Left-corner Transitions on Dependency Parsing

Hiroshi Noji and Yusuke Miyao

National Institute of Informatics (NII)
Tokyo

Big picture

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Goal: Cognitively plausible parser with human like memory constraint

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Assumption: People parse sentences within limited memory capacity

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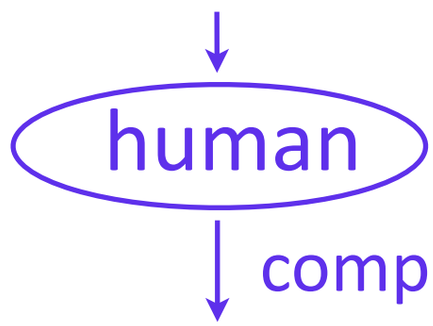

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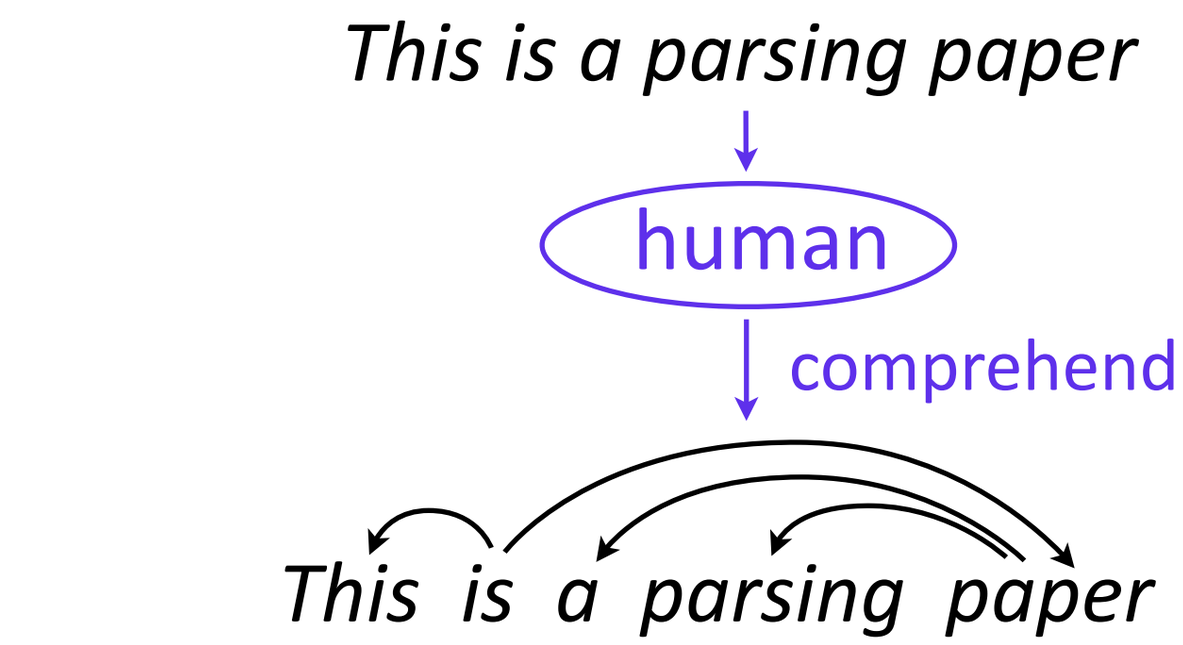

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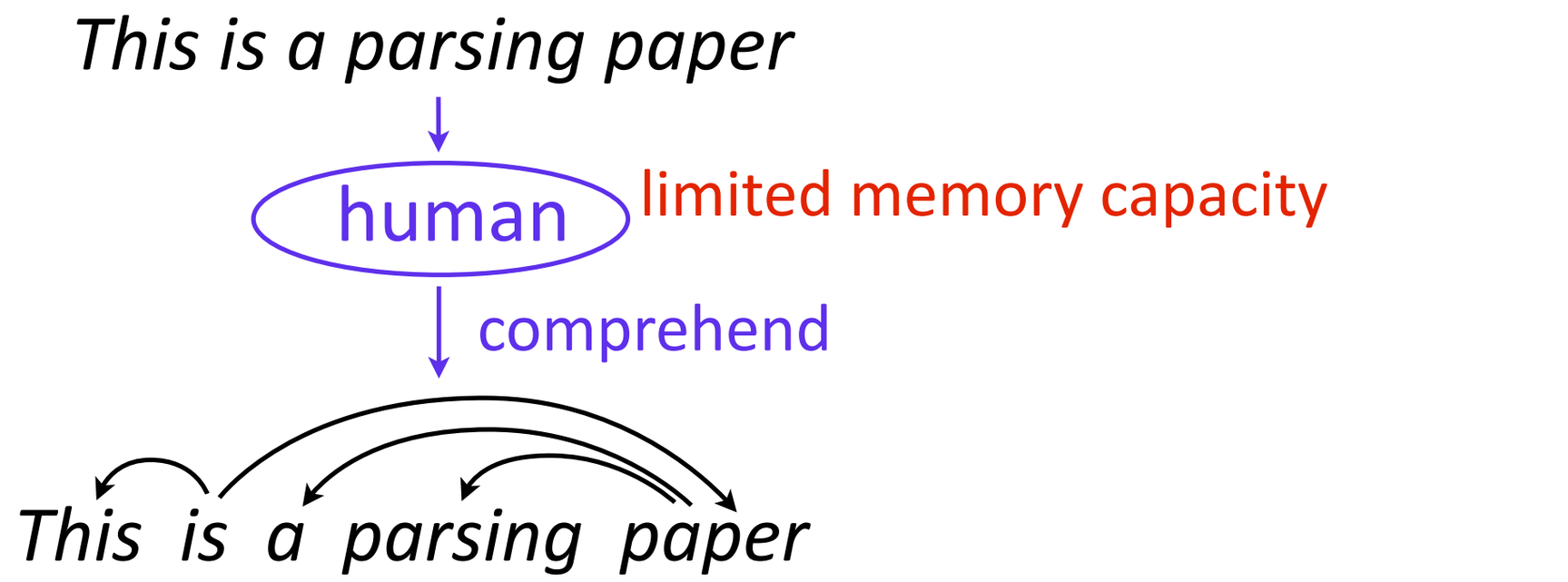

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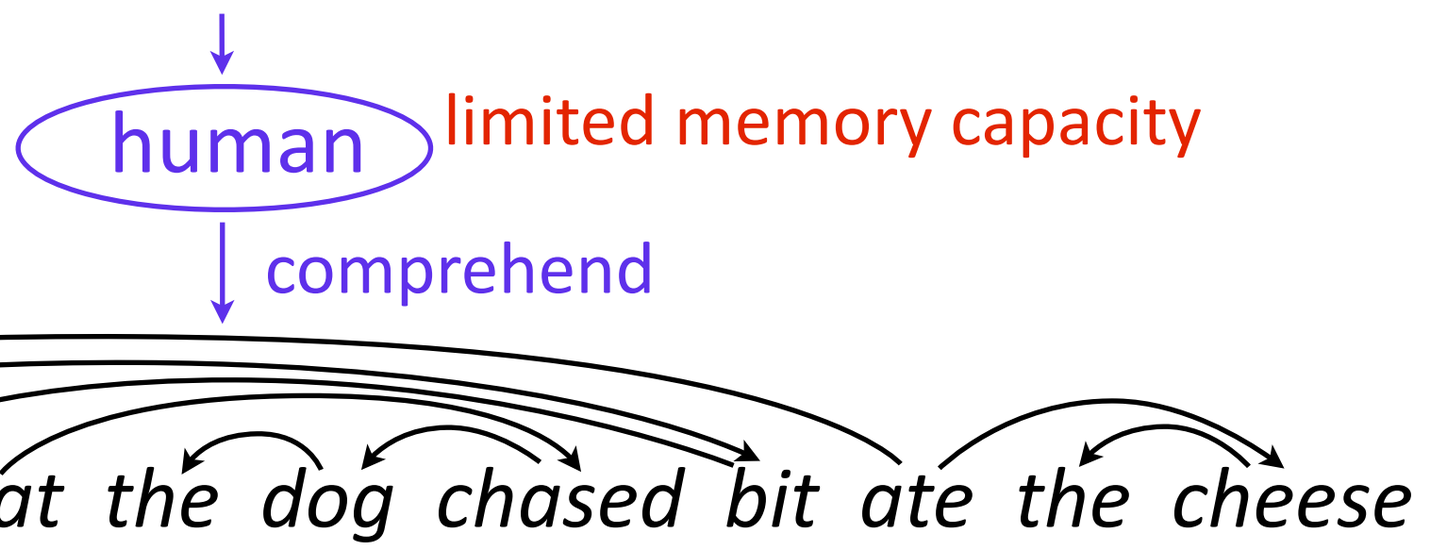

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⇒ Some syntactic construction causes memory overflow

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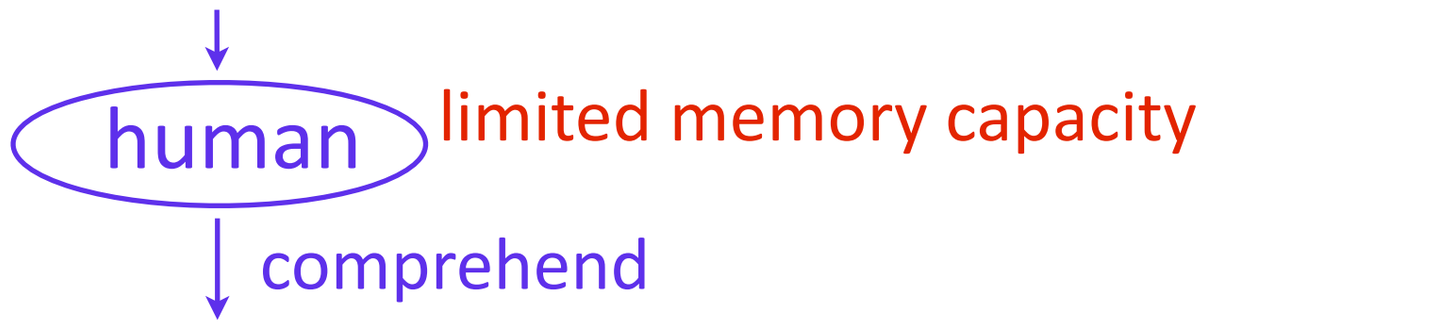

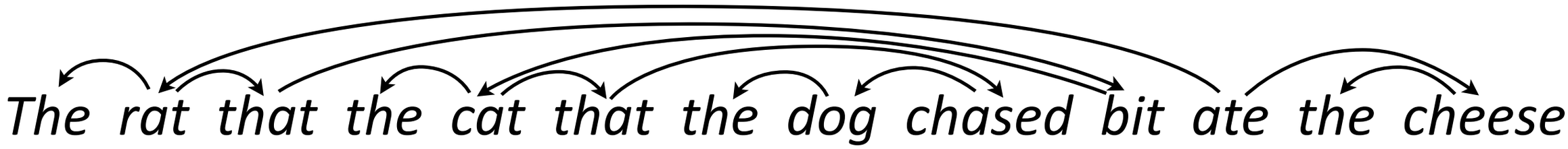

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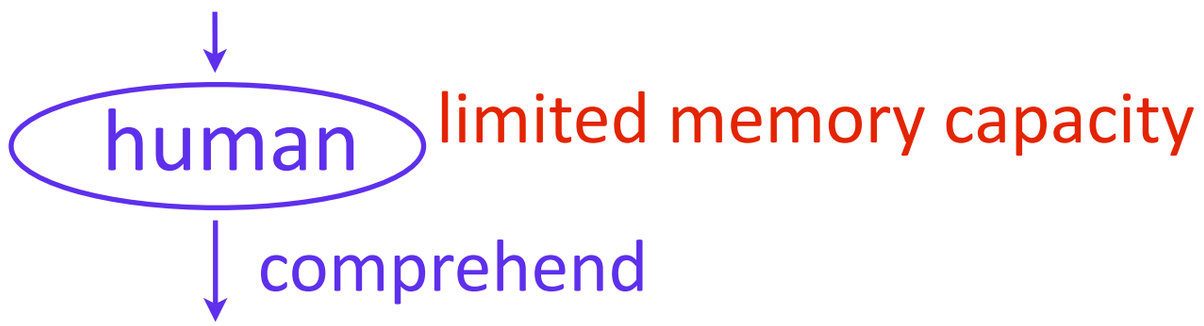

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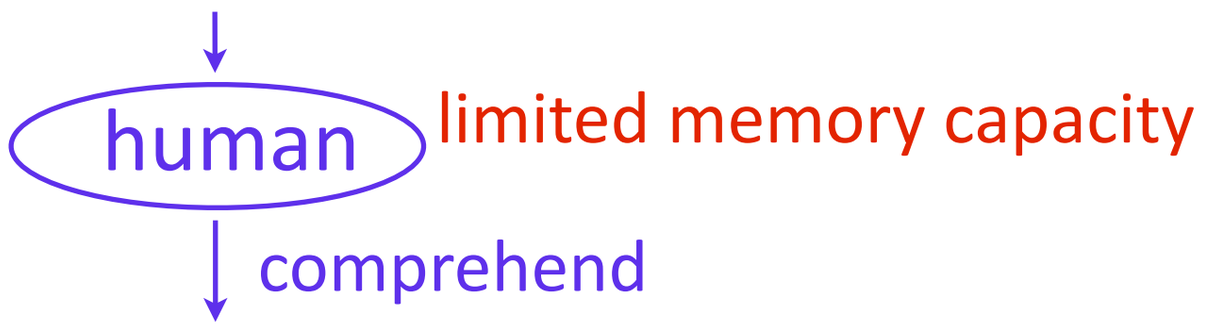

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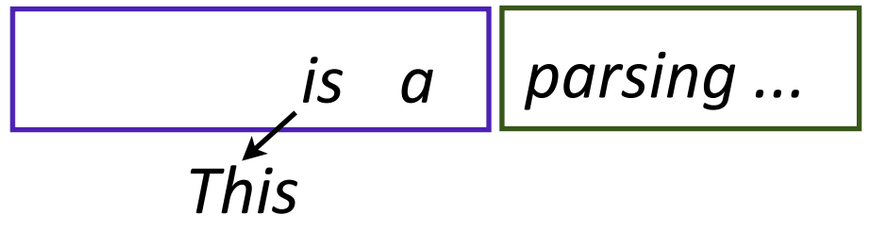
- parse tree is constructed in a stack



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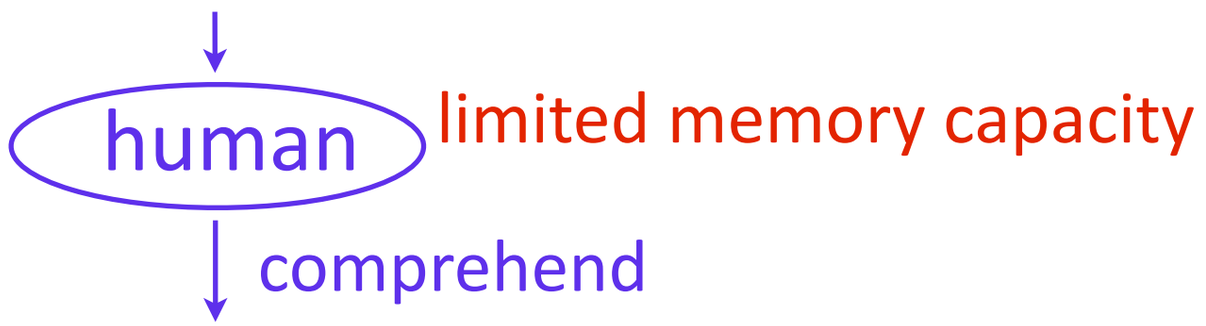
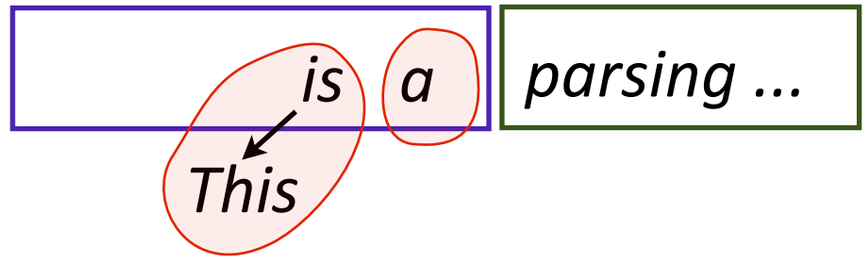


Framework: Stack-based incremental parser

- parse tree is constructed in a stack
- not incur large memory cost for daily occurring sentences



memory cost:

trees in the stack

Our approach: Left-corner for dependency

Left-corner parser [Resnik, 1992; Johnson, 1998]

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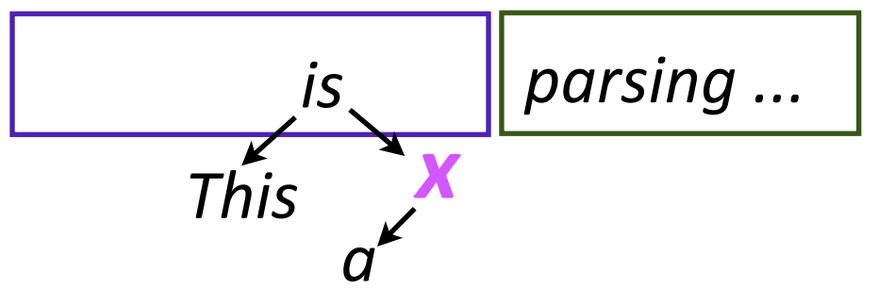

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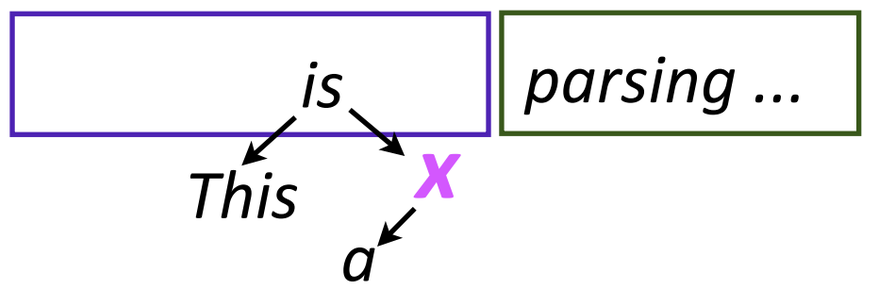

Empirical: Cross-linguistic analysis for its cognitive plausibility

- **Our finding: 17/18 languages rarely require memory cost > 4**

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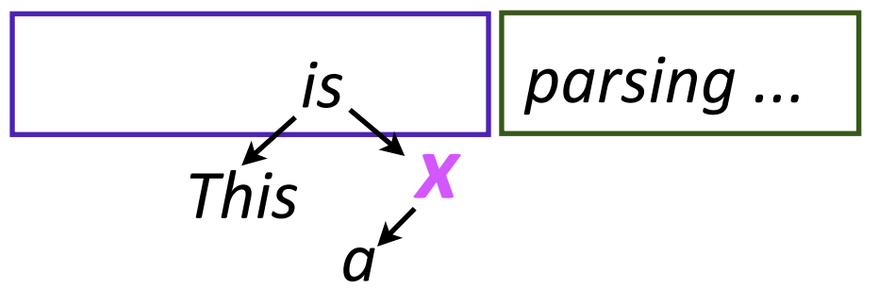

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NOTE: We don't report any automatic parsing results in this work

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Setup

- Psycholinguistic observation
- Left-corner constituency parsing
- Memory cost of dependency parsers

Left-corner dependency parsing

- Key concept: dummy node
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Experiments

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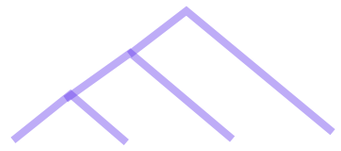

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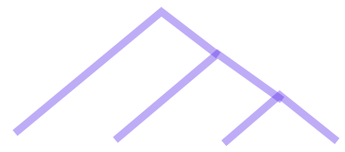

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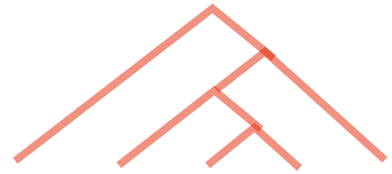

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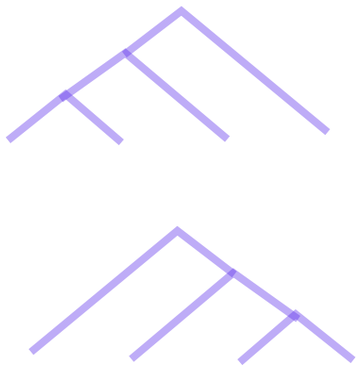

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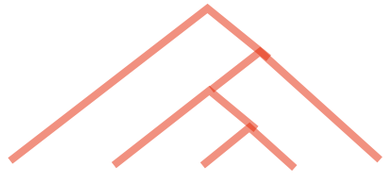

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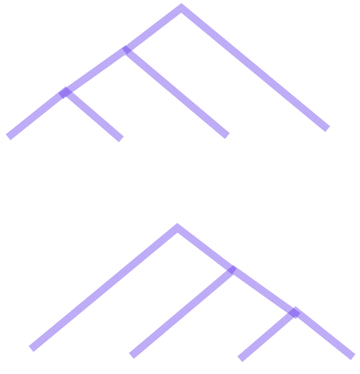

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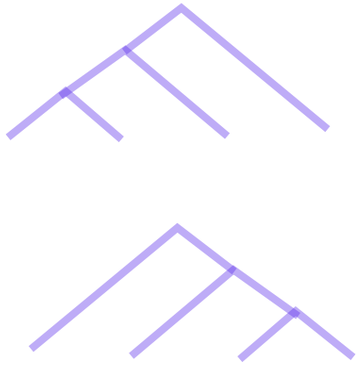

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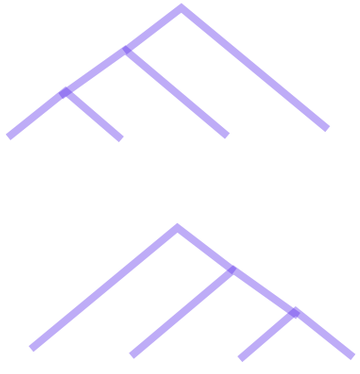

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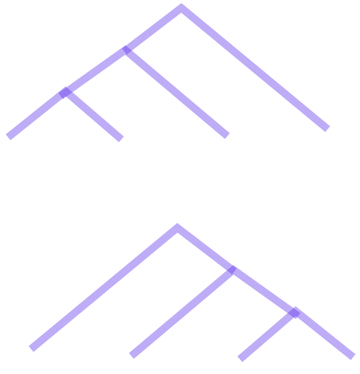

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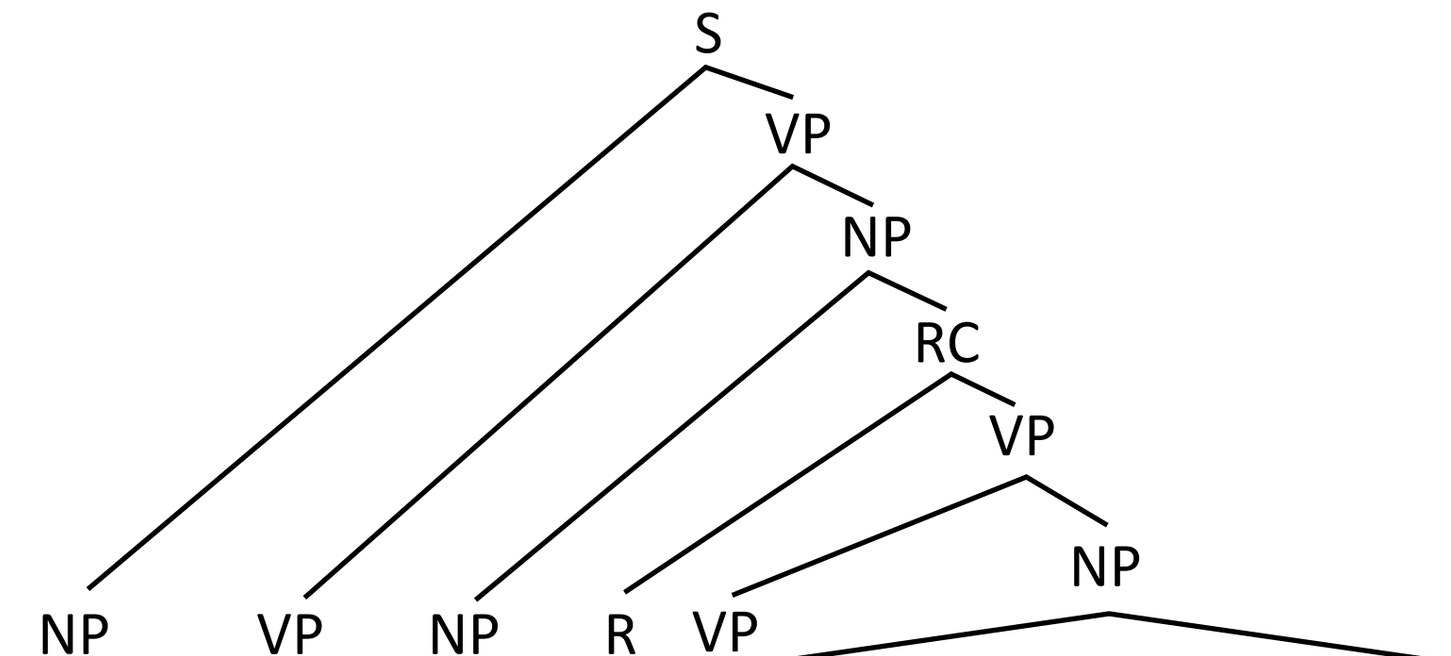

