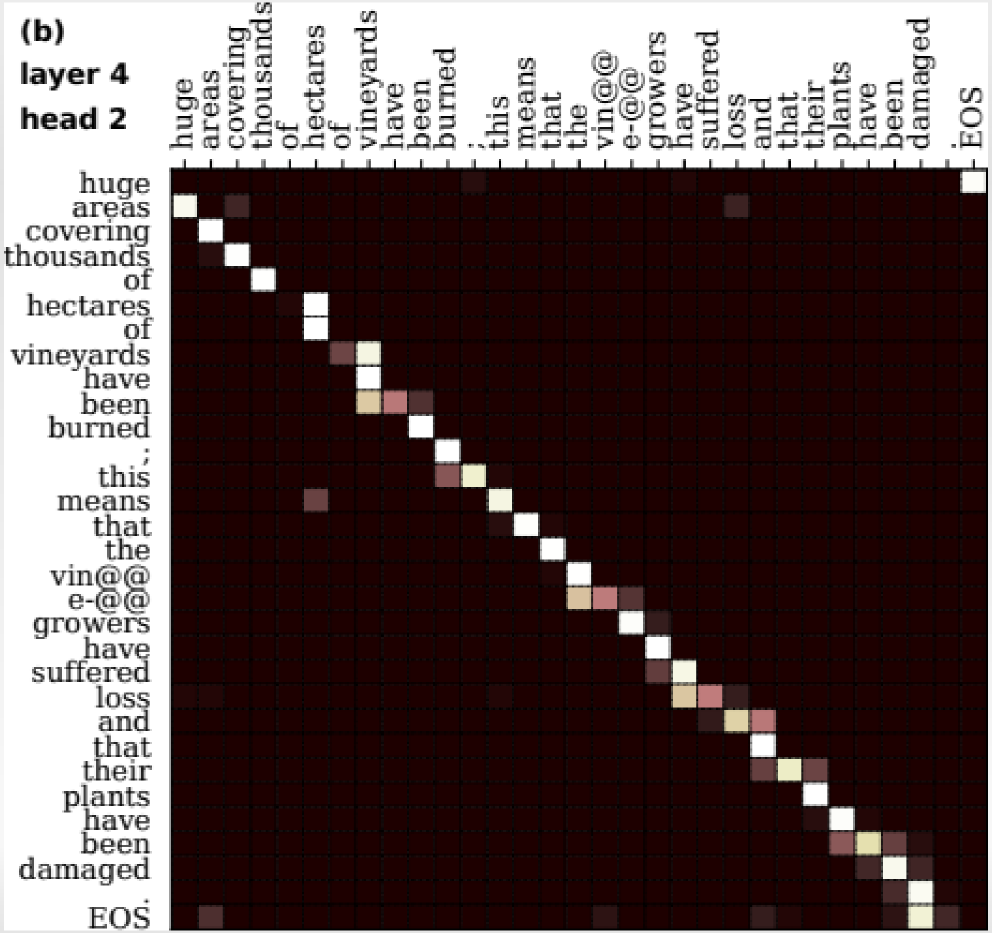
Diagonals (especially 1st layer)