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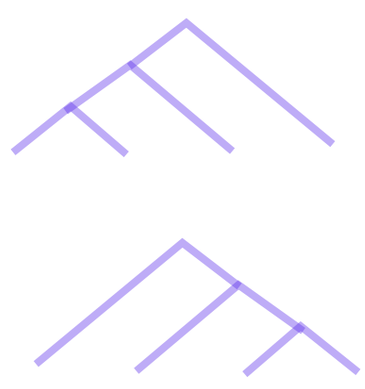

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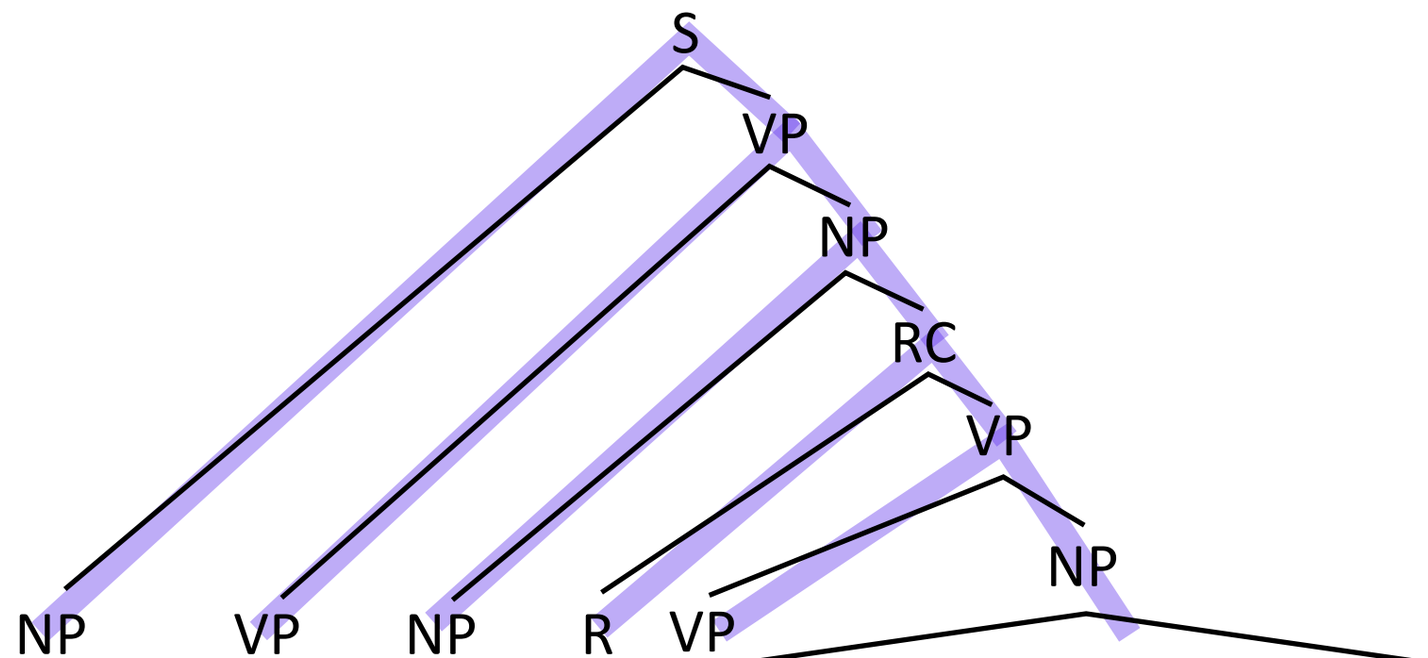

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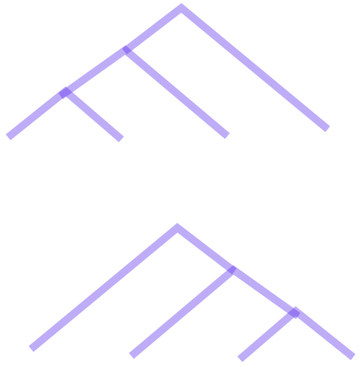

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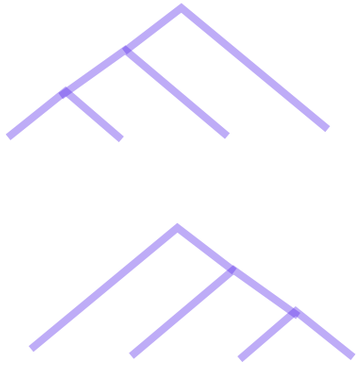

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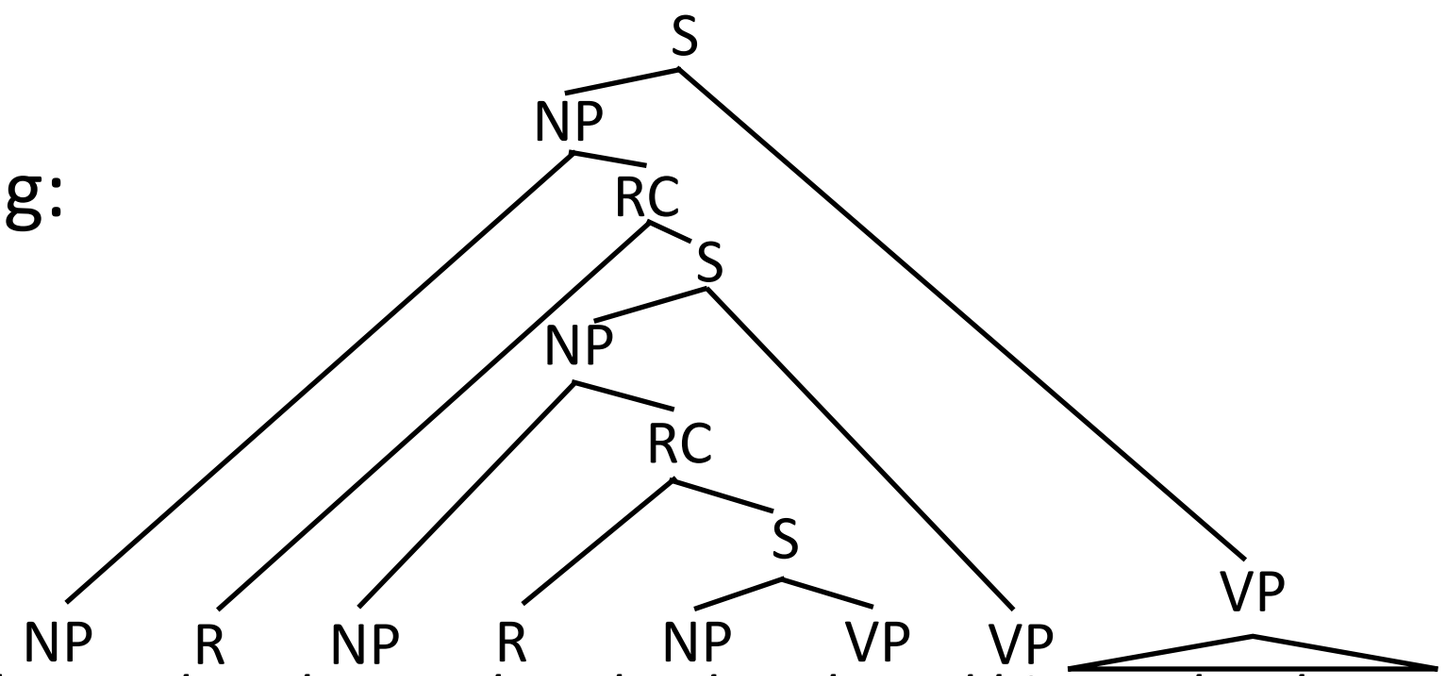

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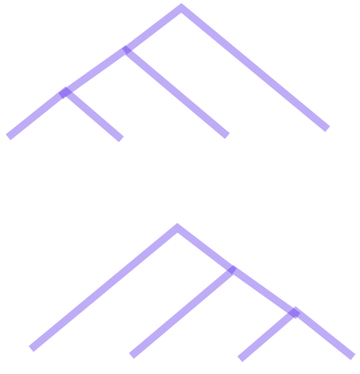

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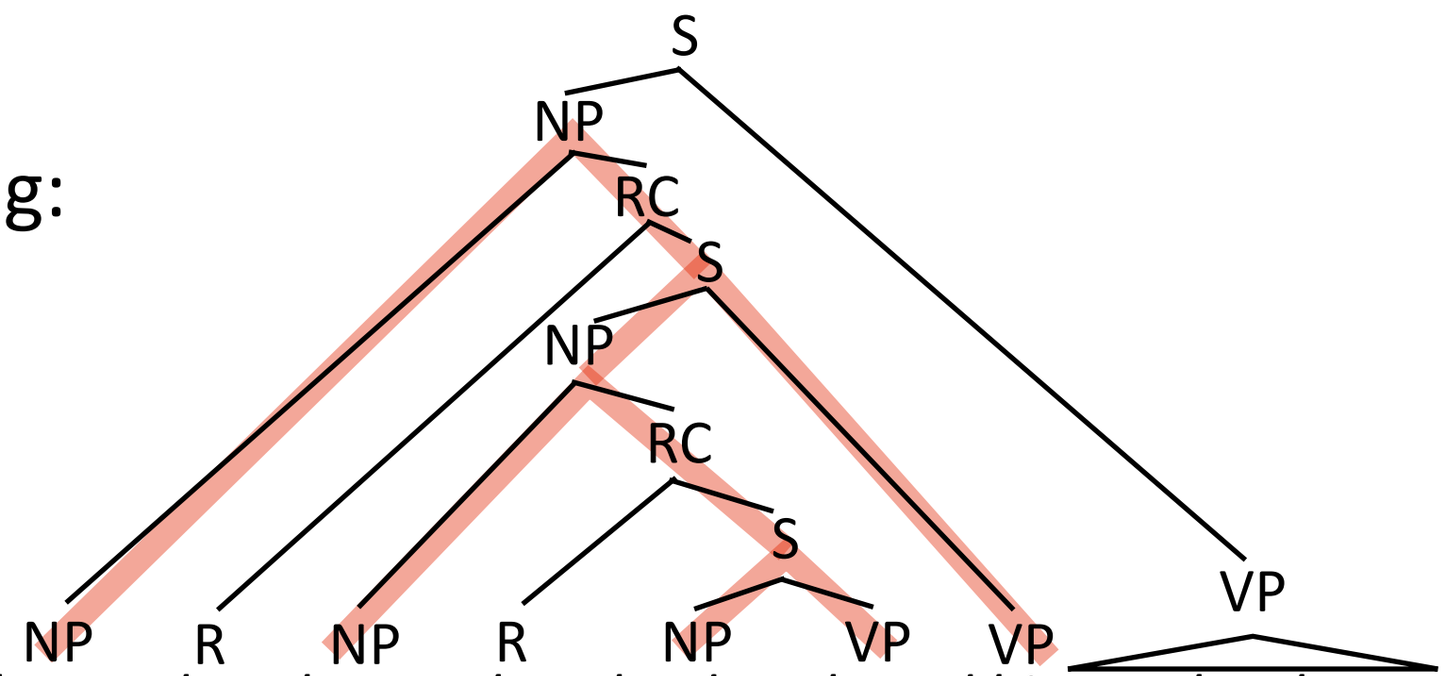

The rat that the cat that the dog chased bit ate the cheese

[Abney & Johnson, 1991; Resnik, 1992; Johnson, 1998]

Left-corner constituency parsing

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Left-corner constituency parsing

Stack-based incremental parsing

- larger stack depth is required only with center-embedded structures

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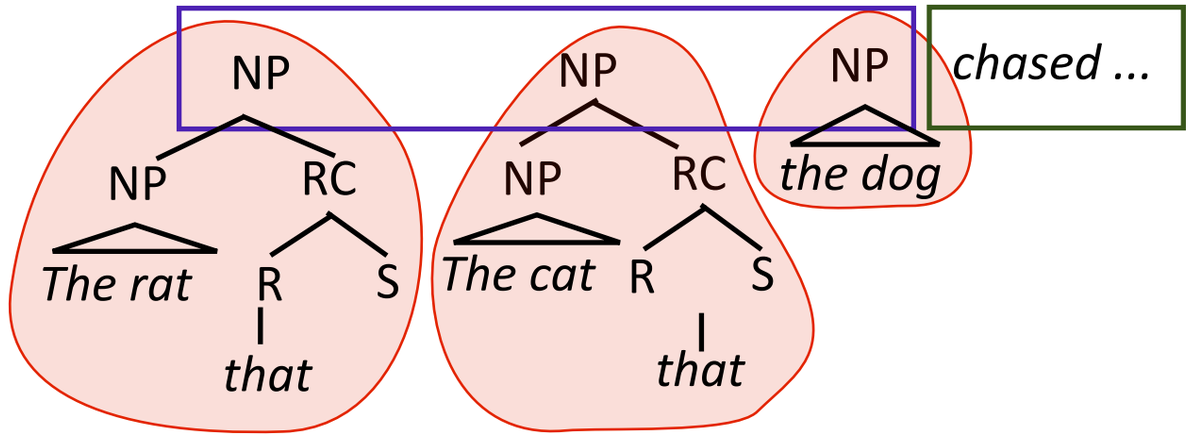

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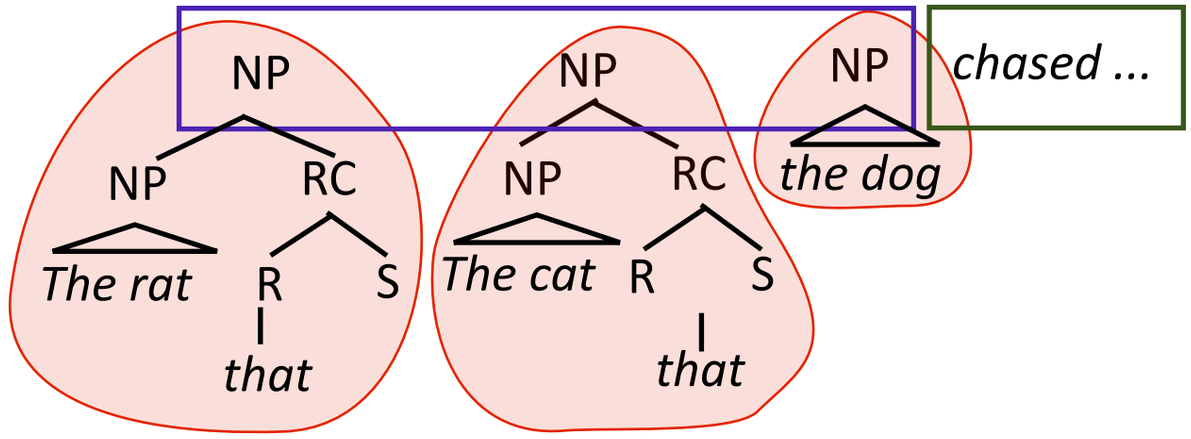

[Schuler et al., 2010] argues it is cognitively plausible, because...

- Almost all **English** treebank sentences don't require cost > 3
- High parsing accuracy within such memory constraint

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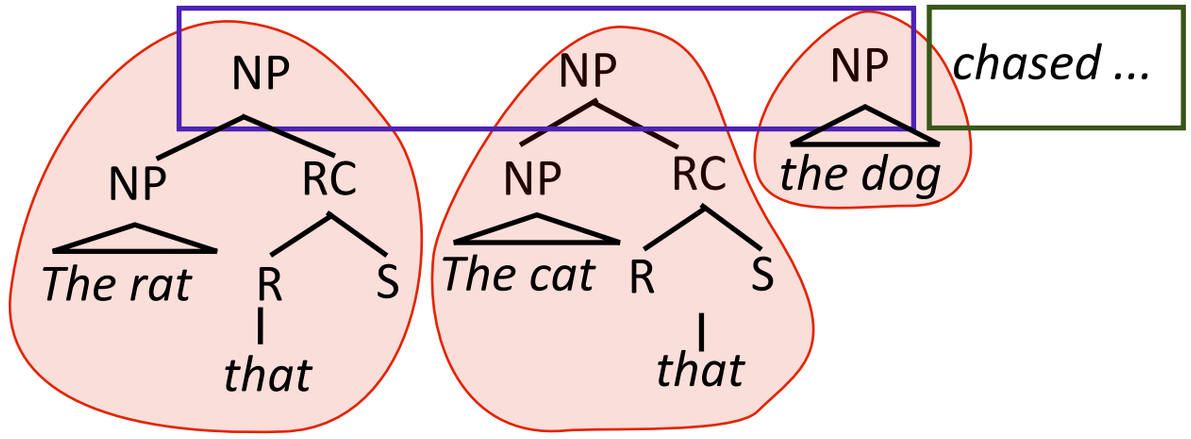

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Our goal: Stack-based **dependency** parser with cognitive plausibility

- Transition-based parser is a stack-based parser for dependency
- **What is the memory cost property of existing parsers?**

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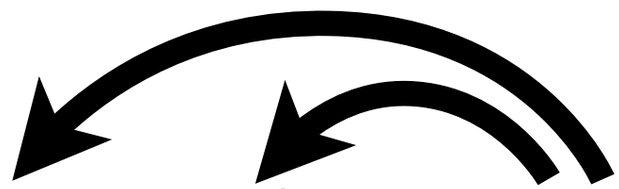

a parsing paper

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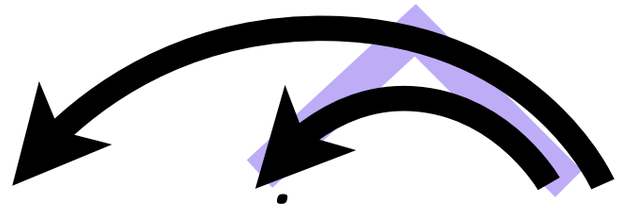

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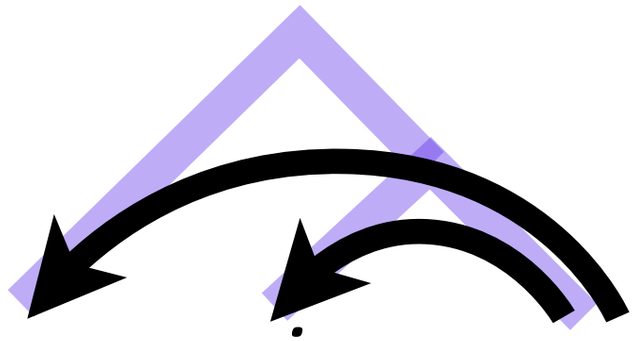

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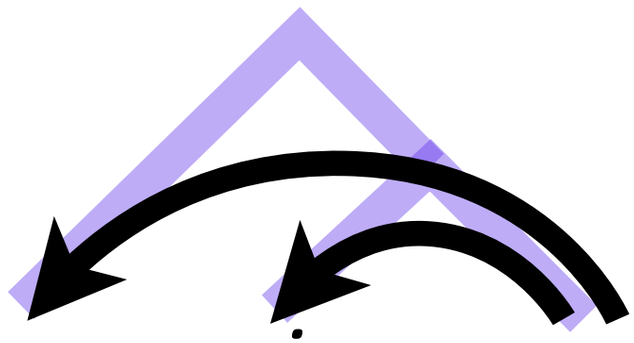

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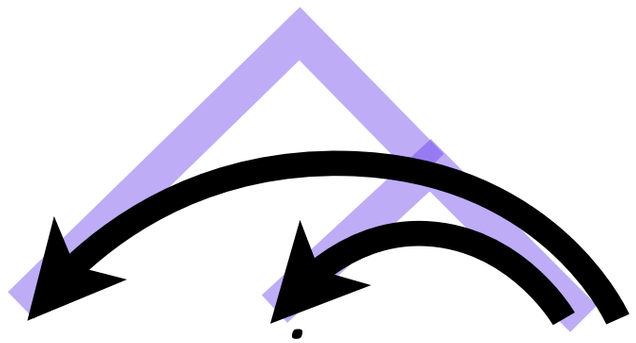

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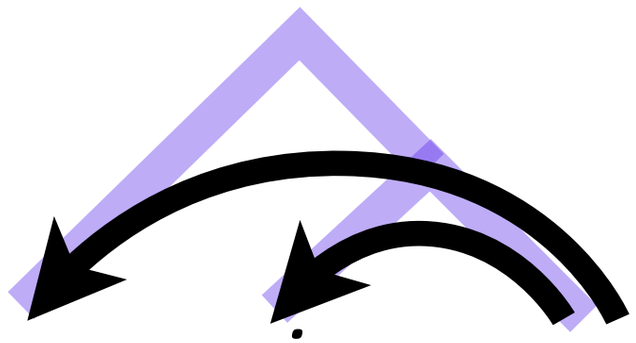

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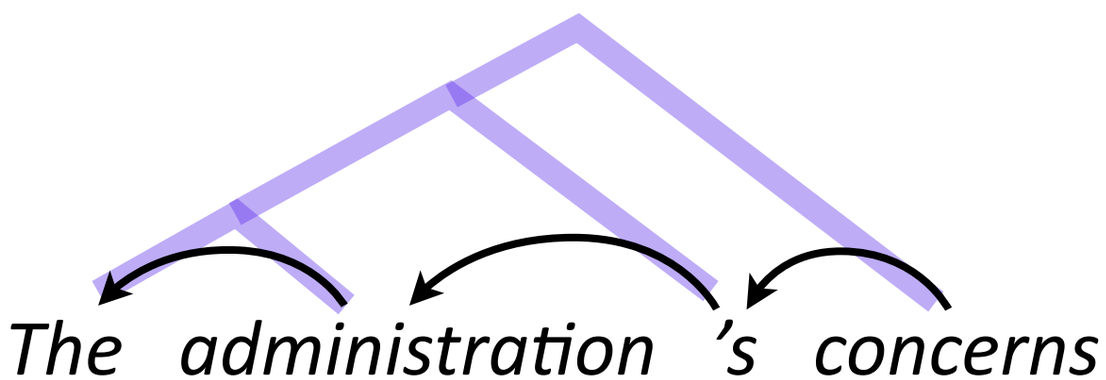

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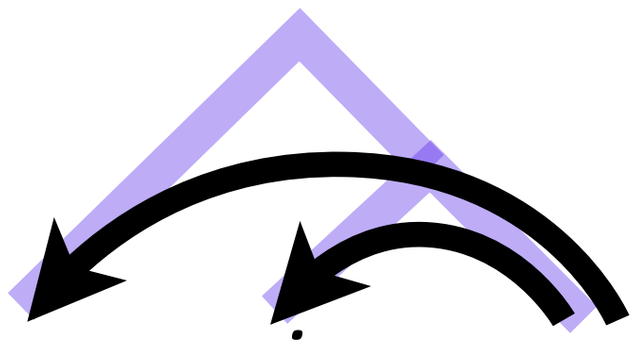

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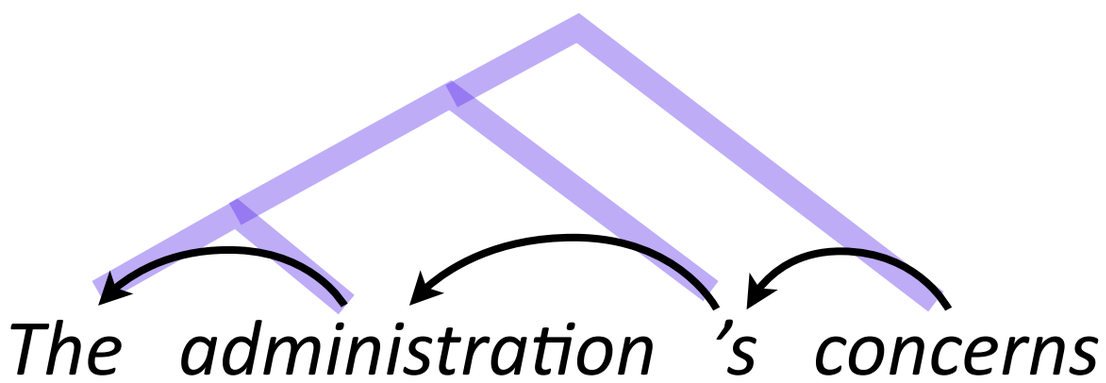

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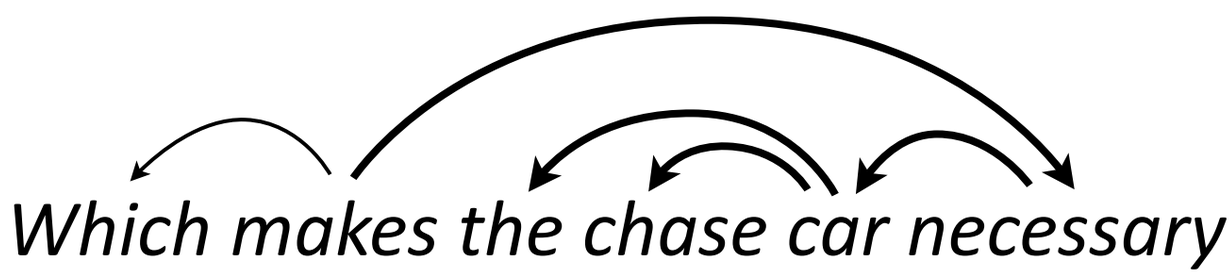