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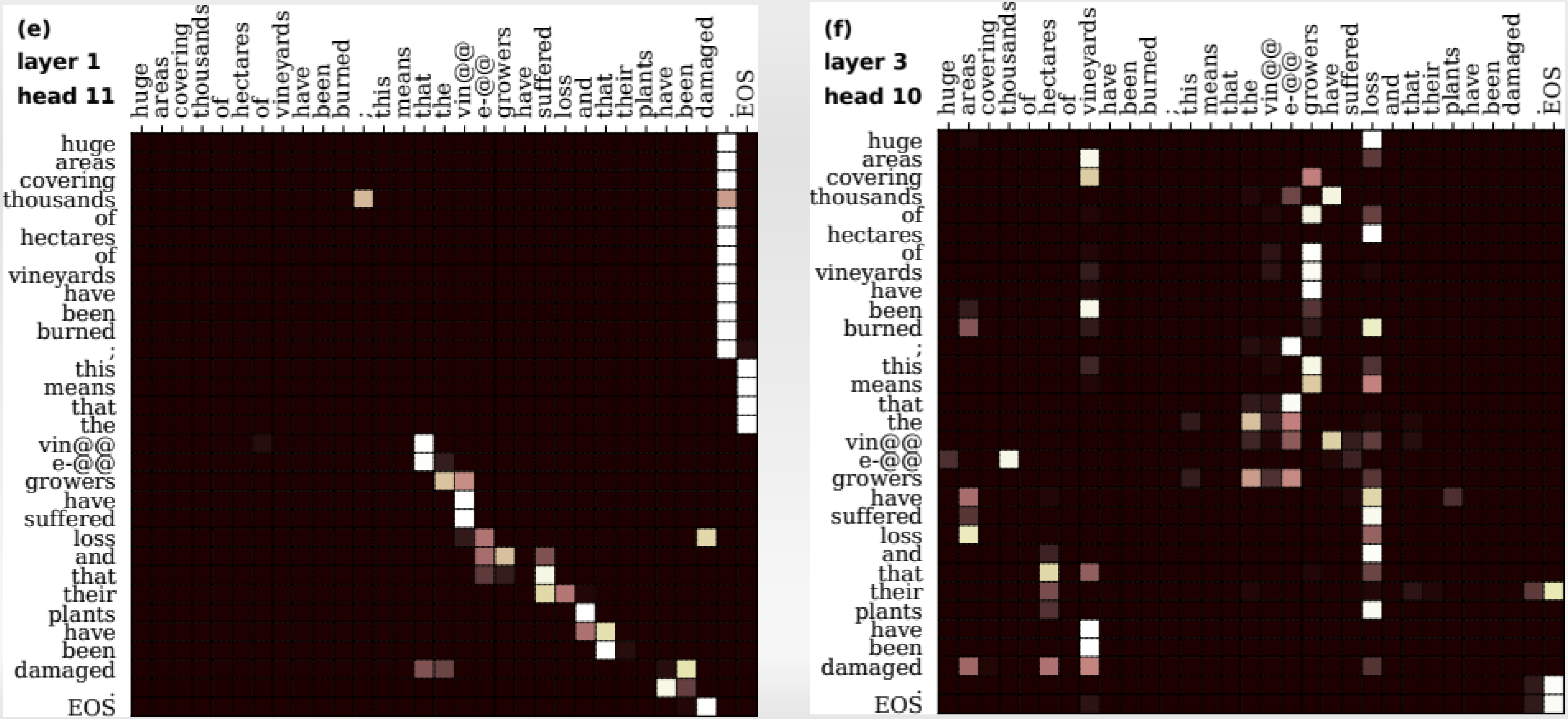
Attend to end, mixed, scattered…



Phrase candidates

- All balusters of length ≥ 2 from **all** heads
  - Subselecting only some of the heads → see the paper!

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  - Average attention weight
  - Sum over all heads
  - Equalize over different phrase lengths

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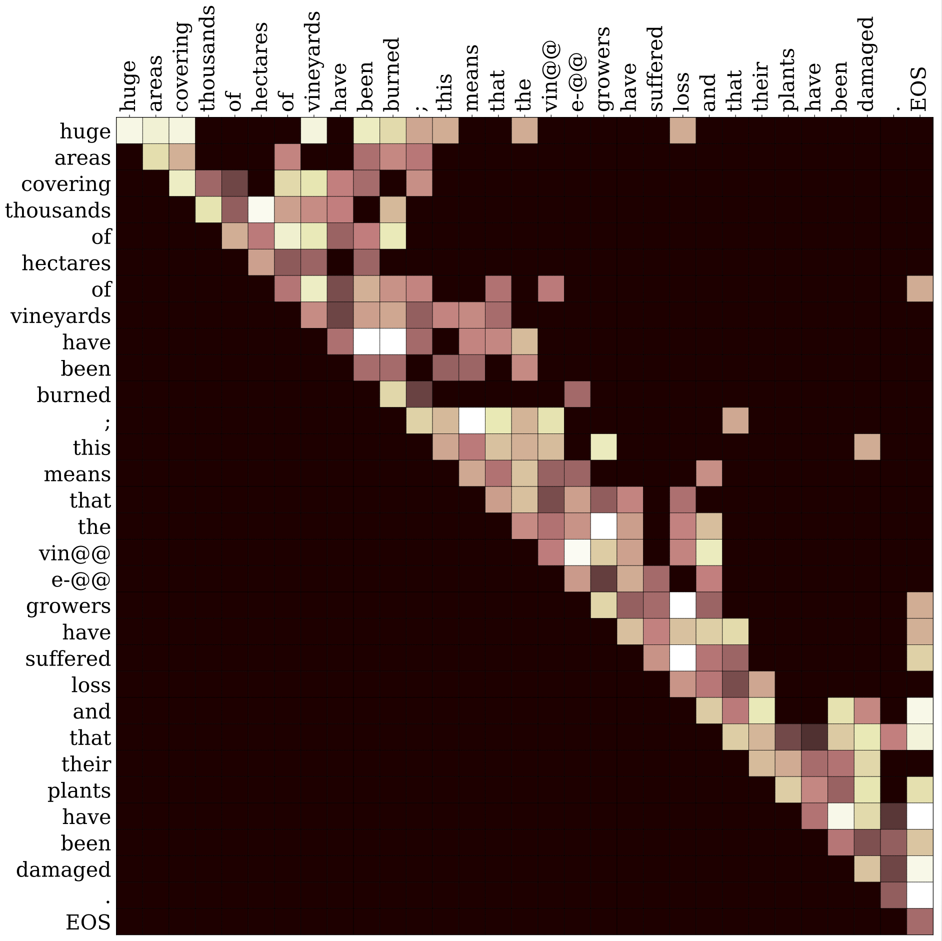