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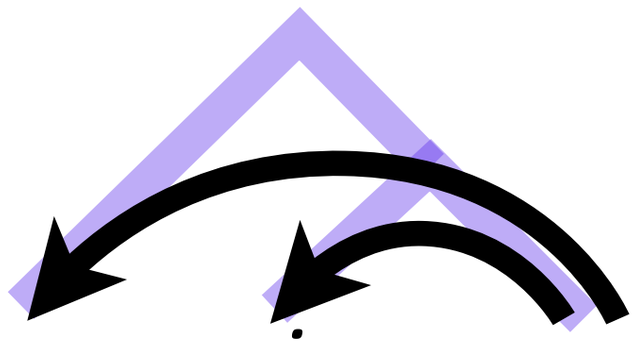

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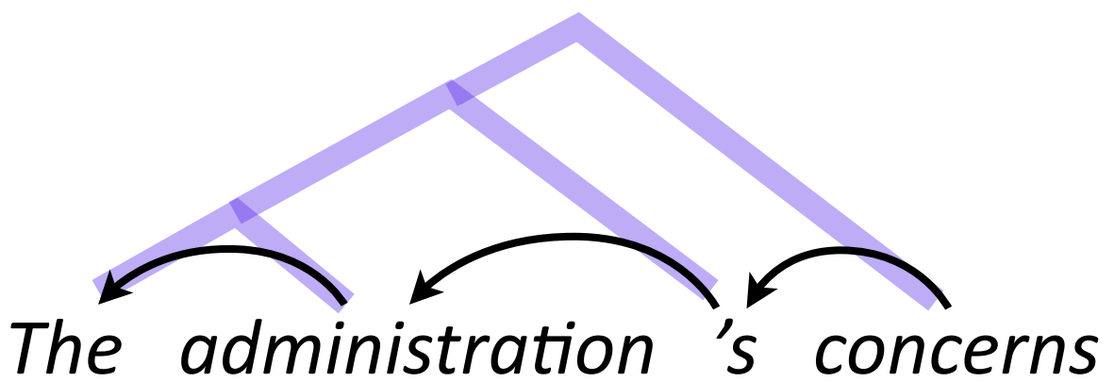

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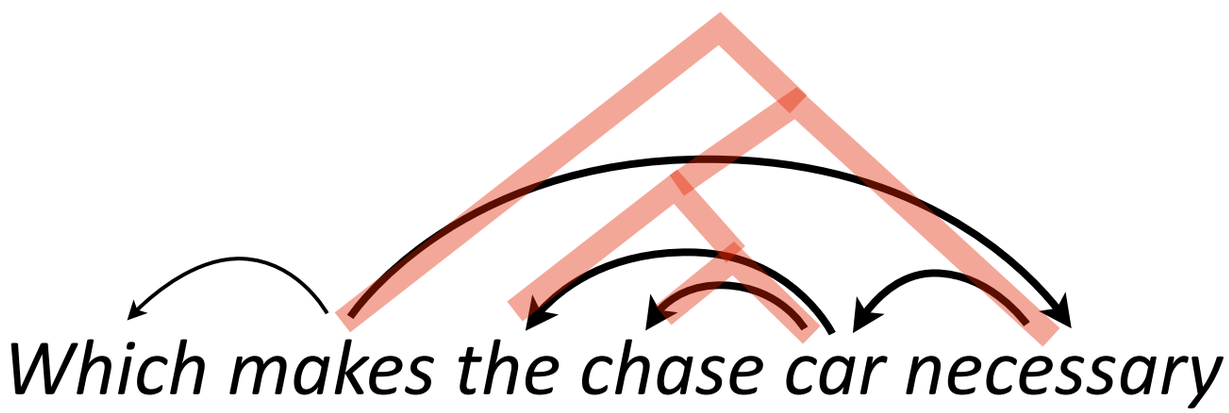

Transition-based dependency parsing

Stack

most

Buffer

popular beer in Ireland

Incrementally...

Transition-based dependency parsing

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popular beer in Ireland

Incrementally...

- read a token from the buffer (shift)

Transition-based dependency parsing

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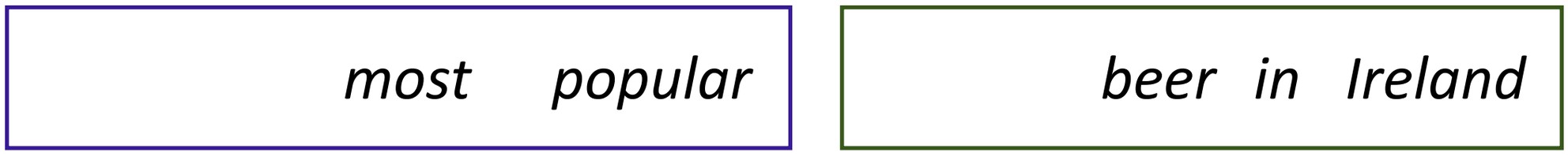
Buffer



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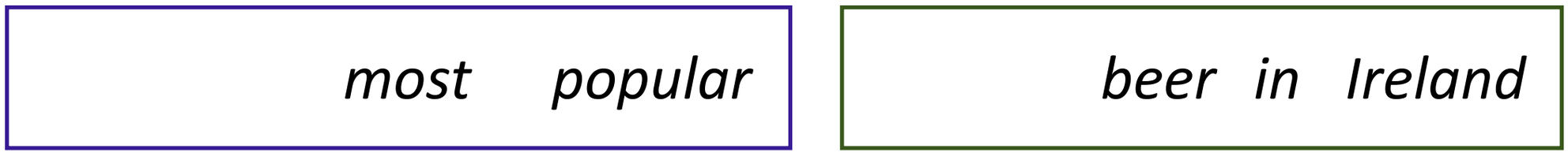

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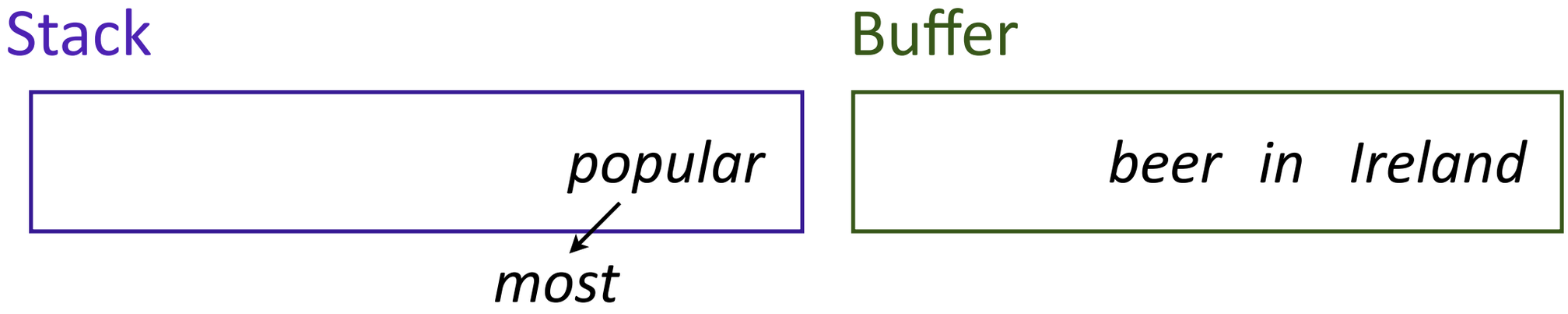

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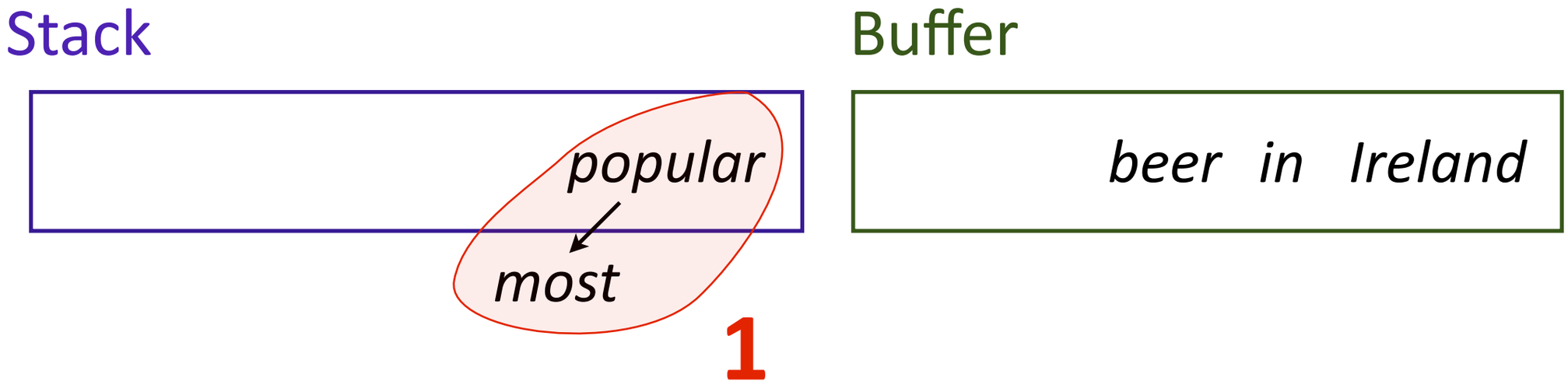

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Memory cost for a parser: number of subtrees on the stack

Several transition systems

Each transition system defines **different transition actions**

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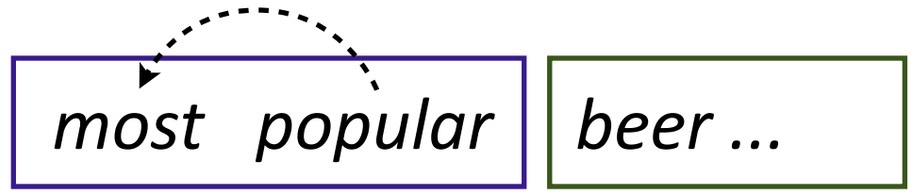
- Arc-standard [Nivre, 2004]

  ⇒ connect two words in the stack



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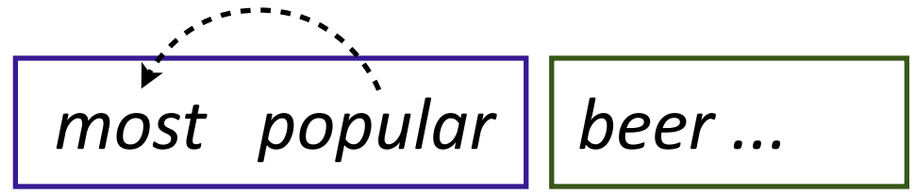

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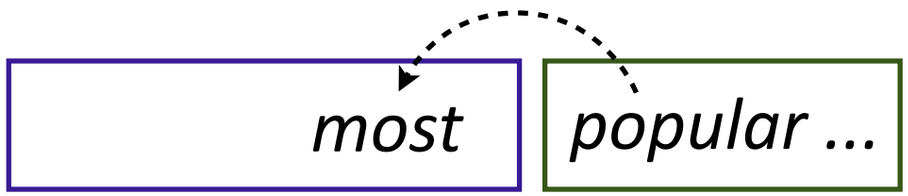

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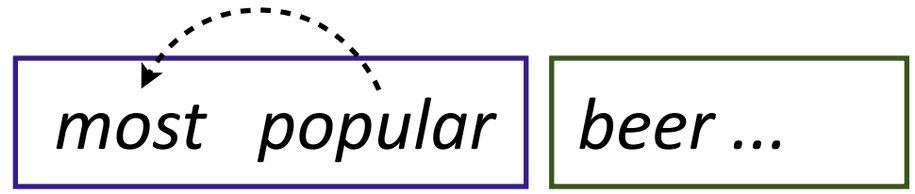

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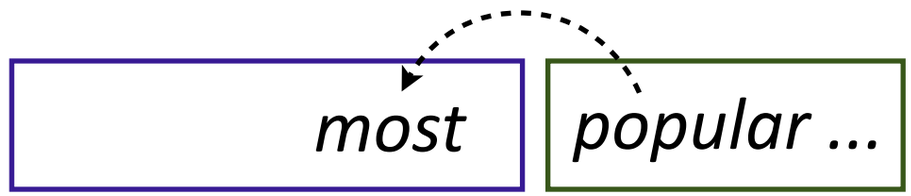
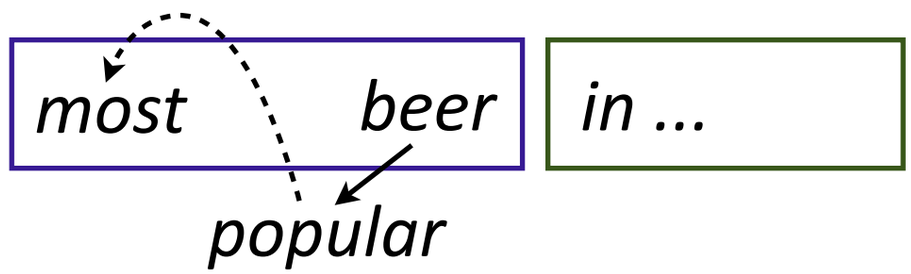


- Spine [Kitagawa & Tanaka-Ishii, 2011; Sartorio et al., 2013]

  ⇒ attaches to a token in a spine



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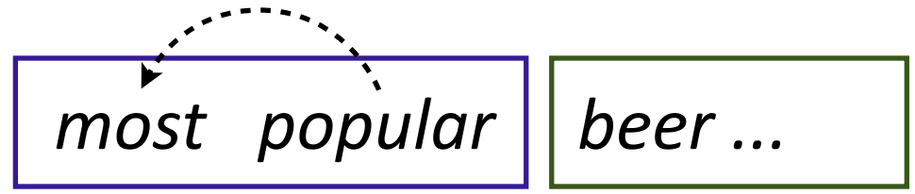

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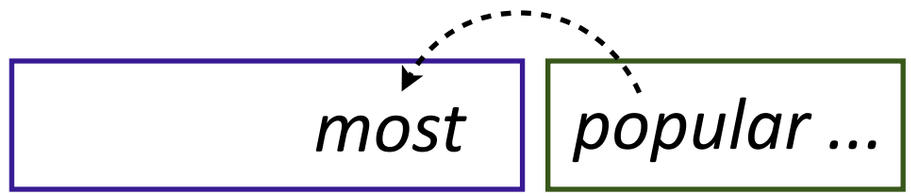

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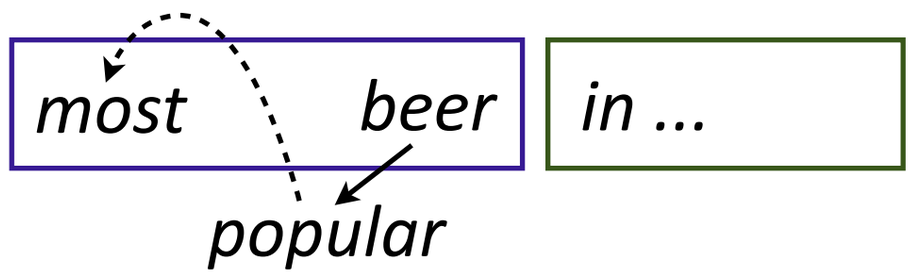

Each system has a different property of memory cost

Desired system: memory cost increases only with center-embedding

Arc-standard: Memory property

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Arc-standard is not a desirable transition system:

- Different memory cost for left- and right-branchings

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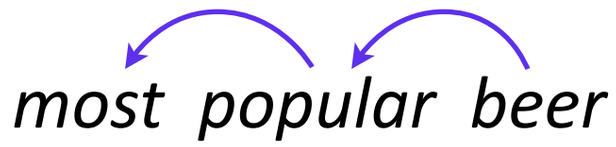

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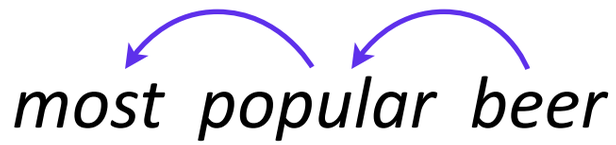

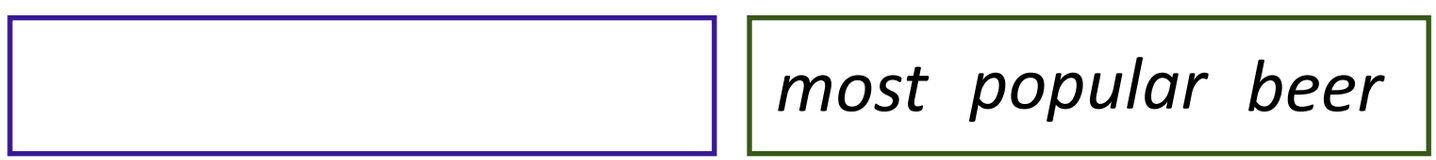

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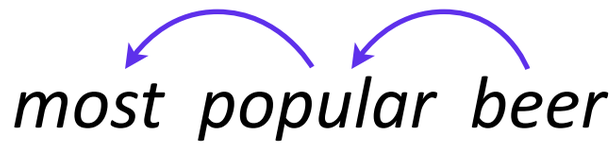

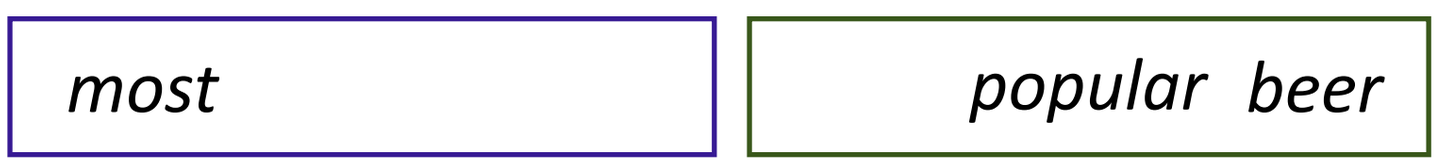

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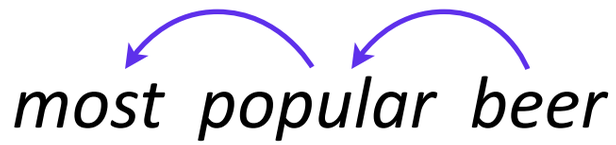

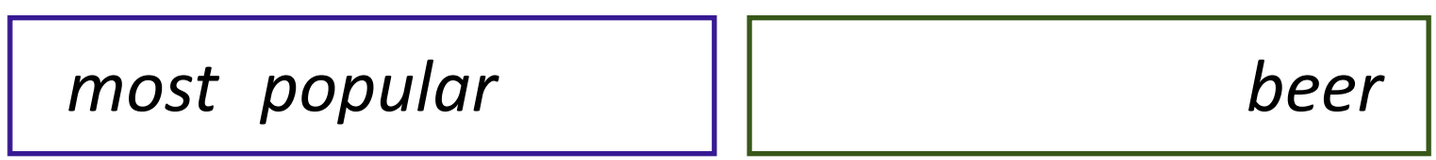

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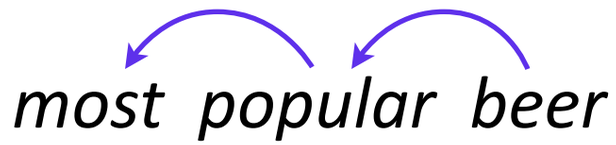

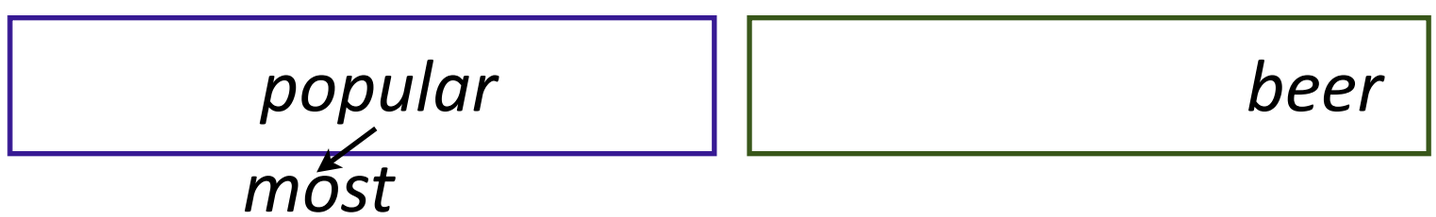

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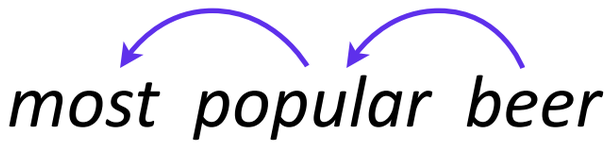

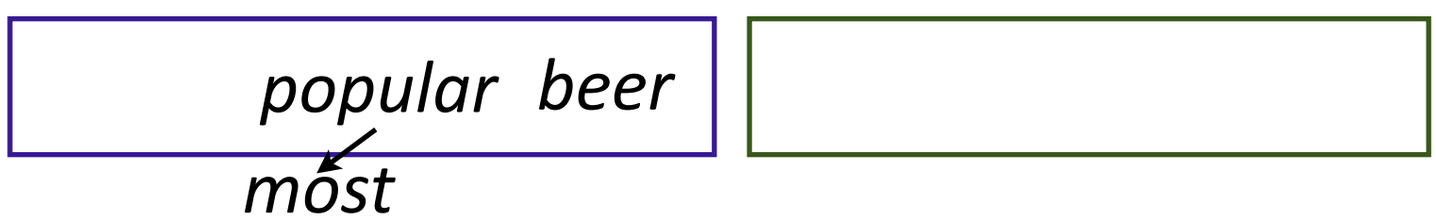

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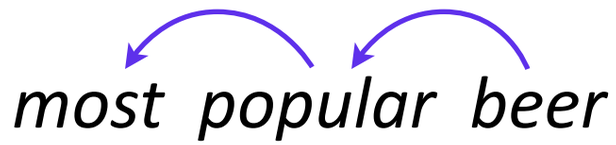

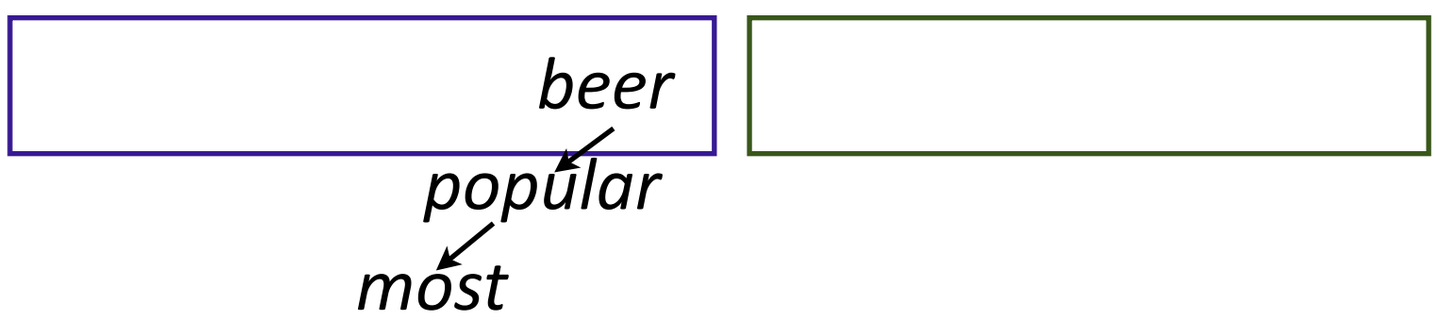

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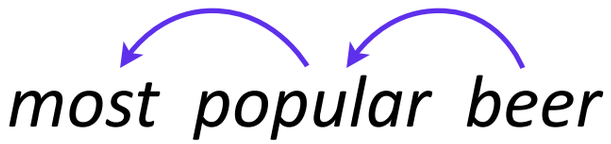
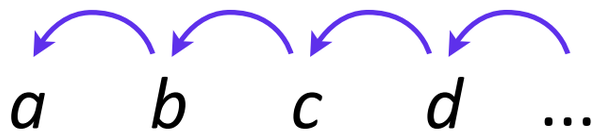
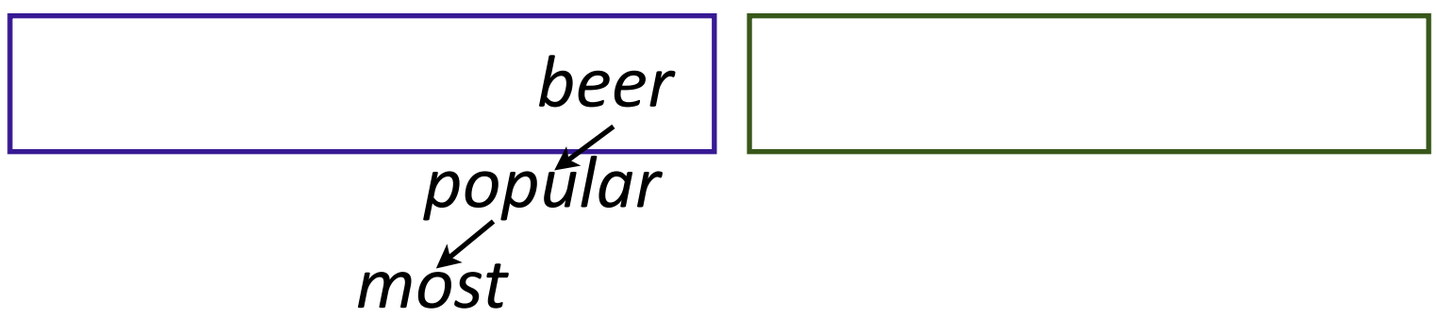