Phrase candidates → constituency tree

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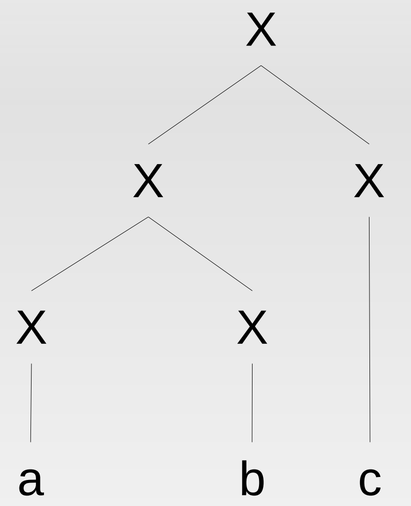
- Binary constituency tree



Phrase candidates → constituency tree

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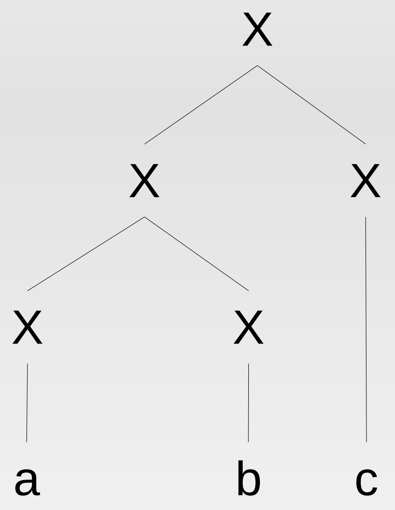
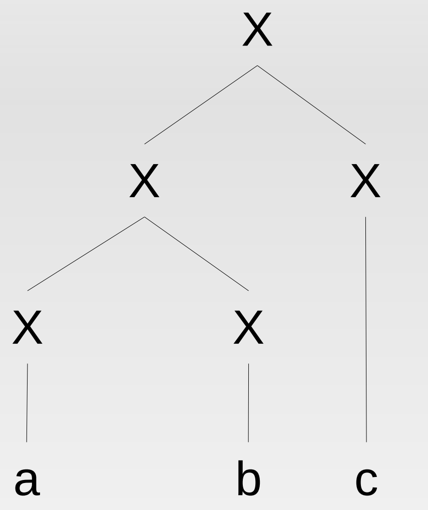


s(T) = s(ab) + s(abc)

Phrase candidates → constituency tree

- Binary constituency tree
- Tree score = sum of phrase scores
- CKY algorithm
    - Finds tree (set of phrases) with maximal score



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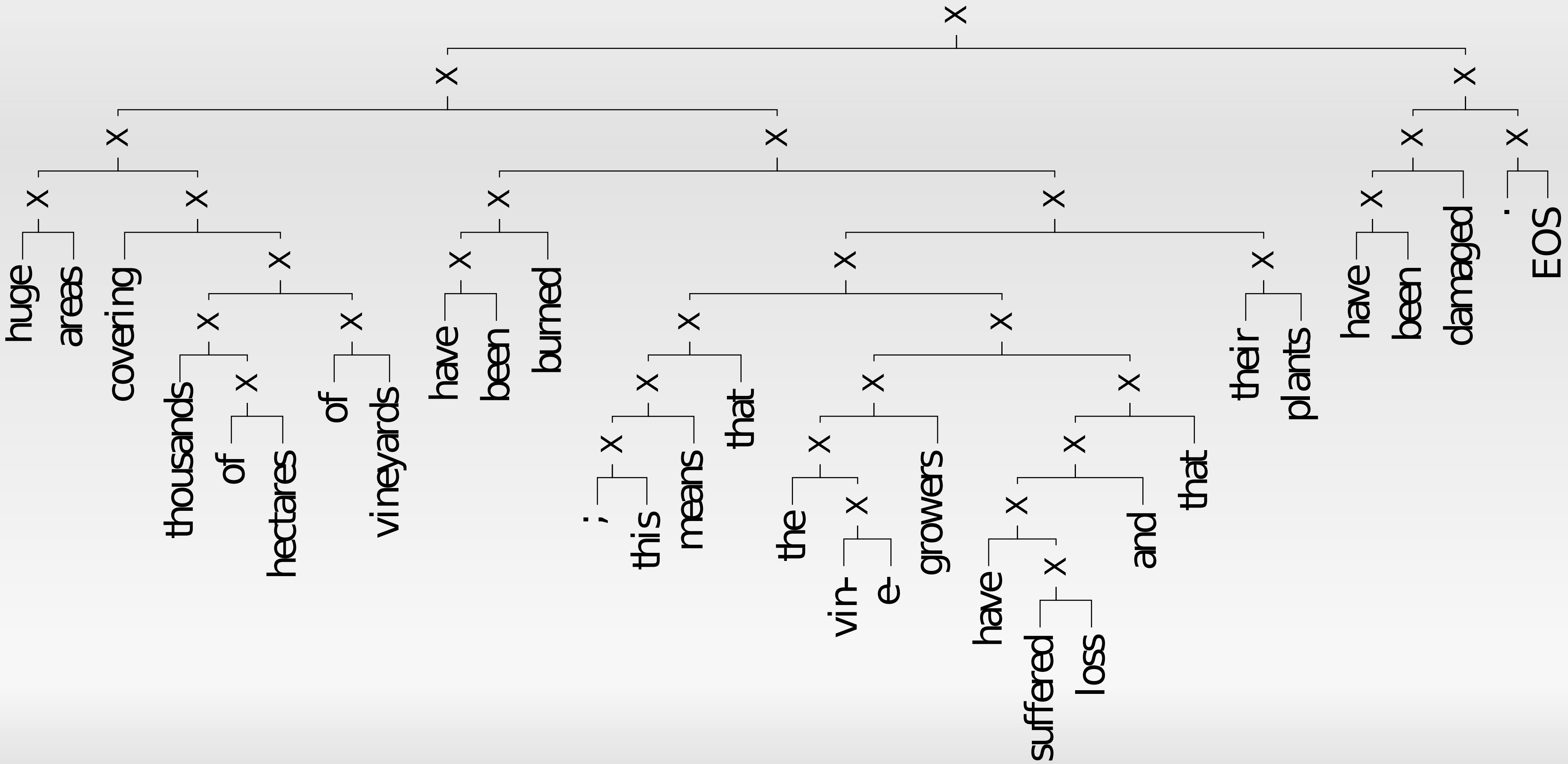
Results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