Max memory cost is 2 (**constant**)



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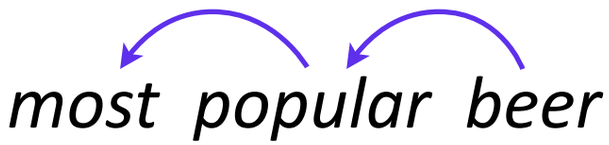

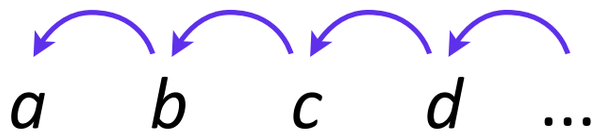

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right-branching:

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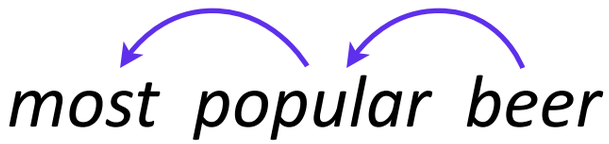

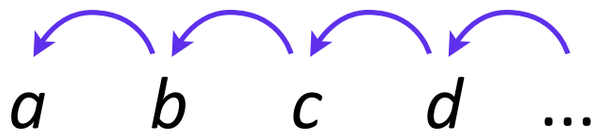

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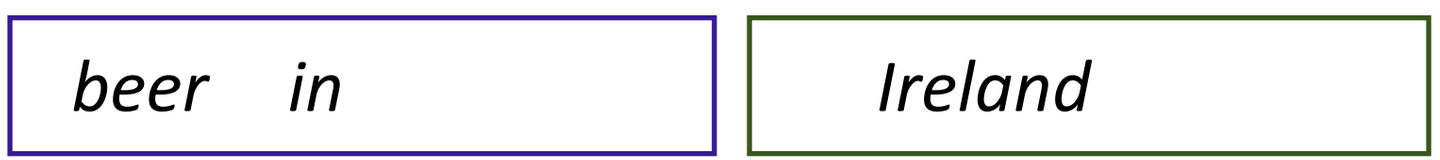

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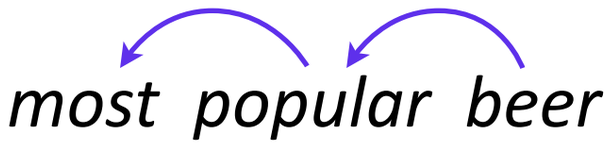
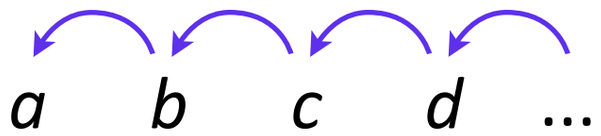
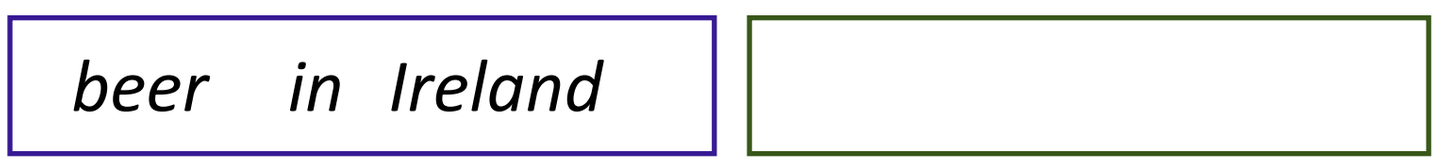




Max memory cost is 2 (**constant**)

right-branching:



Arc-standard: Memory property

Arc-standard is not a desirable transition system:

- Different memory cost for left- and right-branchings

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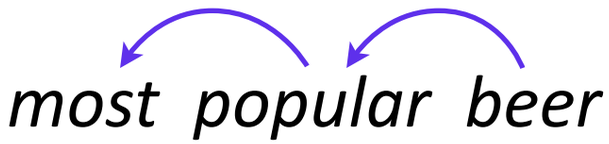

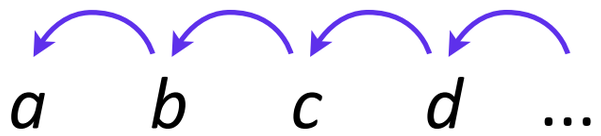

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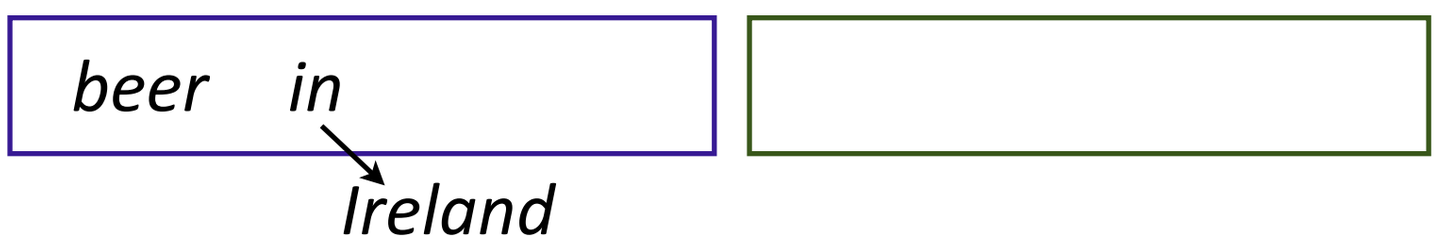

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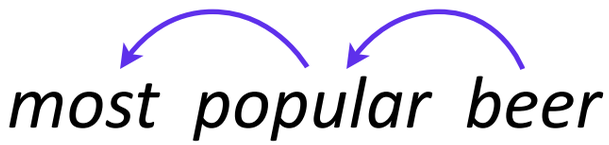

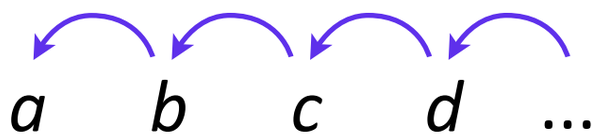

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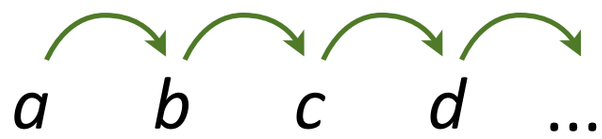
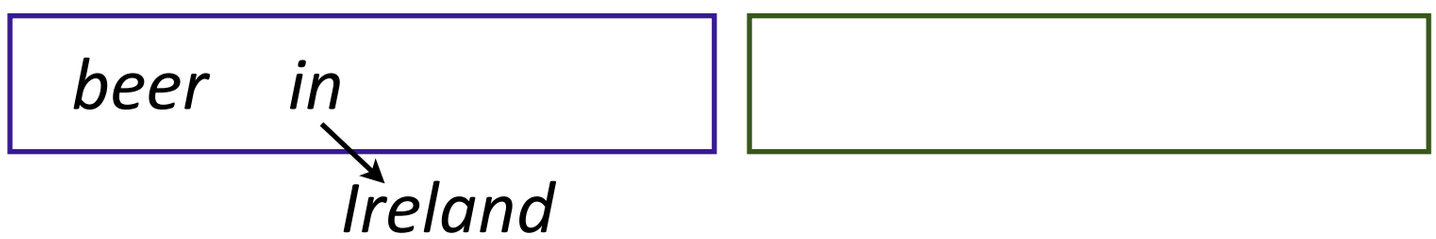


Memory cost increases **linearly**!



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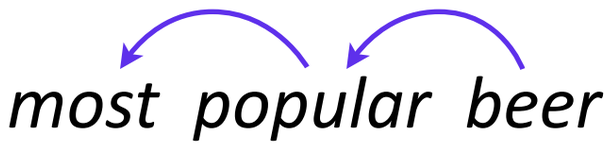

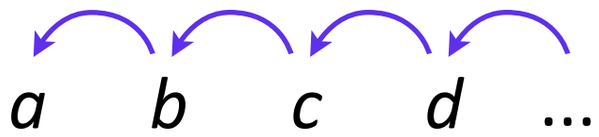

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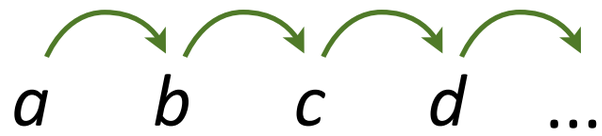
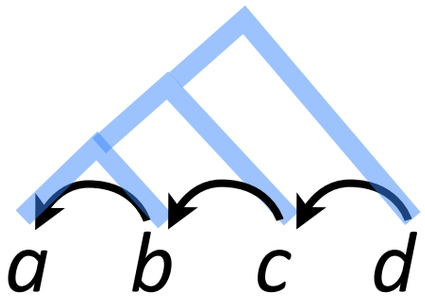
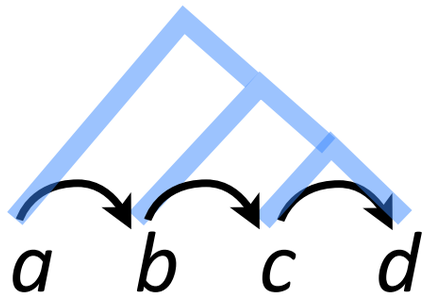
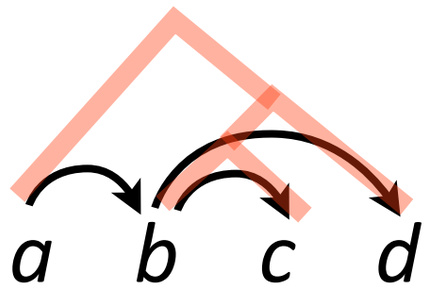


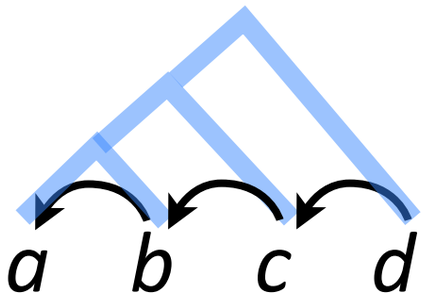
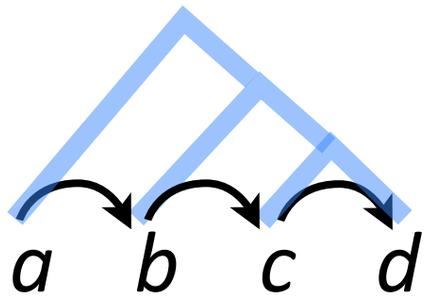
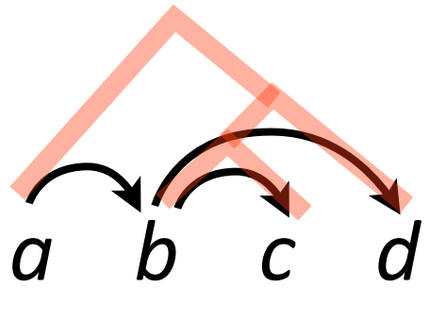
Memory cost increases **linearly**!

- This is because arc-standard is a **bottom-up** algorithm
- For center-embedding: incurs linear cost

Memory cost comparison

			
Arc-standard	O(1)	O(n)	O(n)
Arc-eager/ Spine	O(1)	O(1~n)	O(1~n)
Human	**O(1)**	**O(1)**	**O(n)**

Memory cost comparison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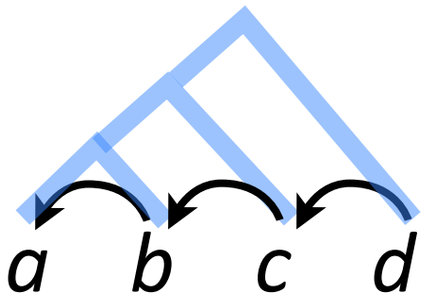
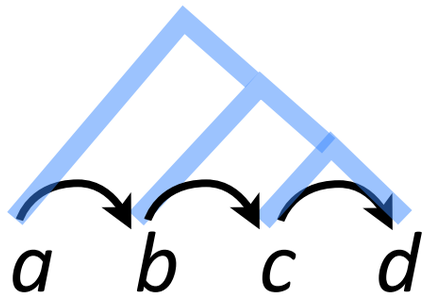
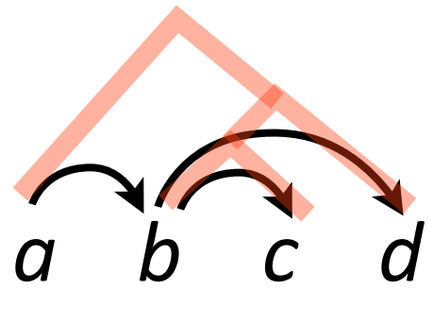
Memory cost comparison

			
Arc-standard	O(1)	O(n) ✗	O(n)
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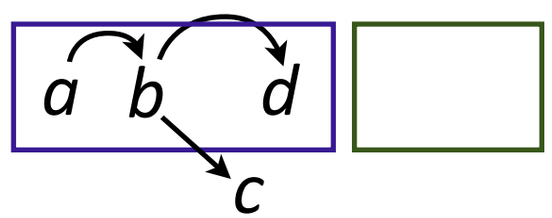
- Arc-eager: incurs no cost as long as all arcs are left-to-right



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	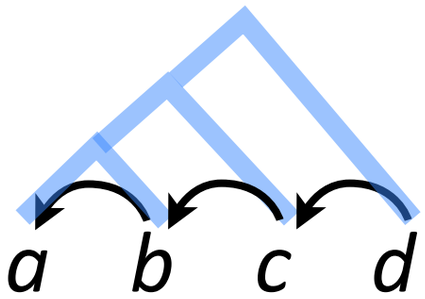	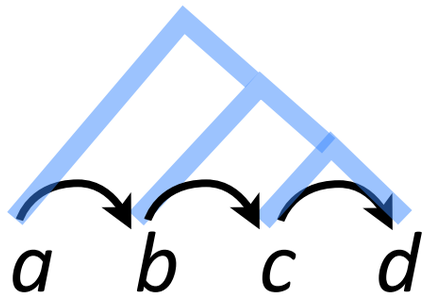	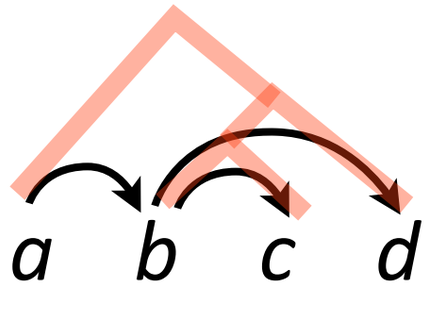
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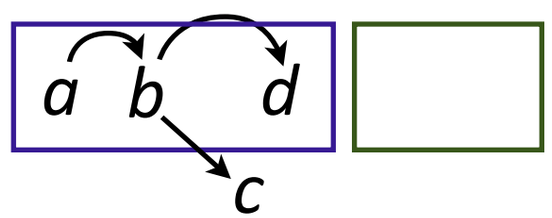
- Arc-eager: incurs no cost as long as all arcs are left-to-right
- Existing systems don't have desired property
  ⇒ We will pursue left-corner transition system



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	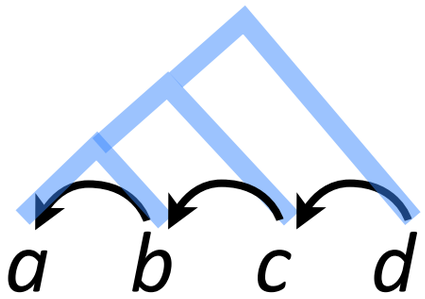	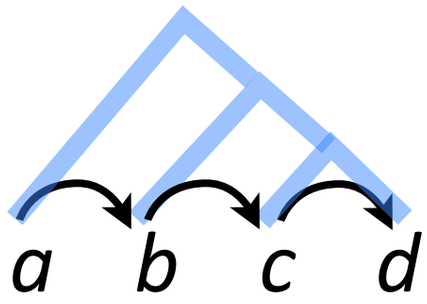	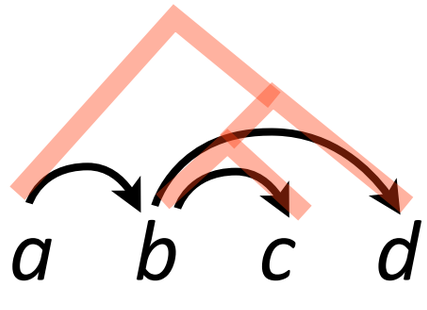
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Left-corner	**O(1)**	**O(1)**	**O(n)**

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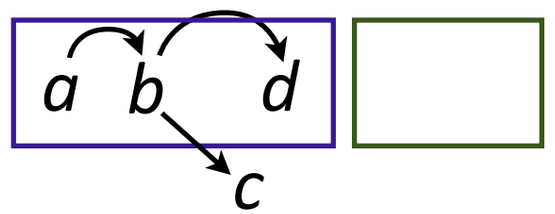

Outline

Setup

- Psycholinguistic observation
- Left-corner constituency parsing
- Memory cost of existing transition-based dependency parsers

Left-corner dependency parsing

- Dummy node
- Parse example and action definition

Experiments

- Memory cost during oracle transitions
- Exploration of syntactic biases

Key idea: transition with prediction

Problem of arc-standard: for right-branchings...

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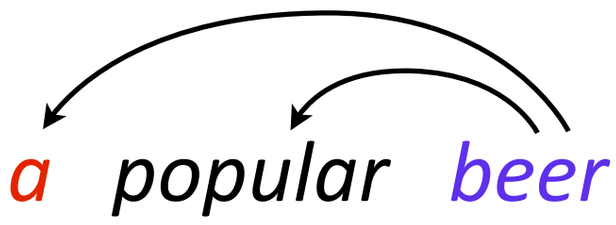

a cannot be reduced before *beer* is shifted

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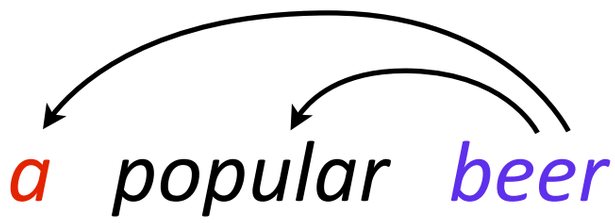

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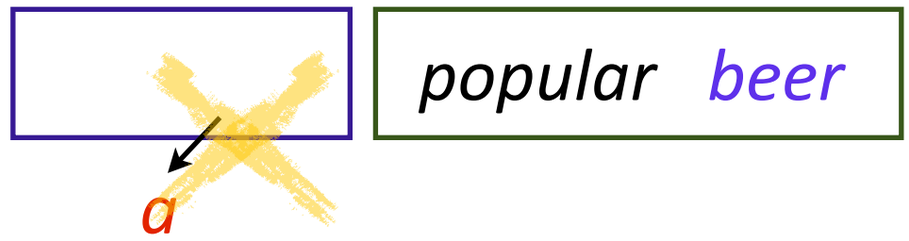

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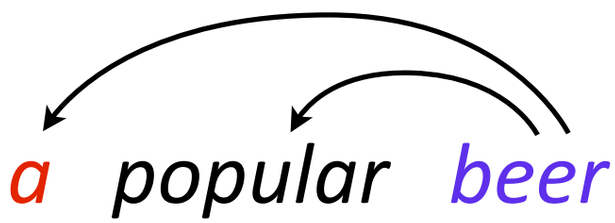

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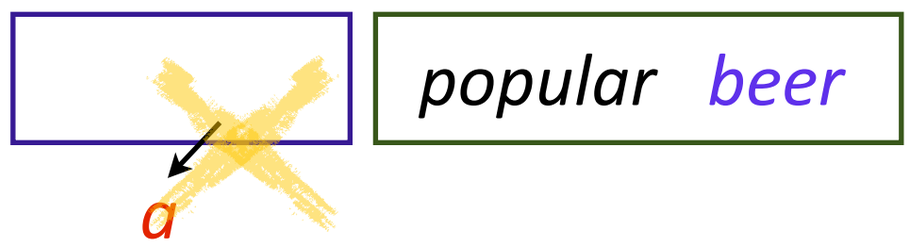

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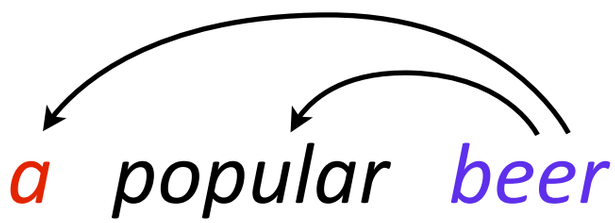

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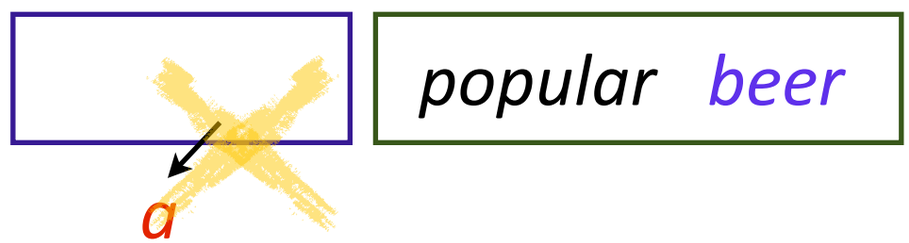

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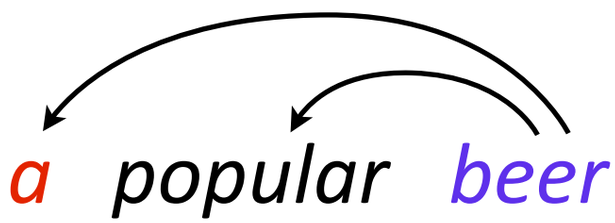

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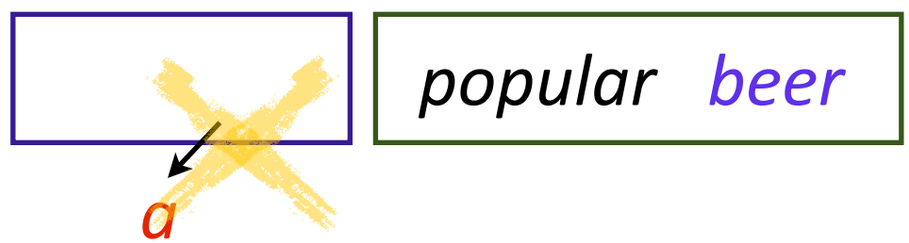

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Solution: right side of subtree is predicted during transition

- Dummy node: represents predicted part in a subtree

Key idea: transition with prediction

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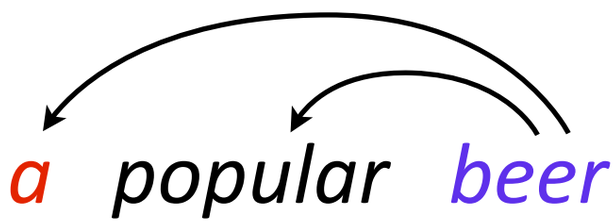

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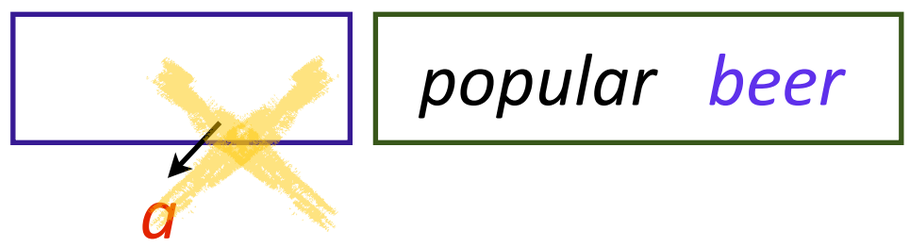

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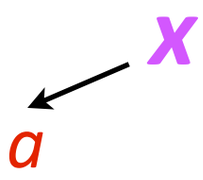

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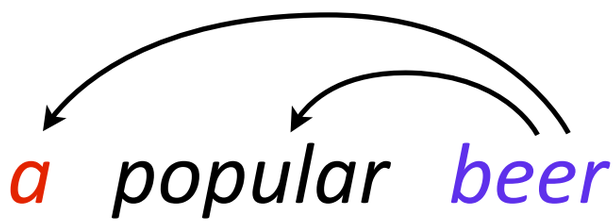

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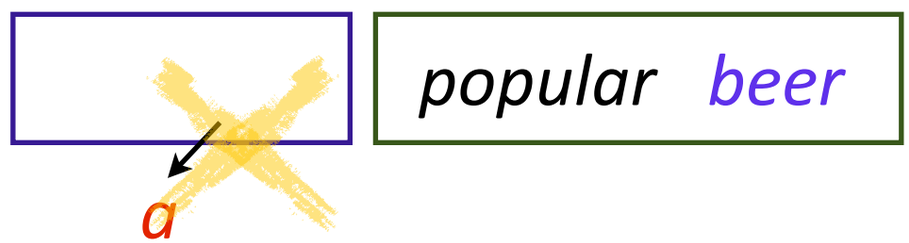

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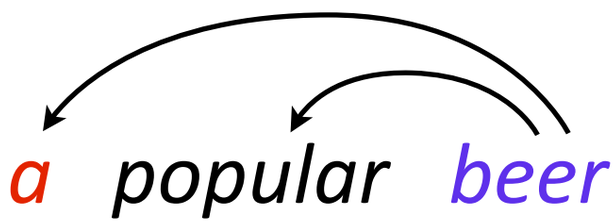

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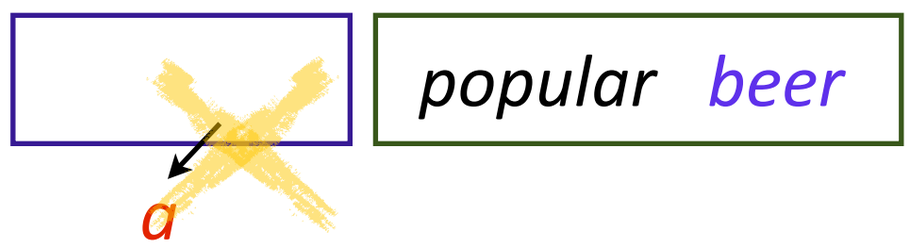
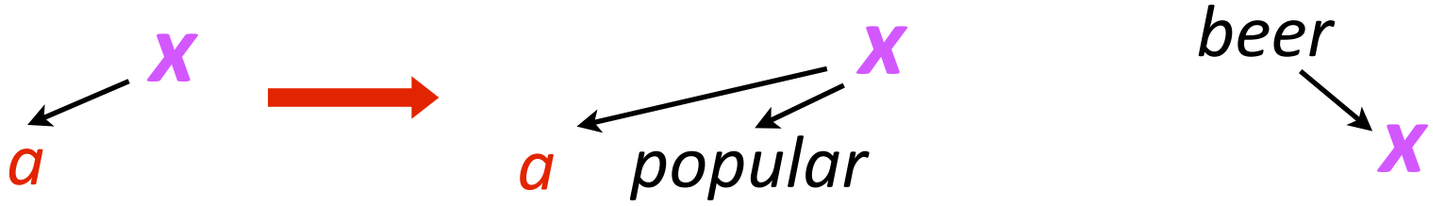


in cannot be reduced before collecting children

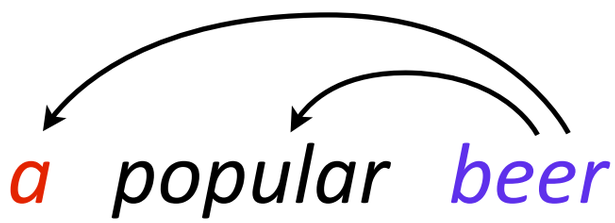
Solution: right side of subtree is predicted during transition

- Dummy node: represents predicted part in a subtree

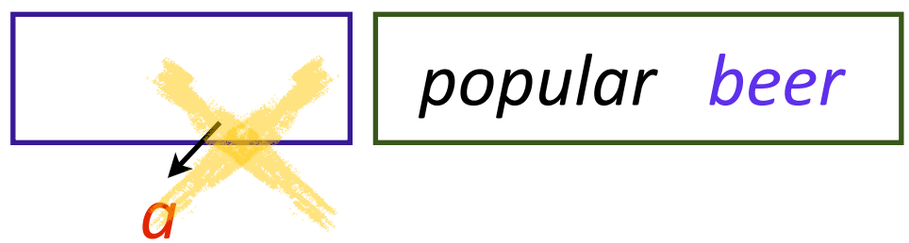


Key idea: transition with prediction

Problem of arc-standard: for right-branchings...



a cannot be reduced before *beer* is shifted



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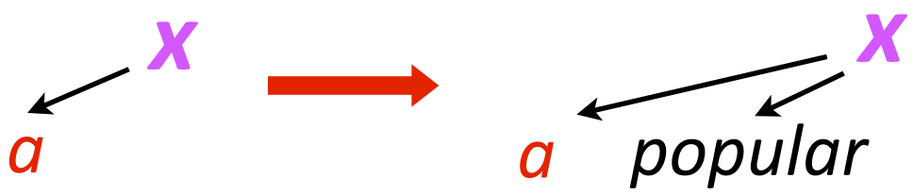
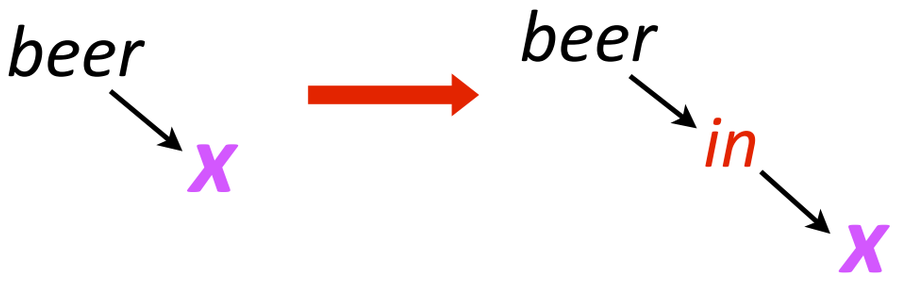




Parsing example

Stack

Buffer

a popular beer in Ireland

Parsing example

Stack

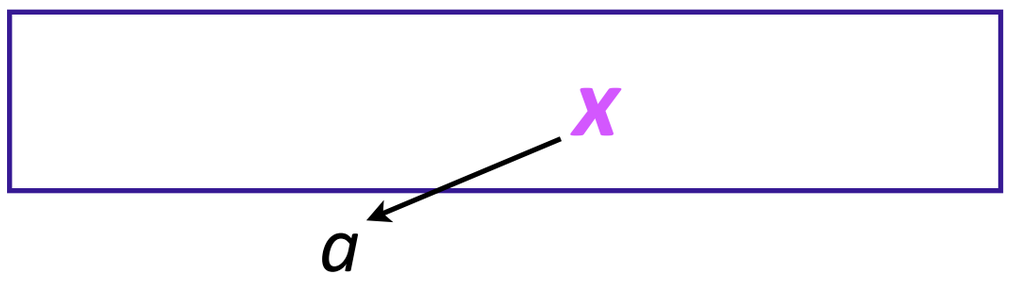
a

Buffer

popular beer in Ireland

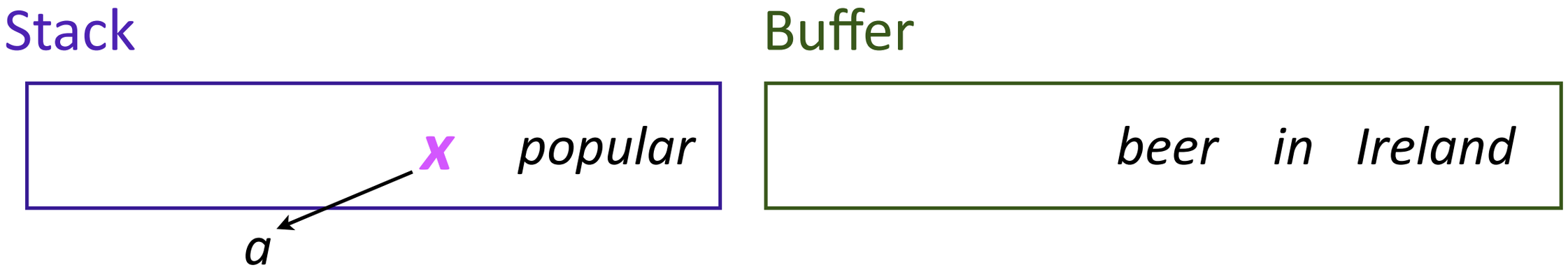
Parsing example

Stack



Buffer

Parsing example



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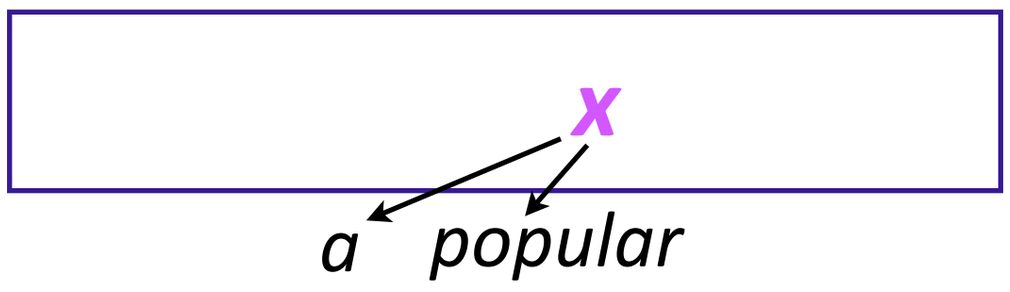
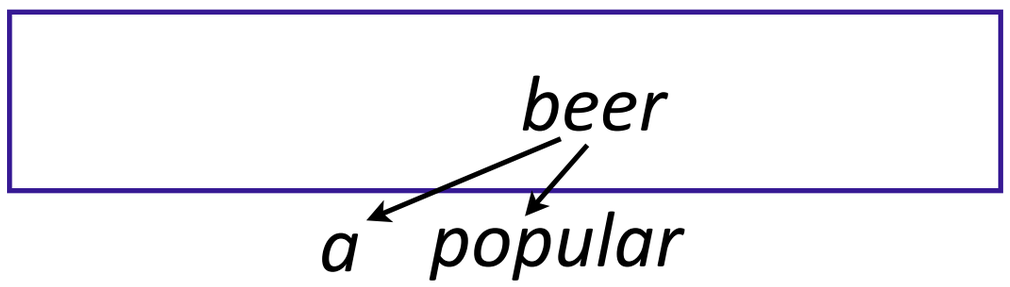
Stack



Buffer

Parsing example

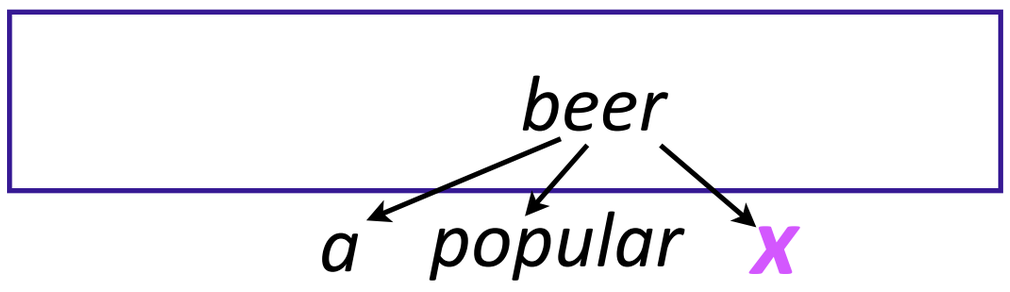
Stack



Buffer

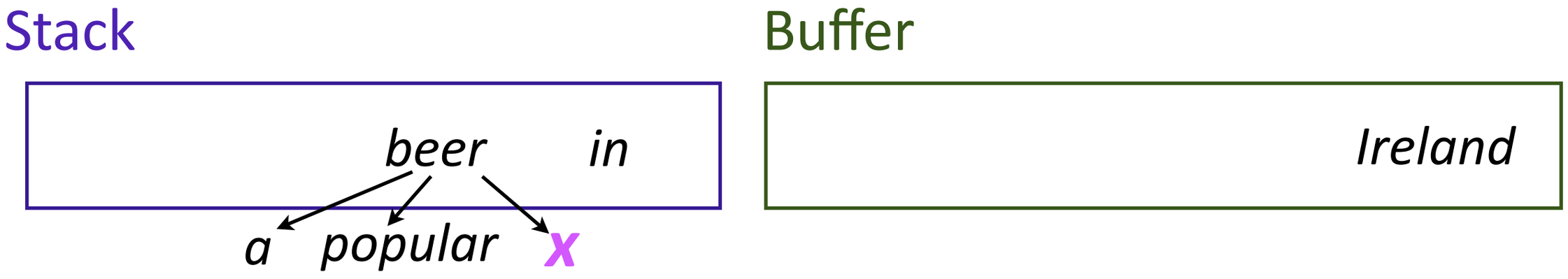
Parsing example

Stack



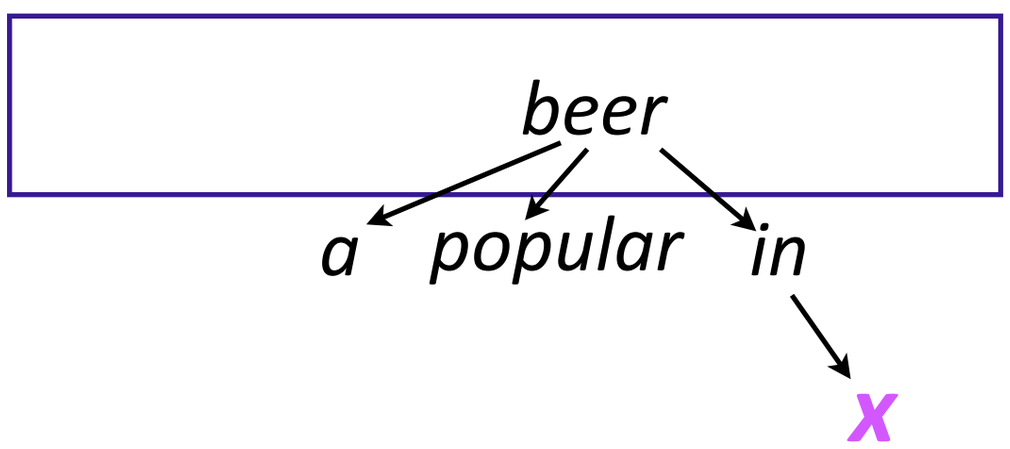
Buffer

Parsing example



Parsing example

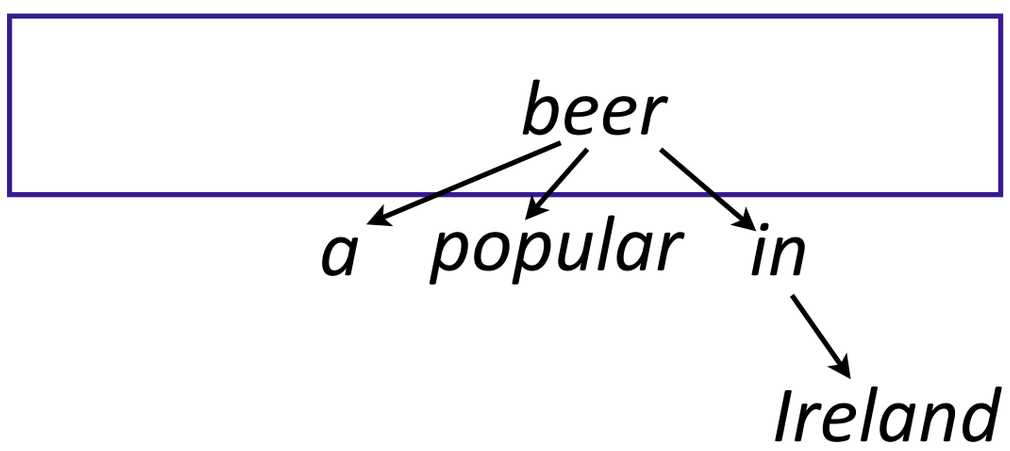
Stack



Buffer

Parsing example

Stack



Buffer

4 kinds of actions

SHIFT

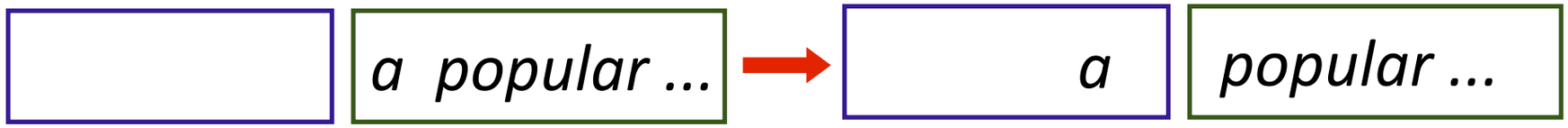
INSERT

PRED (**left**/right)

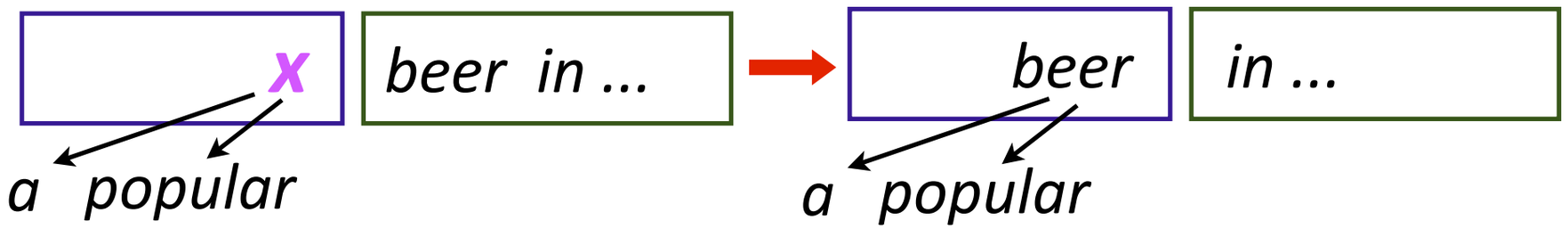
COMP (**left**/right)

4 kinds of actions

SHIFT



INSERT



PRED (**left**/right)

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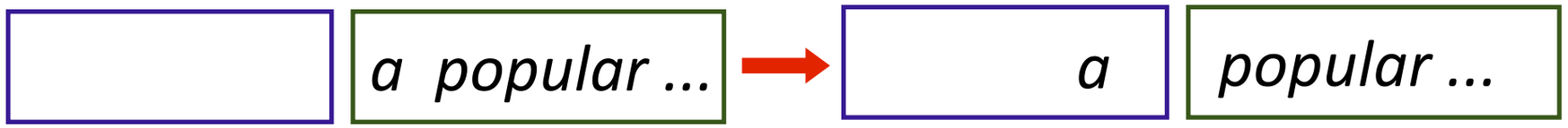
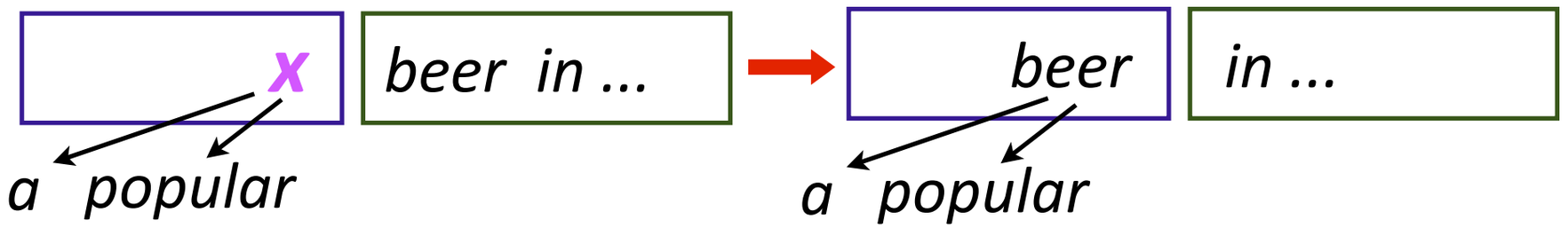
4 kinds of actions

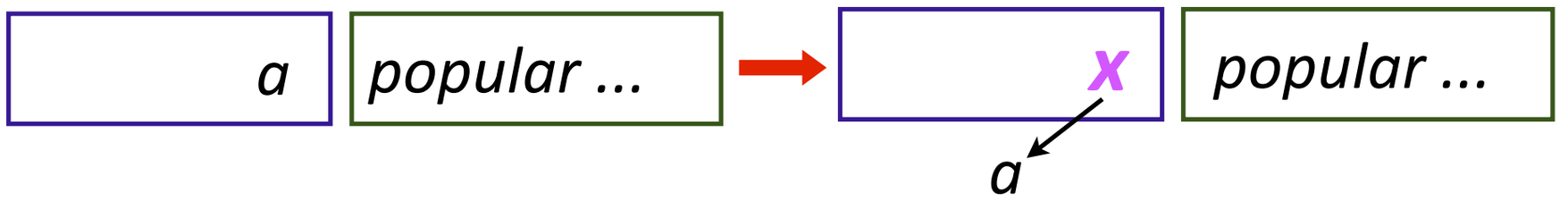
SHIFT



INSERT



PRED (**left**/right)

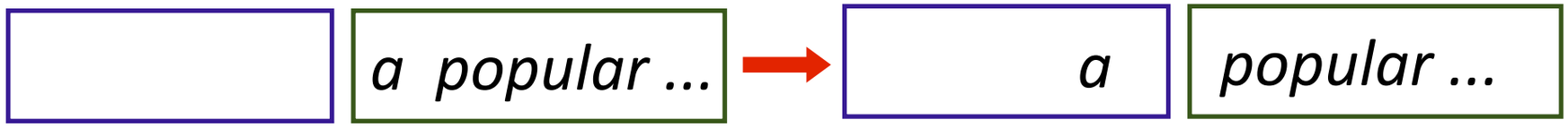


create a new dummy node

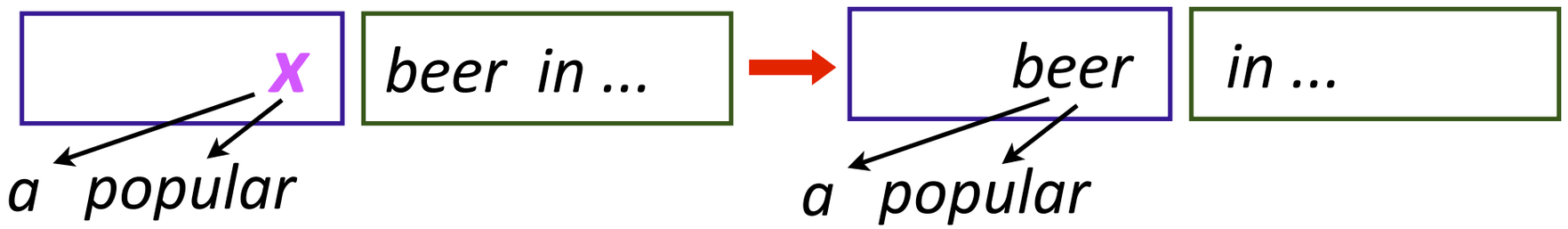
COMP (**left**/right)

4 kinds of actions

SHIFT



INSERT



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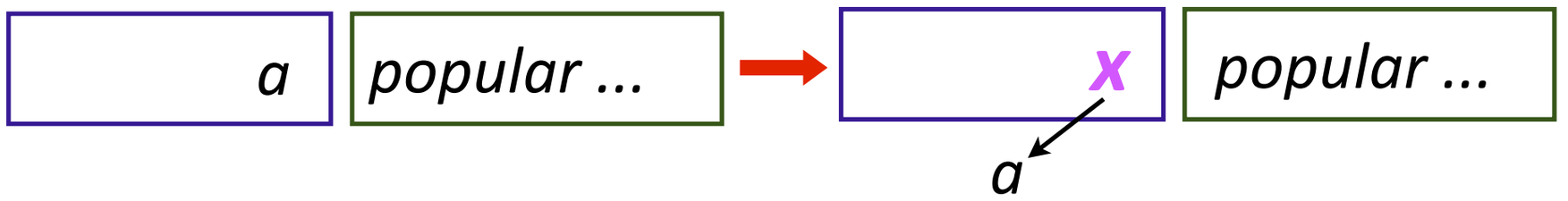

create a new dummy node

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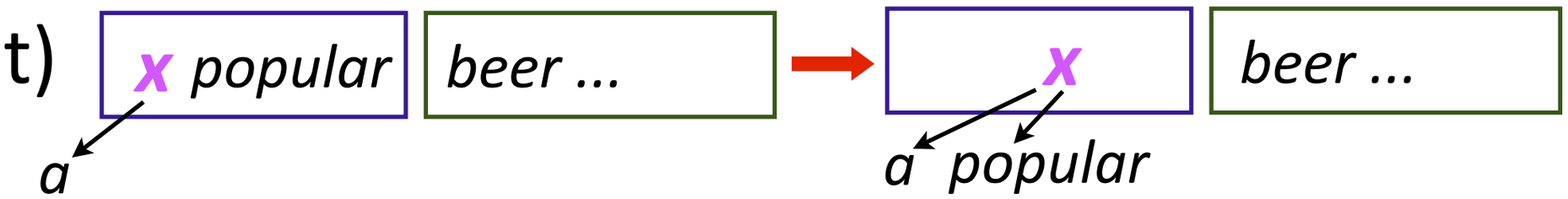
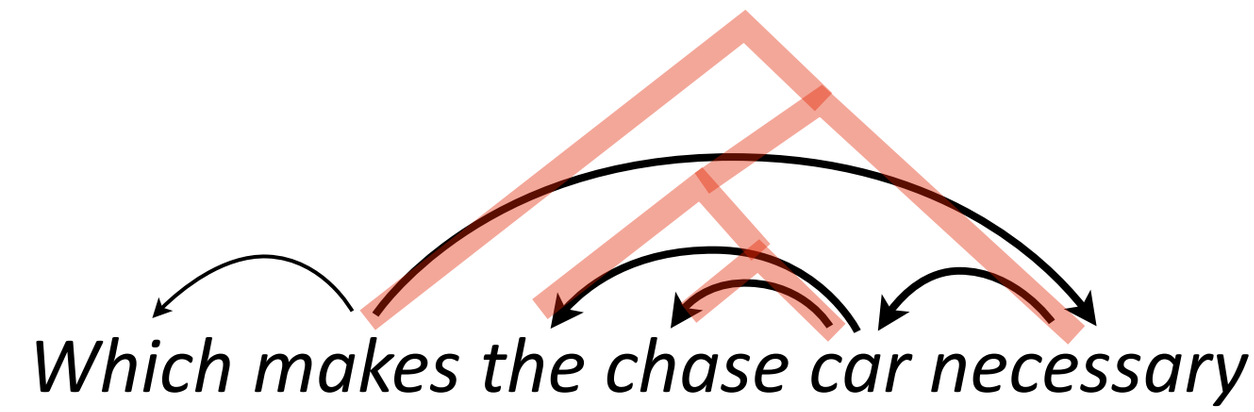