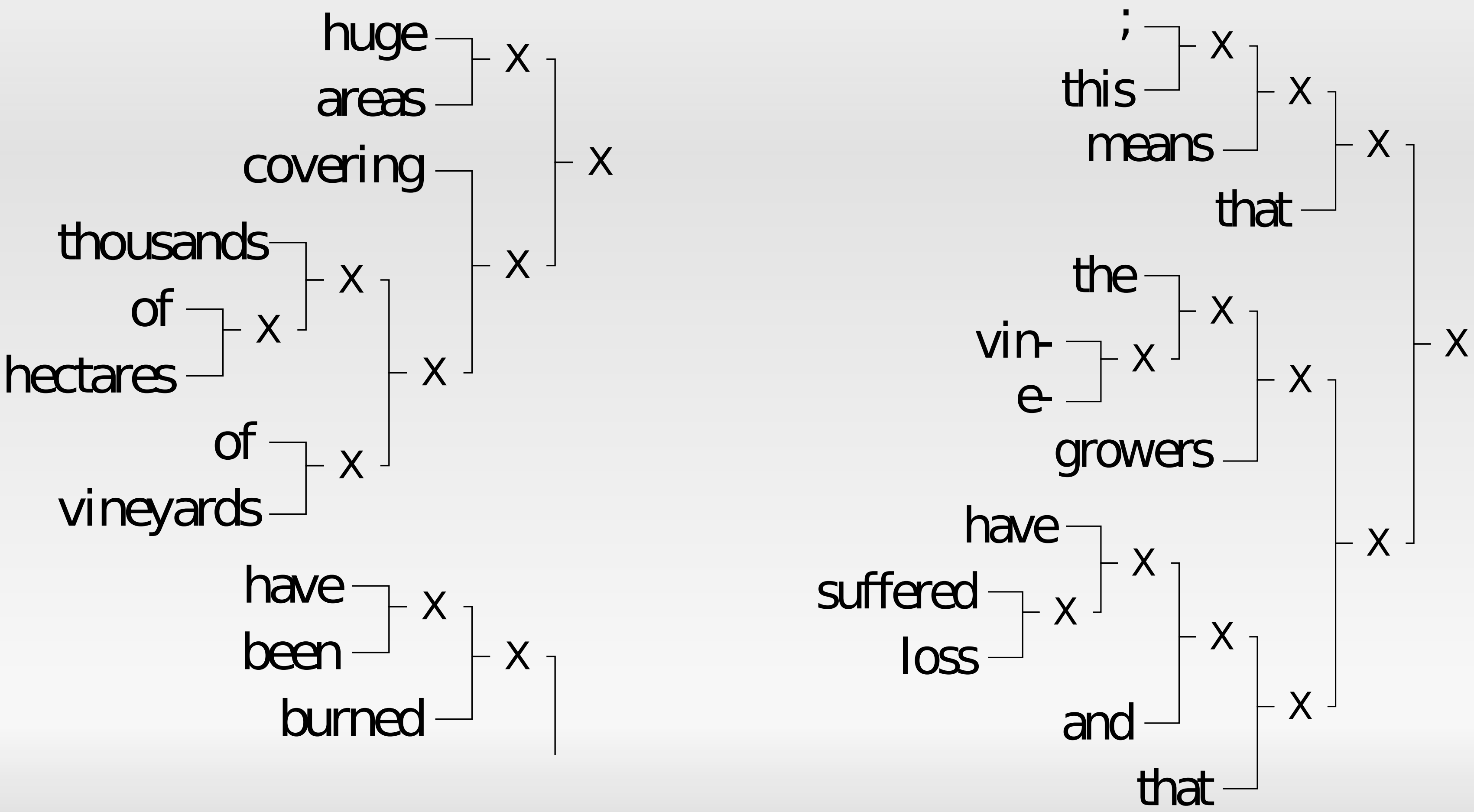
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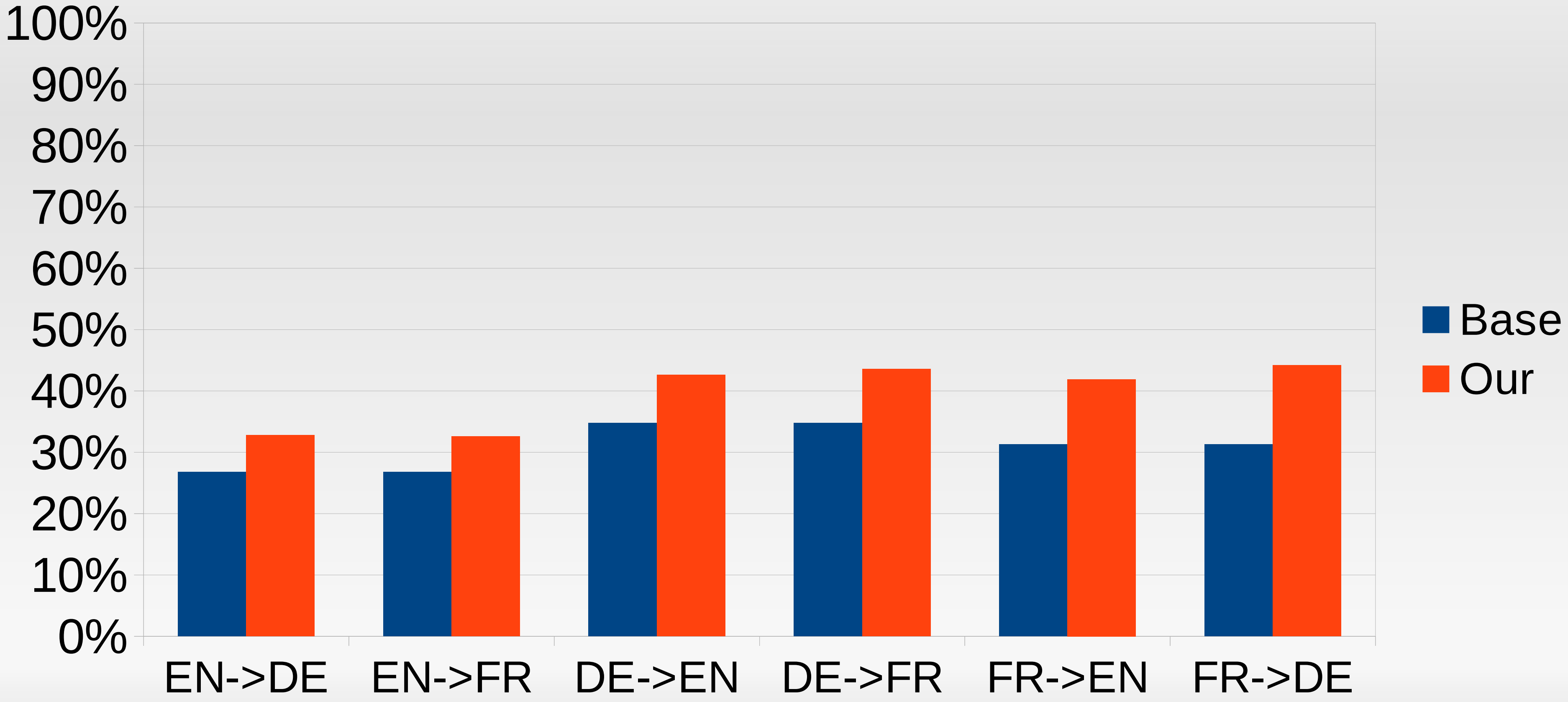
Comparison to standard syntactic trees



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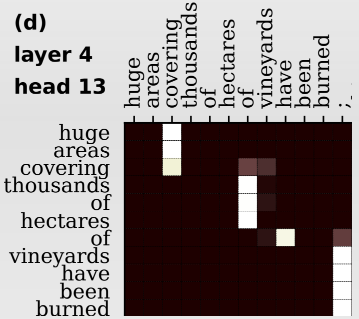
  - Contiguous sequence of output states
  - Attention to the same one input state



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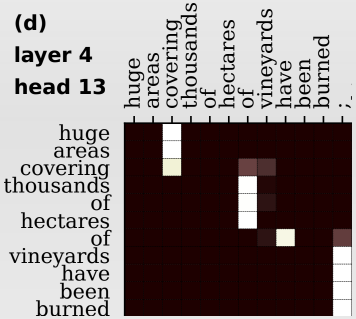

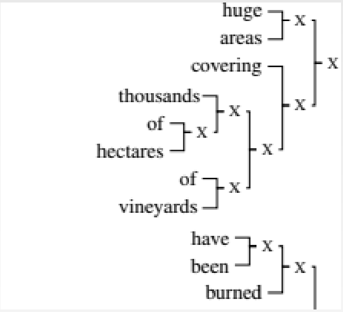

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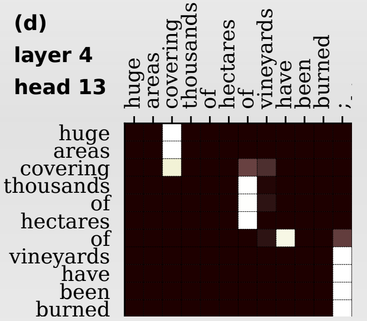
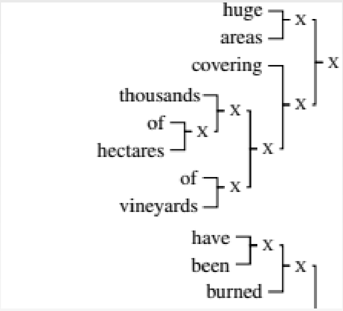
- Compare to **standard syntactic trees**
  - **~40% match**; base ~30% match





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