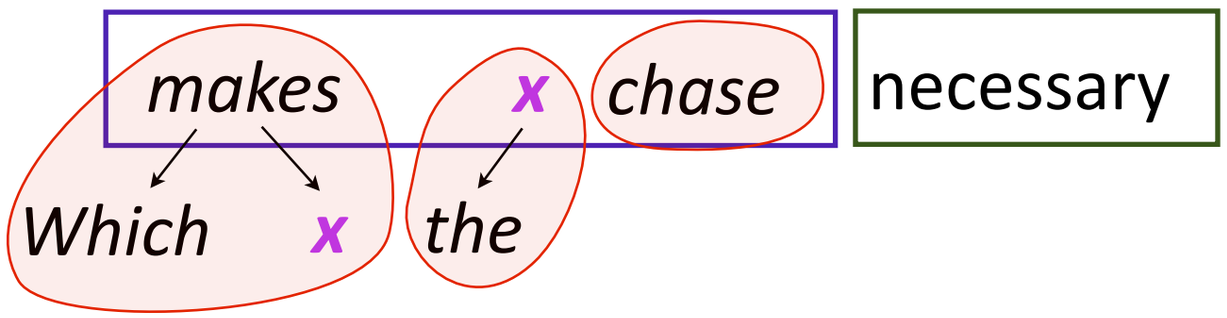
connect two trees via a dummy node

Characteristics

Characteristics

Non-constant cost only with center-embedding:





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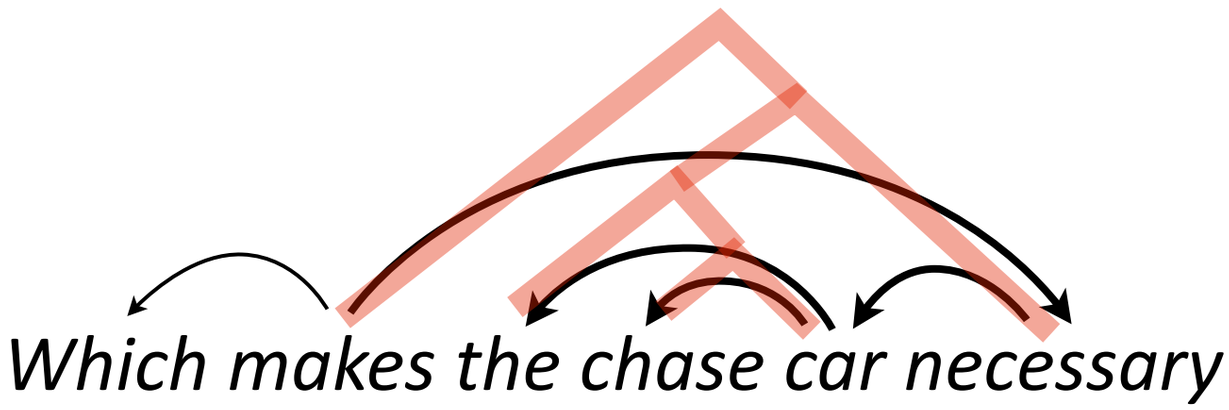
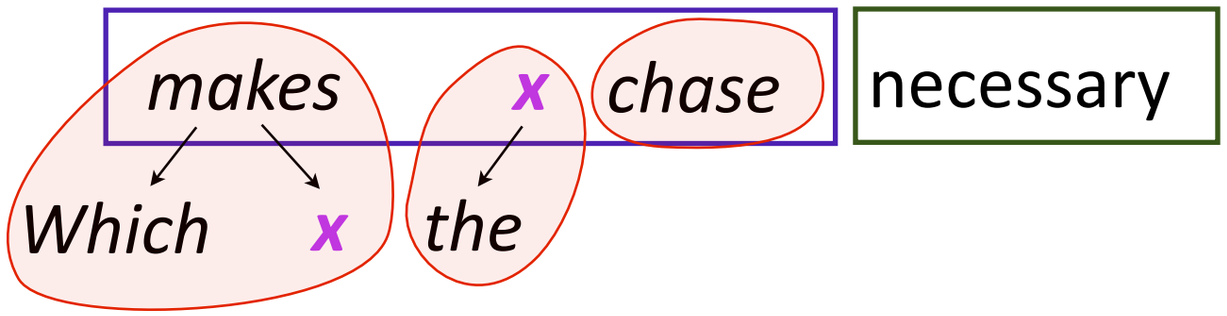


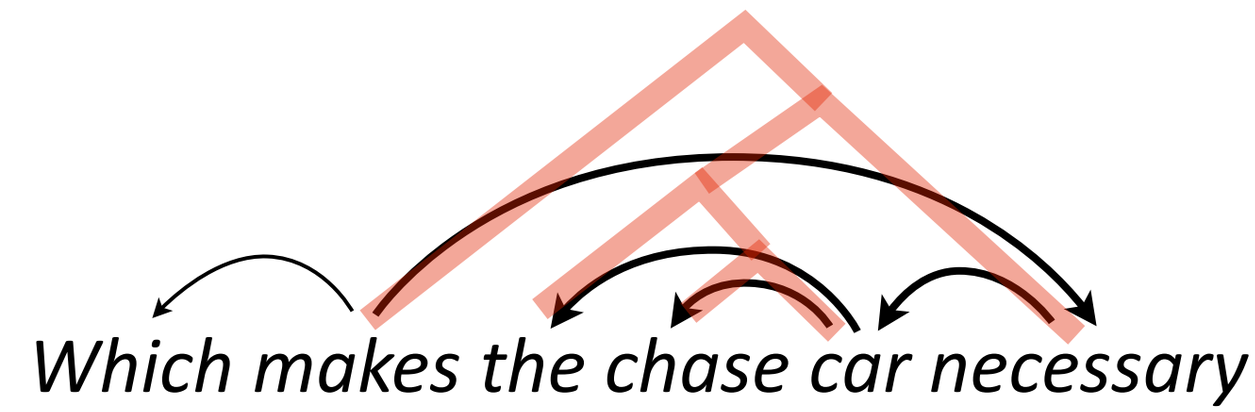


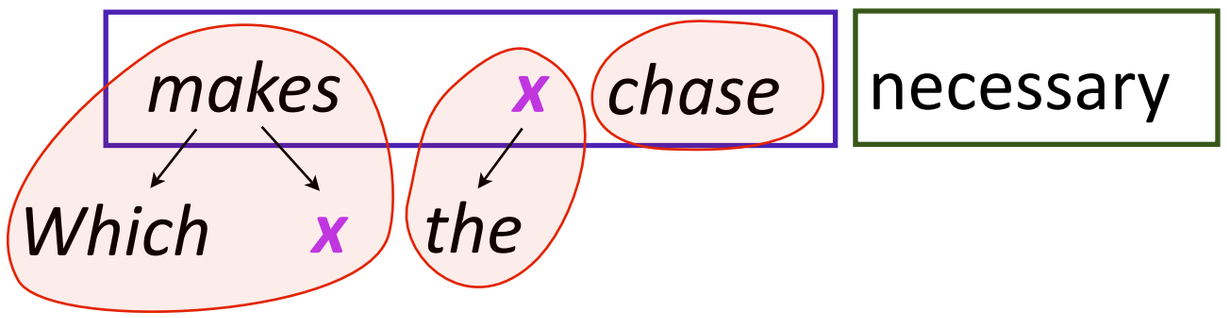
Deep connection to constituency left-corner parsing

- PRED can be interpreted as original **predict** with CNF:

Characteristics

Non-constant cost only with center-embedding:





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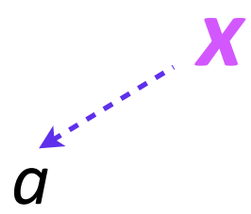

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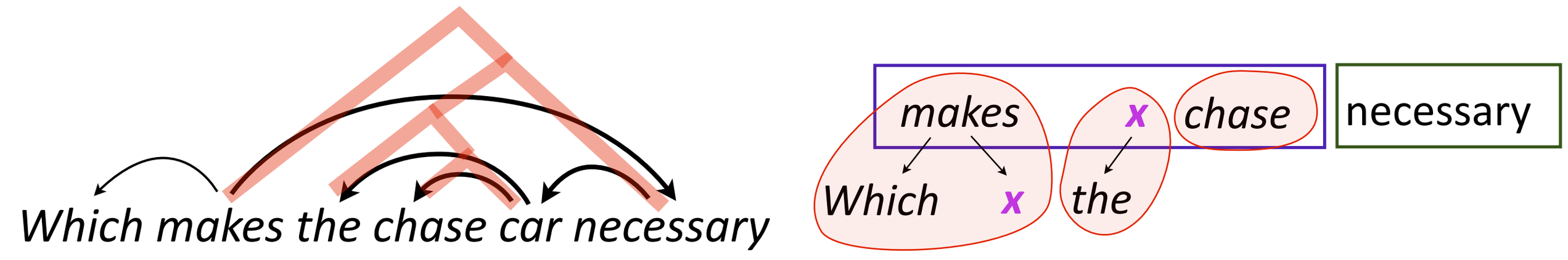

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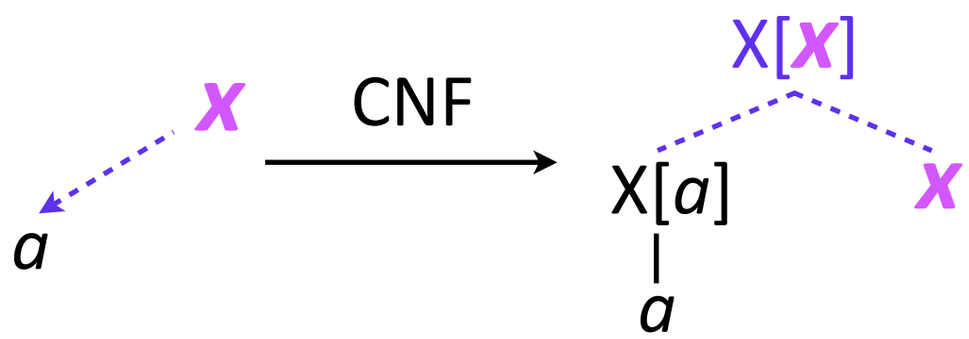

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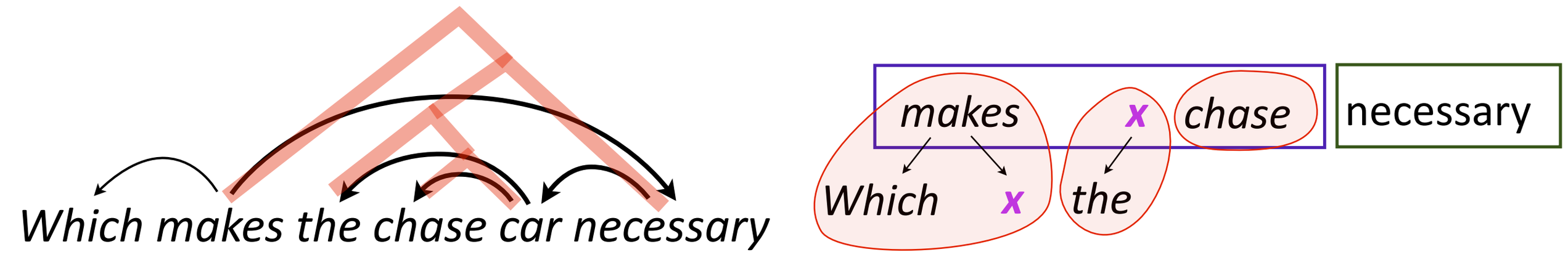

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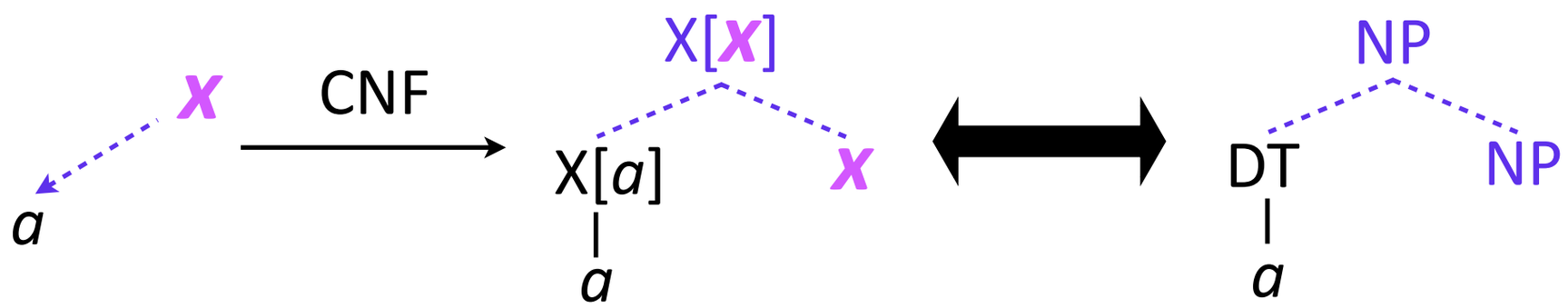

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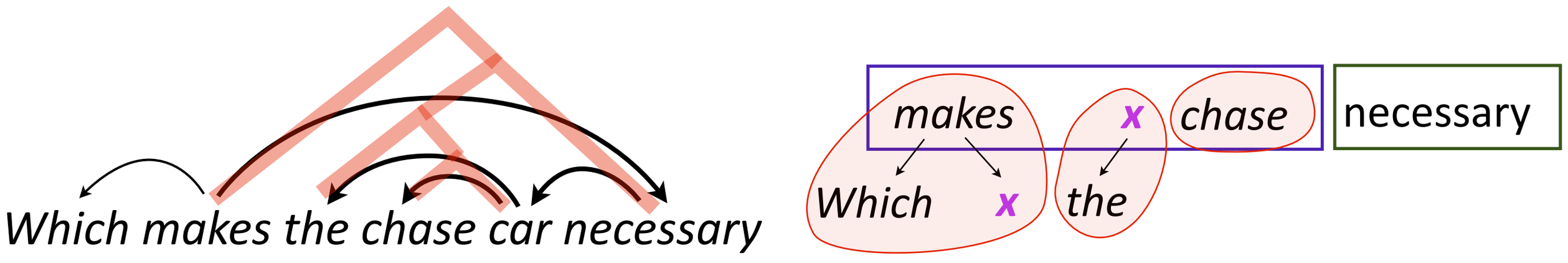

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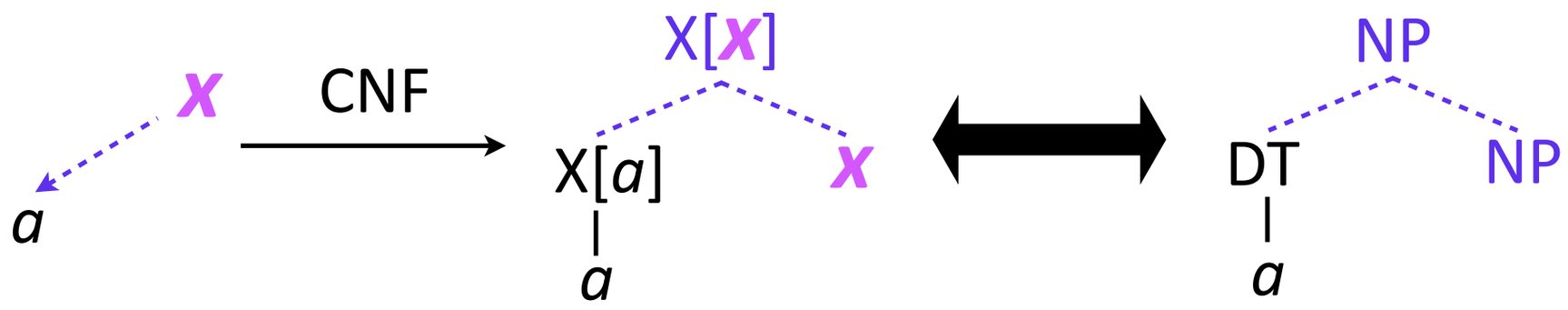

- COMP is also connected to **composite** in [Resnik, 1992]

Outline

Setup

- Psycholinguistic observation
- Left-corner constituency parsing
- Memory cost of dependency parsers

Left-corner dependency parsing

- Key concept: dummy node
- Parse example and action definition

Experiments

- Memory cost during oracle transitions
- Exploration of syntactic biases

Experimental setting

Experimental setting

Dataset: CoNLL 06/07 shared tasks (18 language treebanks)

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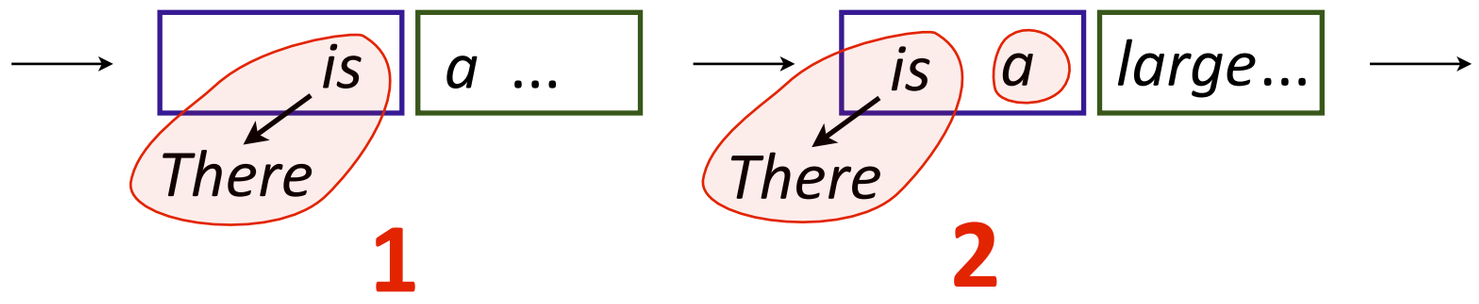
Evaluation: Required memory cost to recognize gold dependency trees in treebanks



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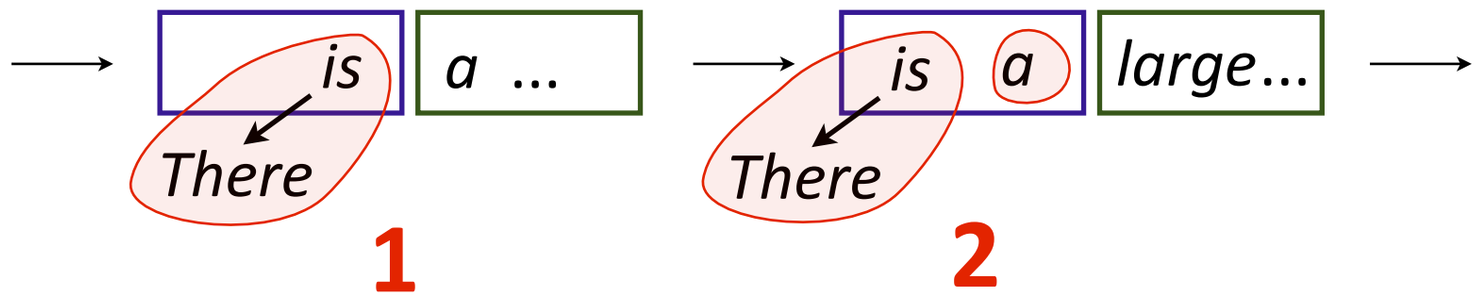
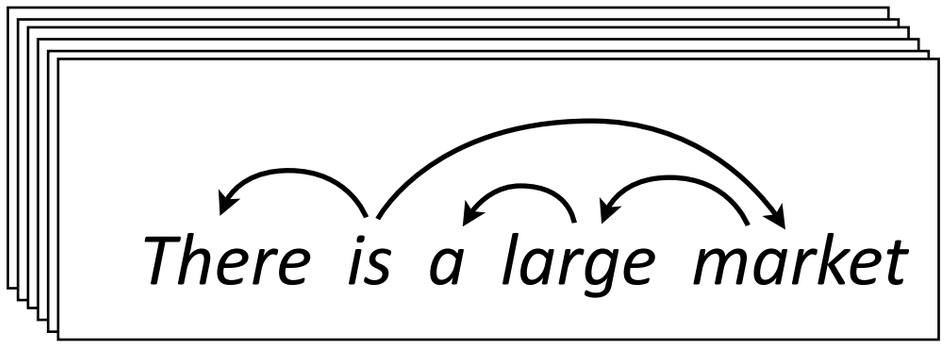


- Our interest: cross-linguistically cognitively plausible parser
- Such parser should use less memory for recognizing sentences

across diverse languages

Example: English

Given the dependency treebank:



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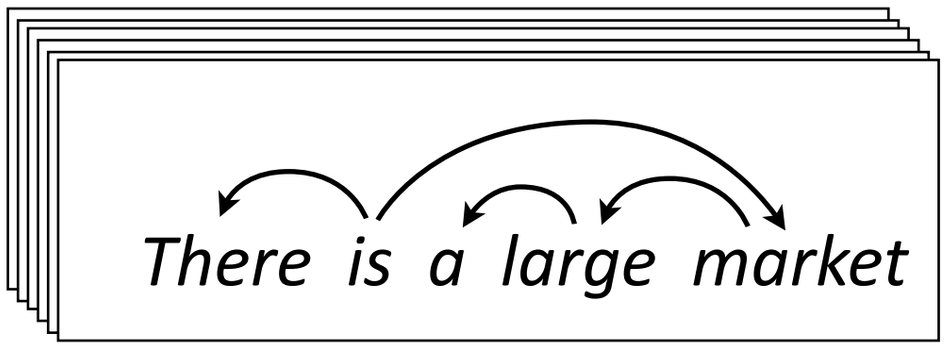

- Select a transition system (here arc-standard)

Example: English

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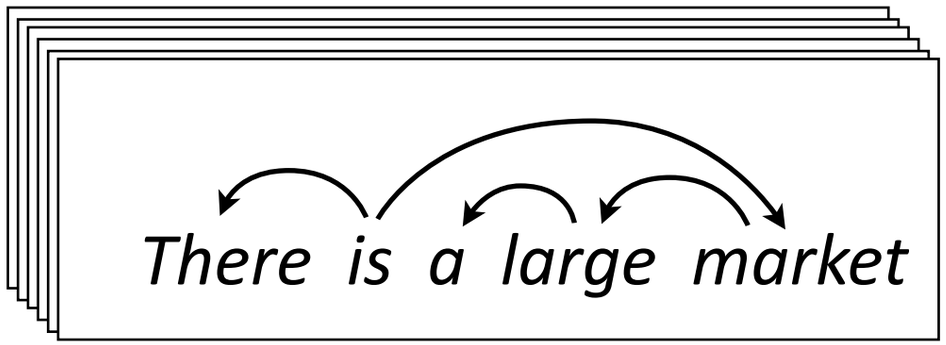
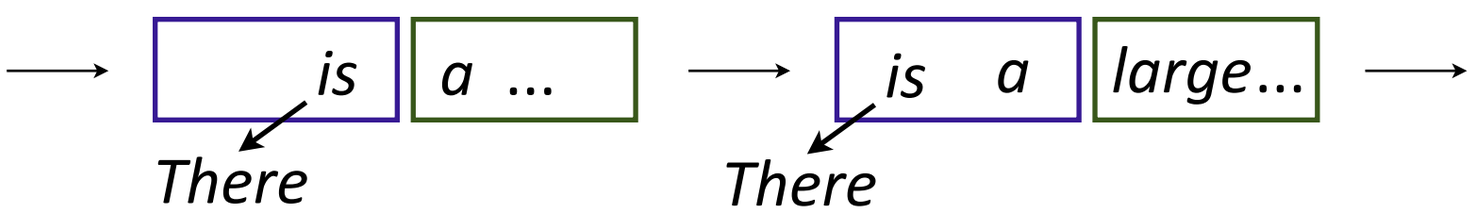
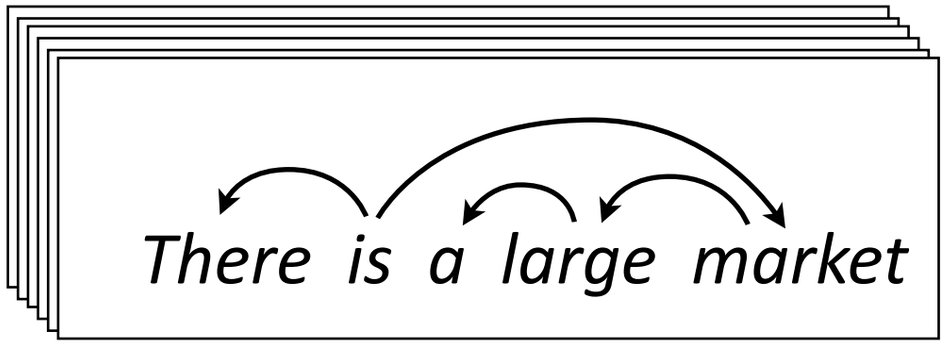


- Select a transition system (here arc-standard)
- Simulate oracle transitions (recover gold dependency)



Example: English

Given the dependency treebank:



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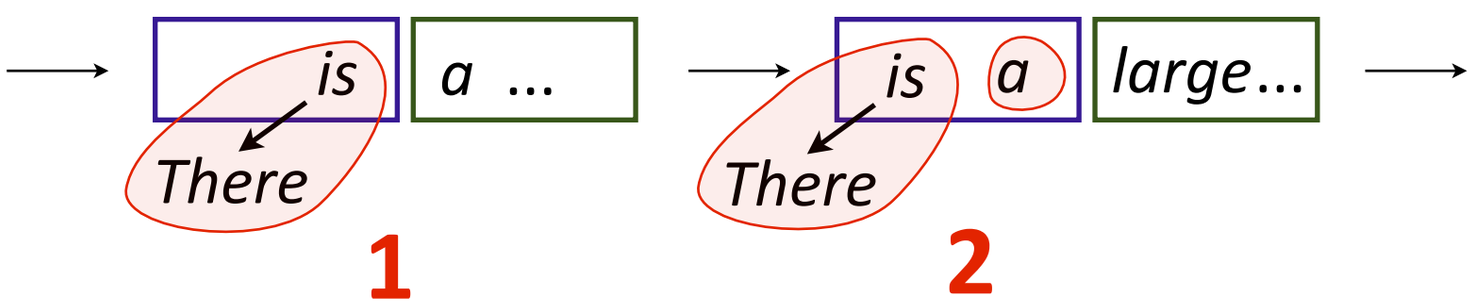

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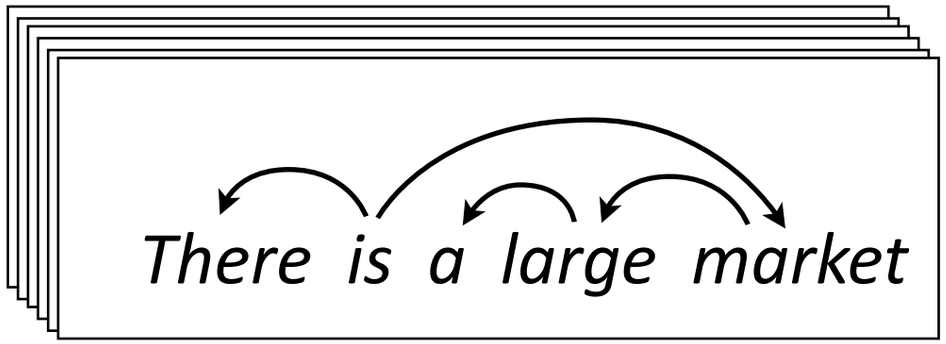

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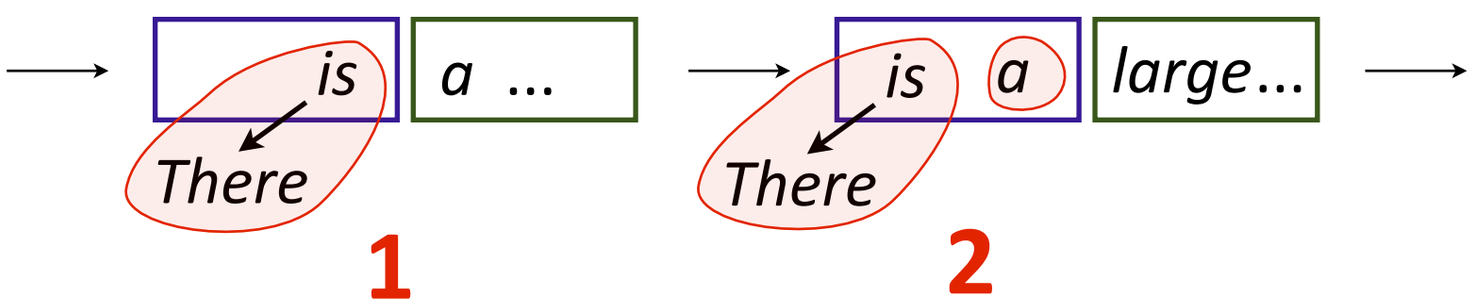
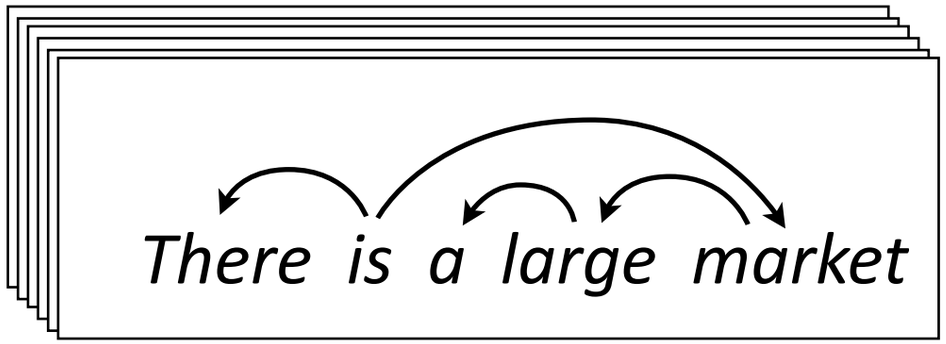


How many times each memory cost happens?

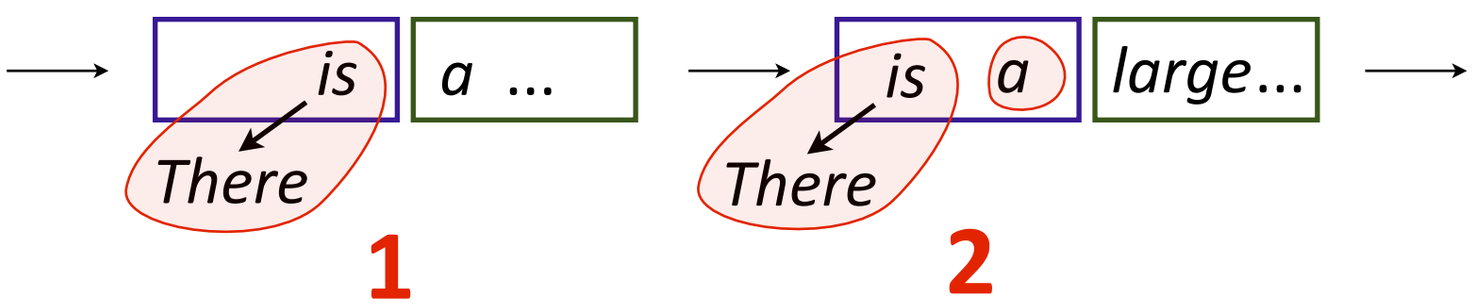
Example: English

Given the dependency treebank:



	# times
1	99,610
2	151,198
3	136,937
...	

- Select a transition system (here arc-standard)
- Simulate oracle transitions (recover gold dependency)



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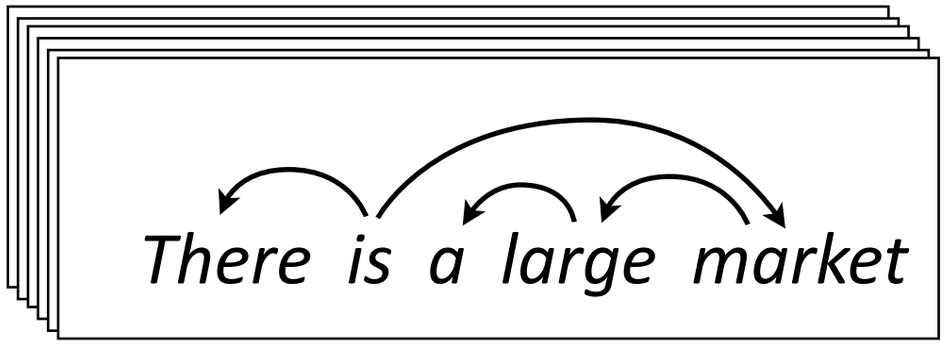

- Select a transition system (here arc-standard)
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	# times	frequency (cumulative)
1	99,610	
2	151,198	
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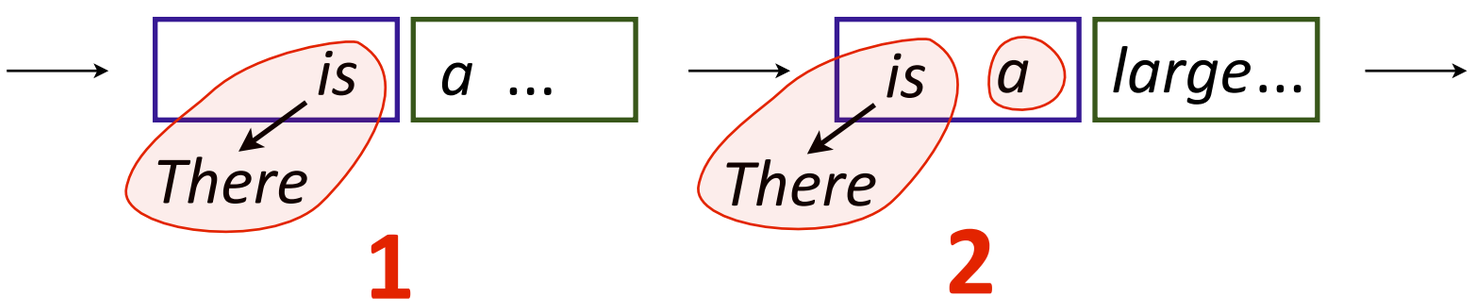
...		



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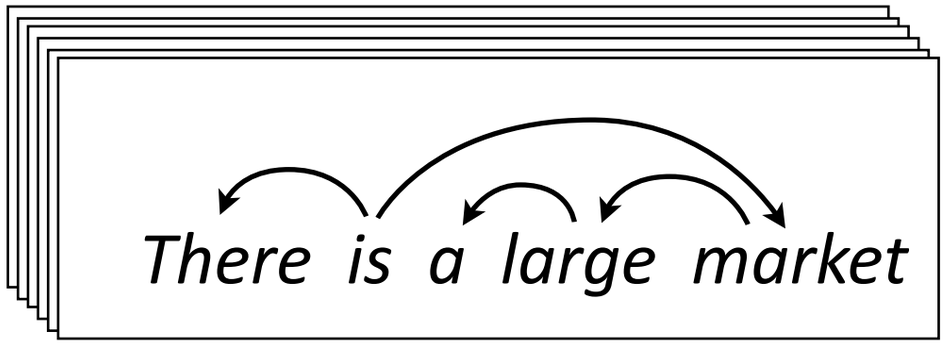

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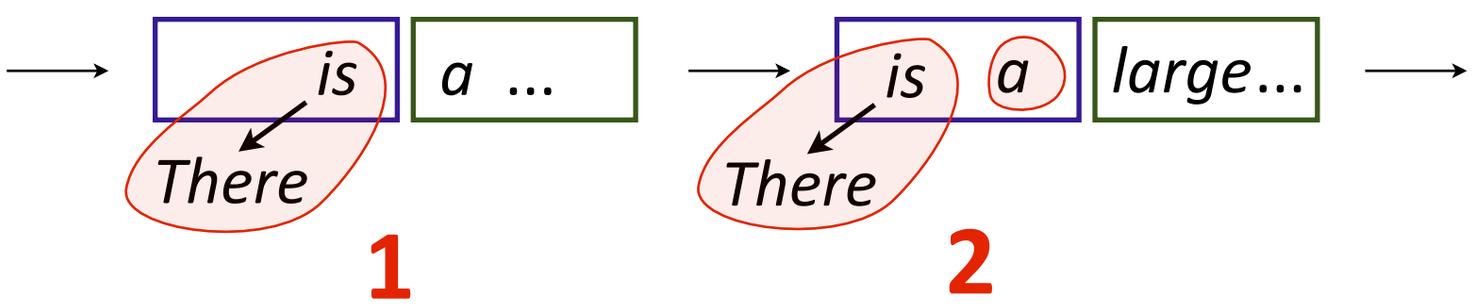

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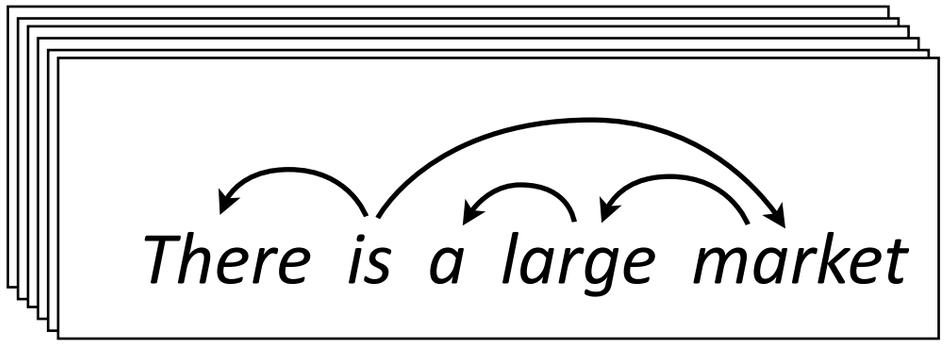

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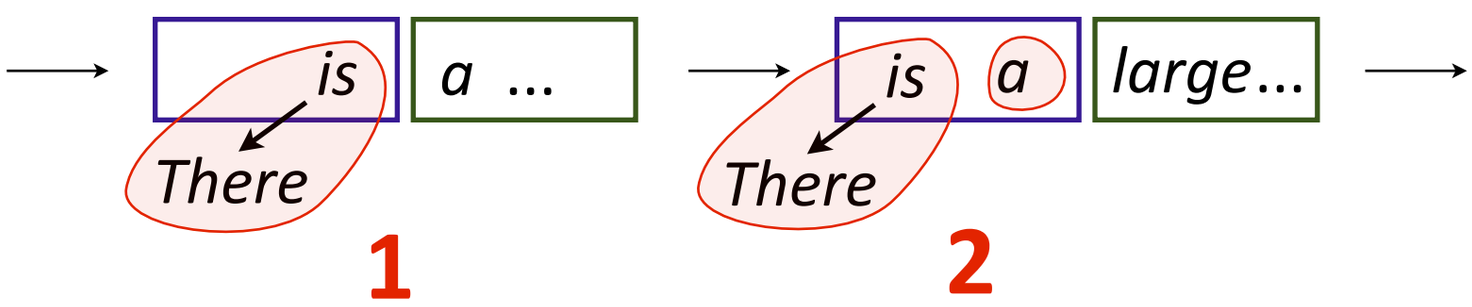

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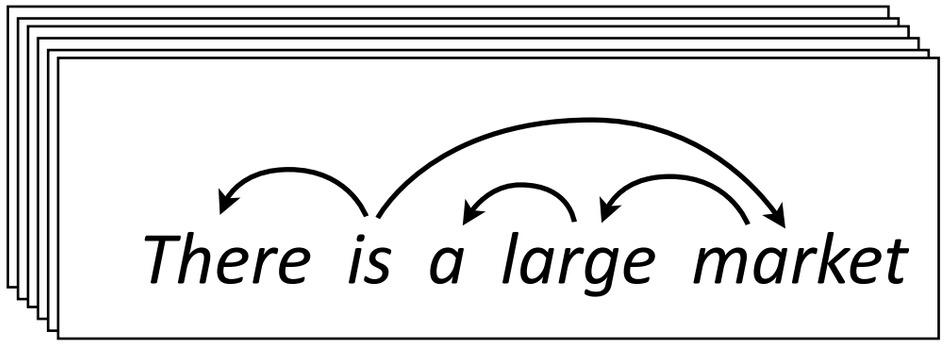

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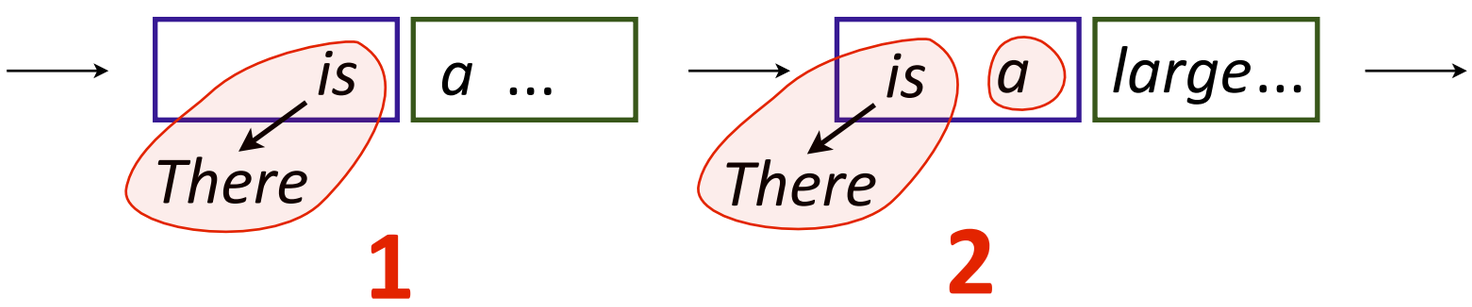

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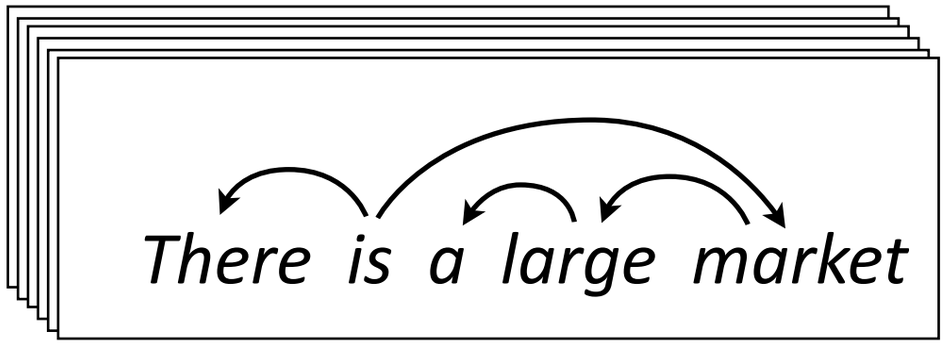

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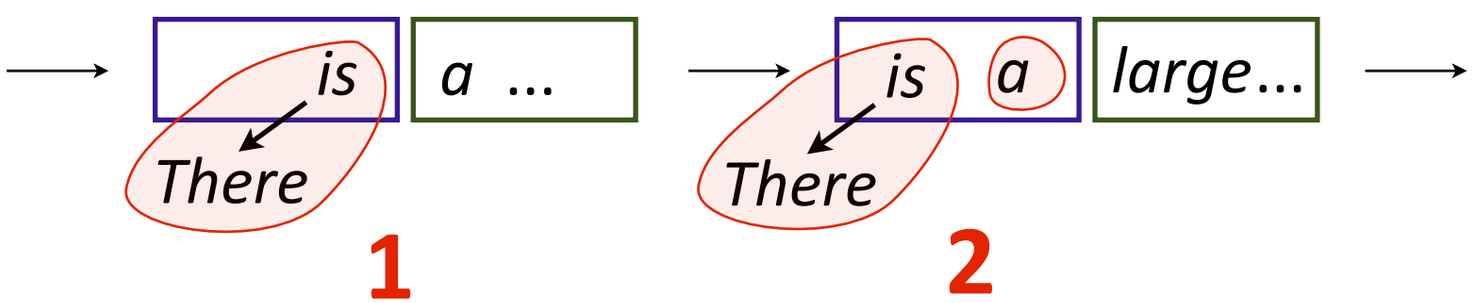

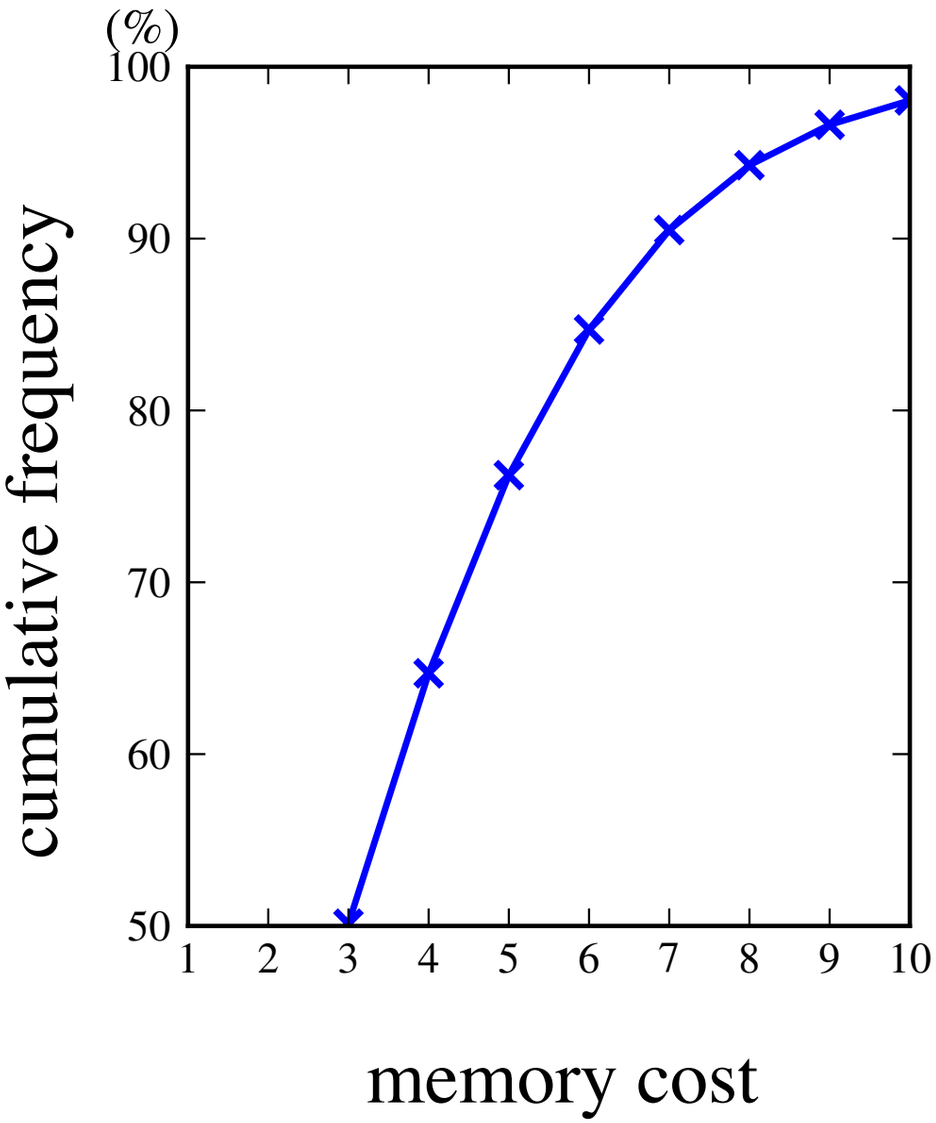

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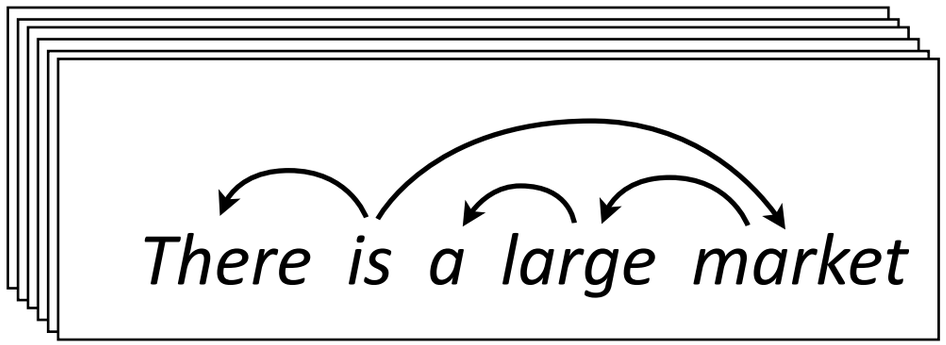

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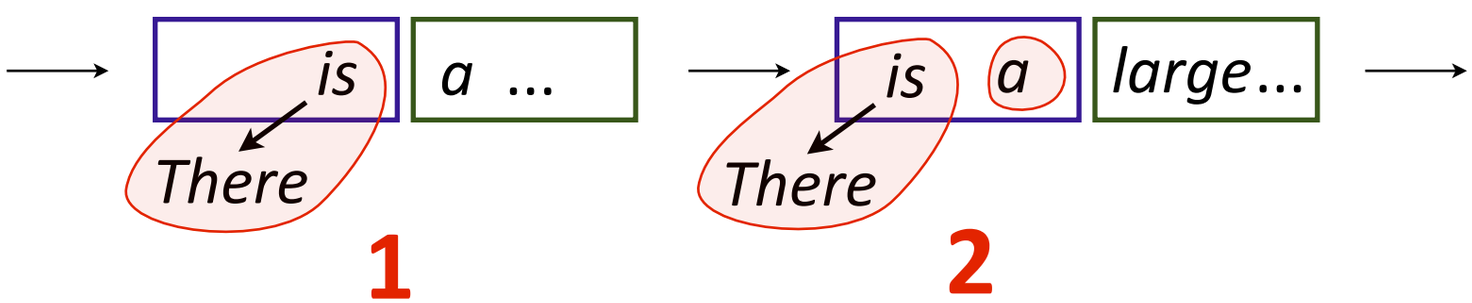

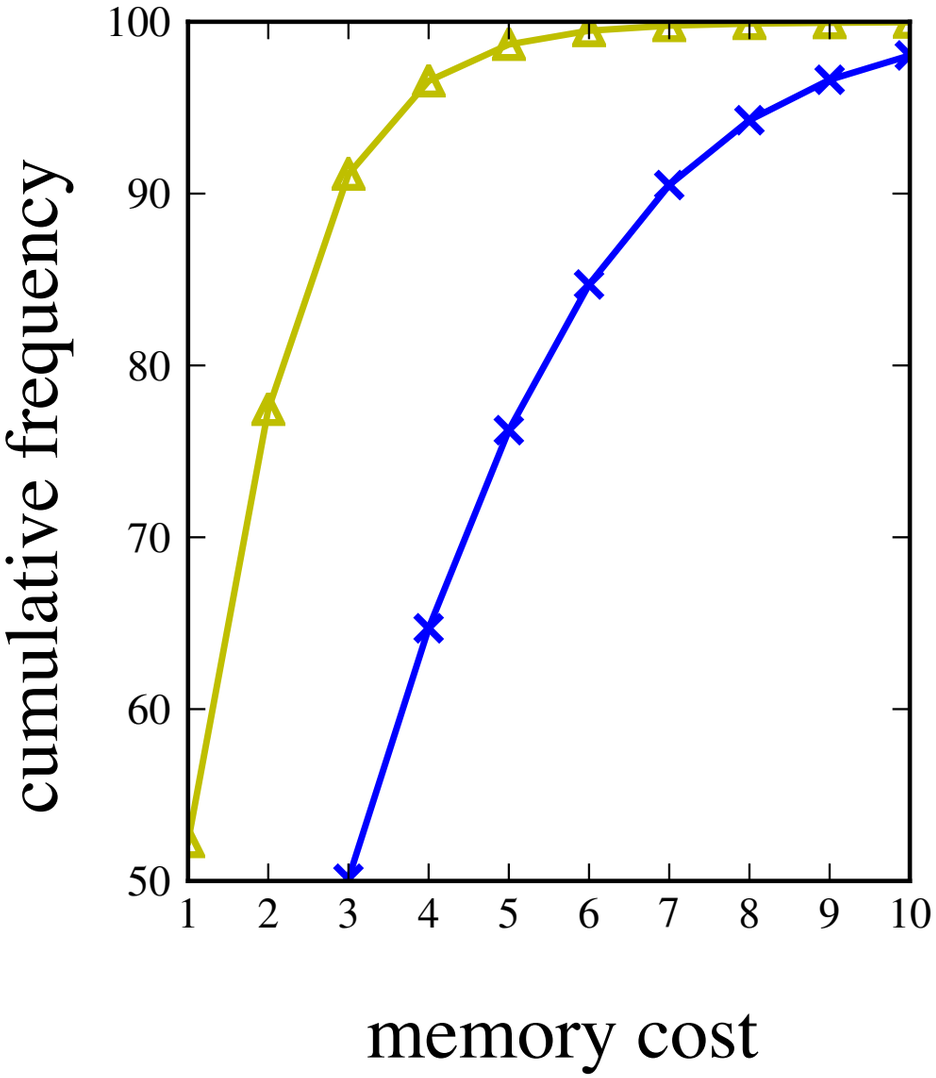

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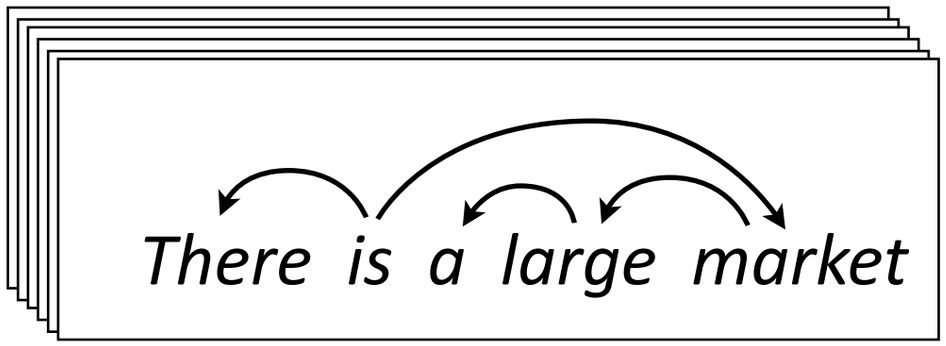

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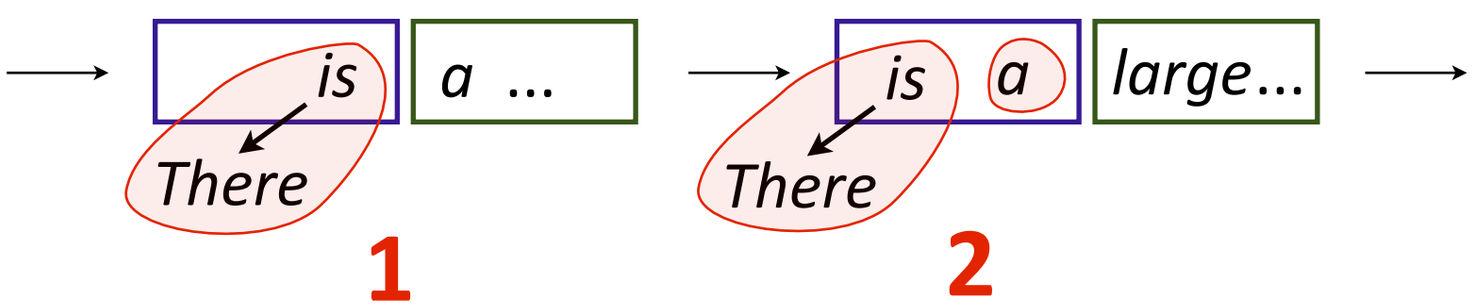

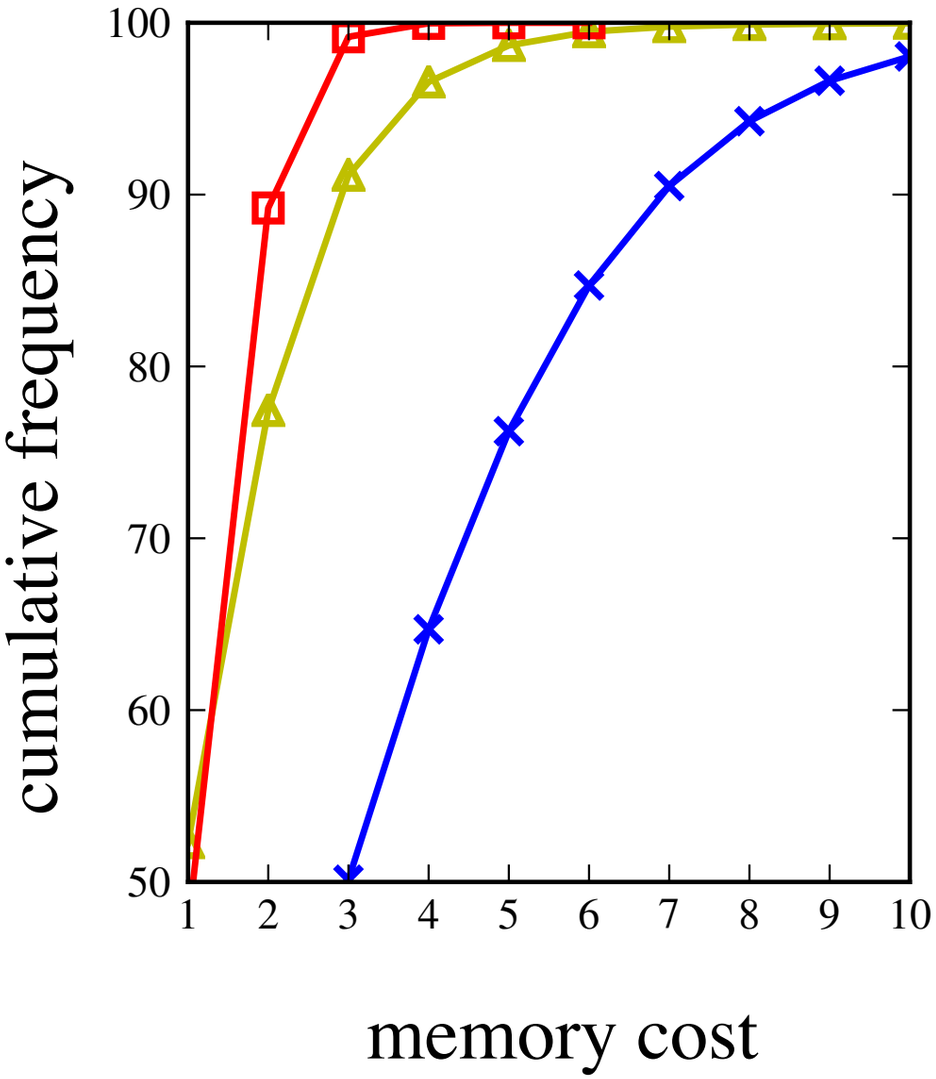

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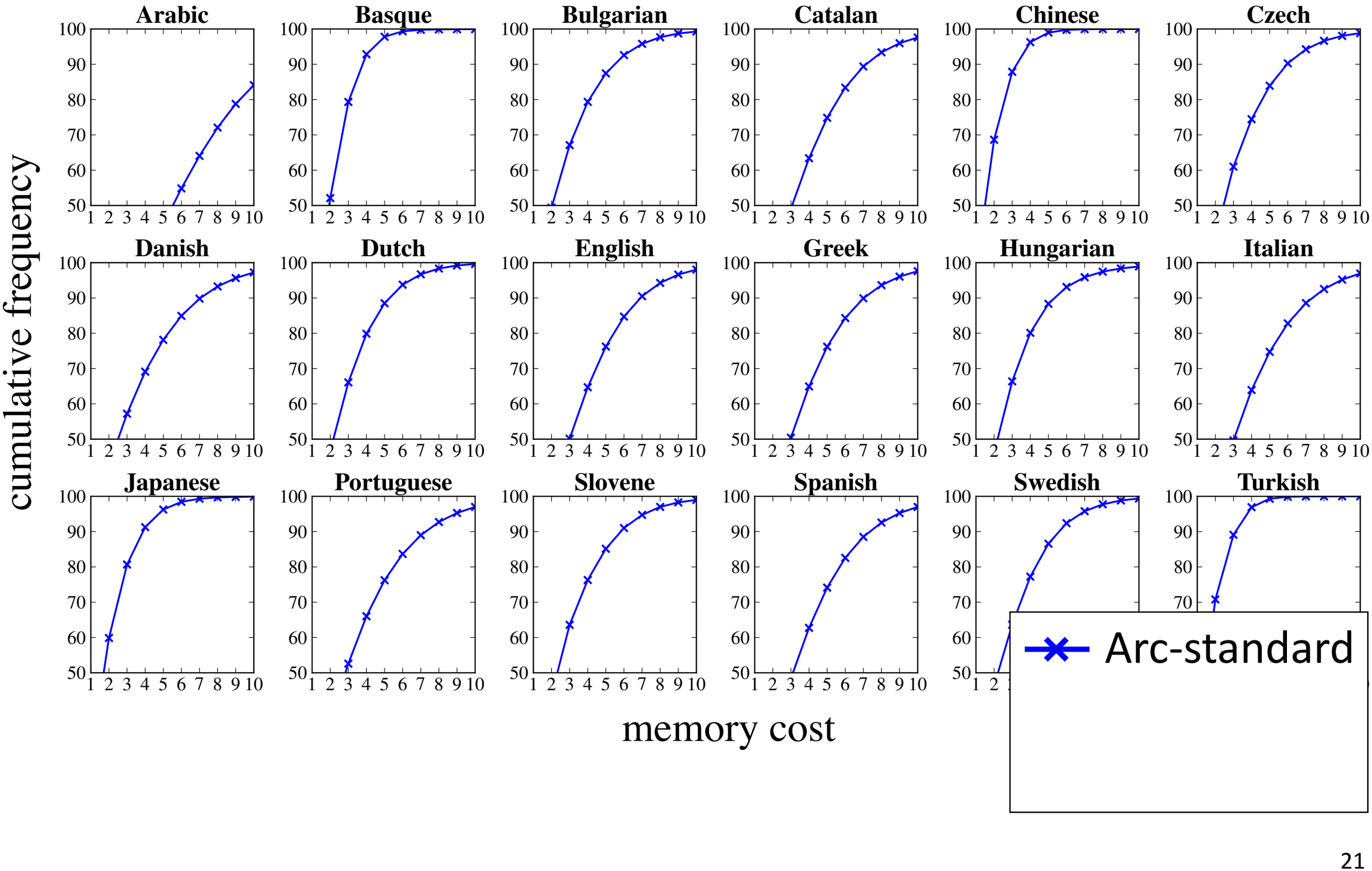

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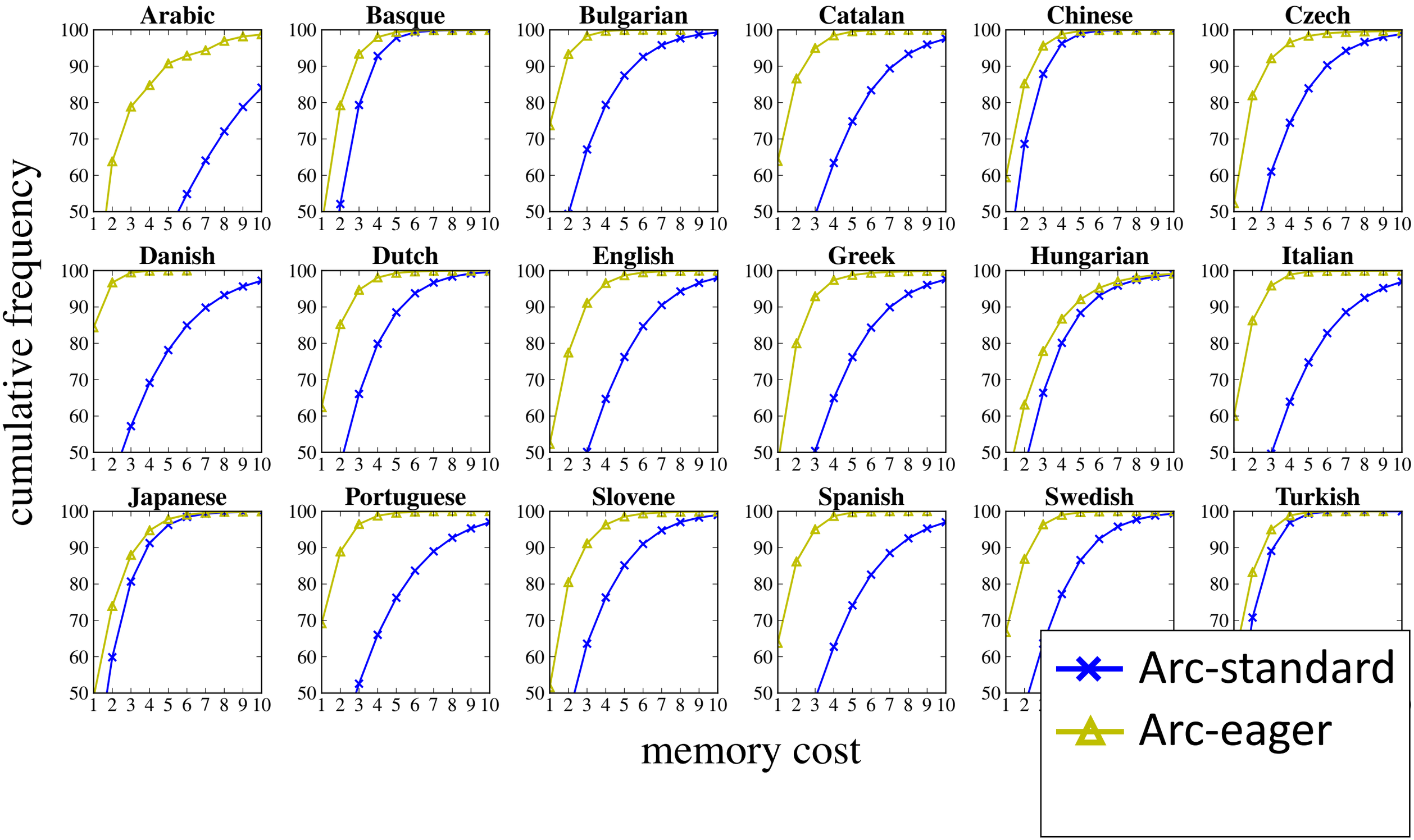

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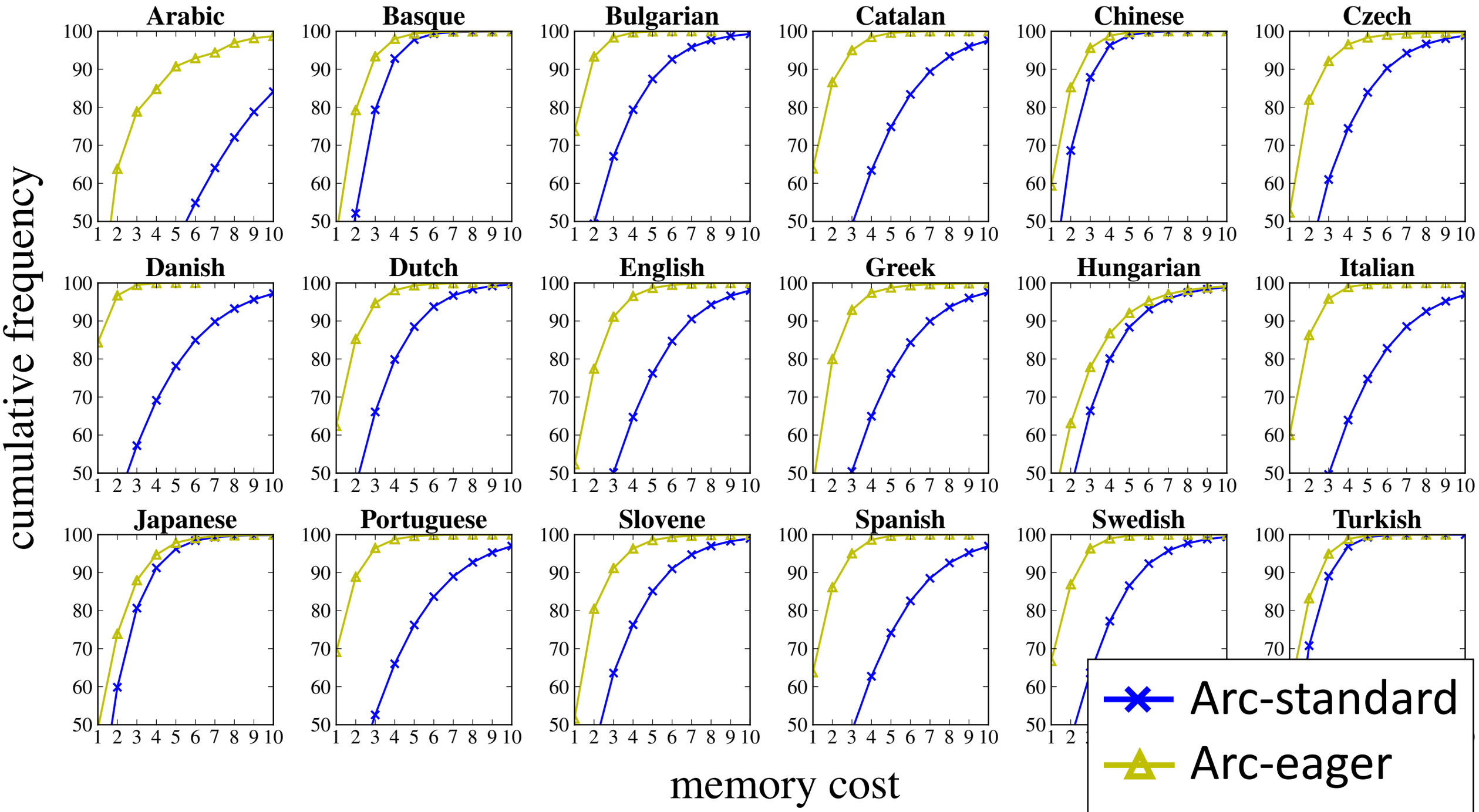

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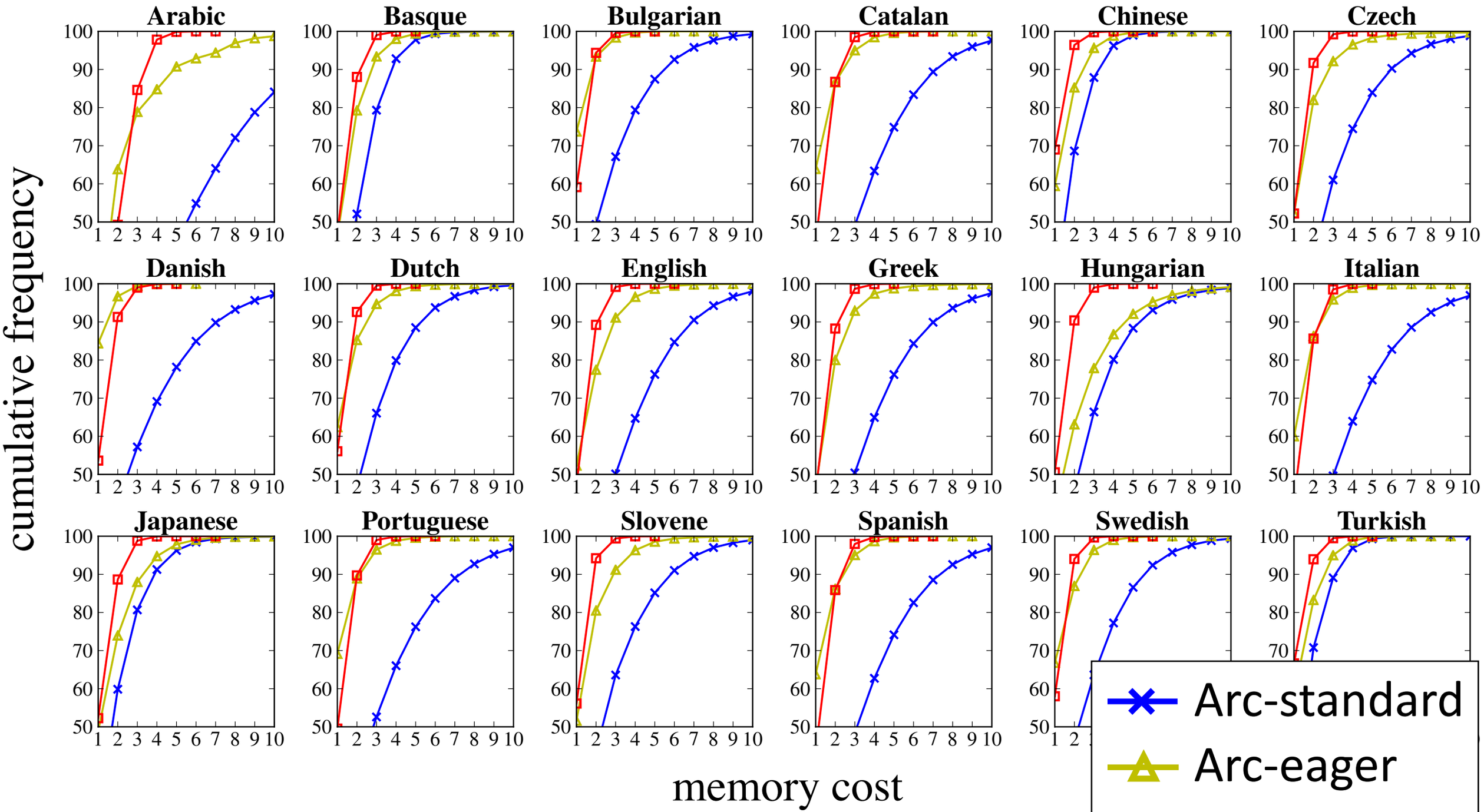

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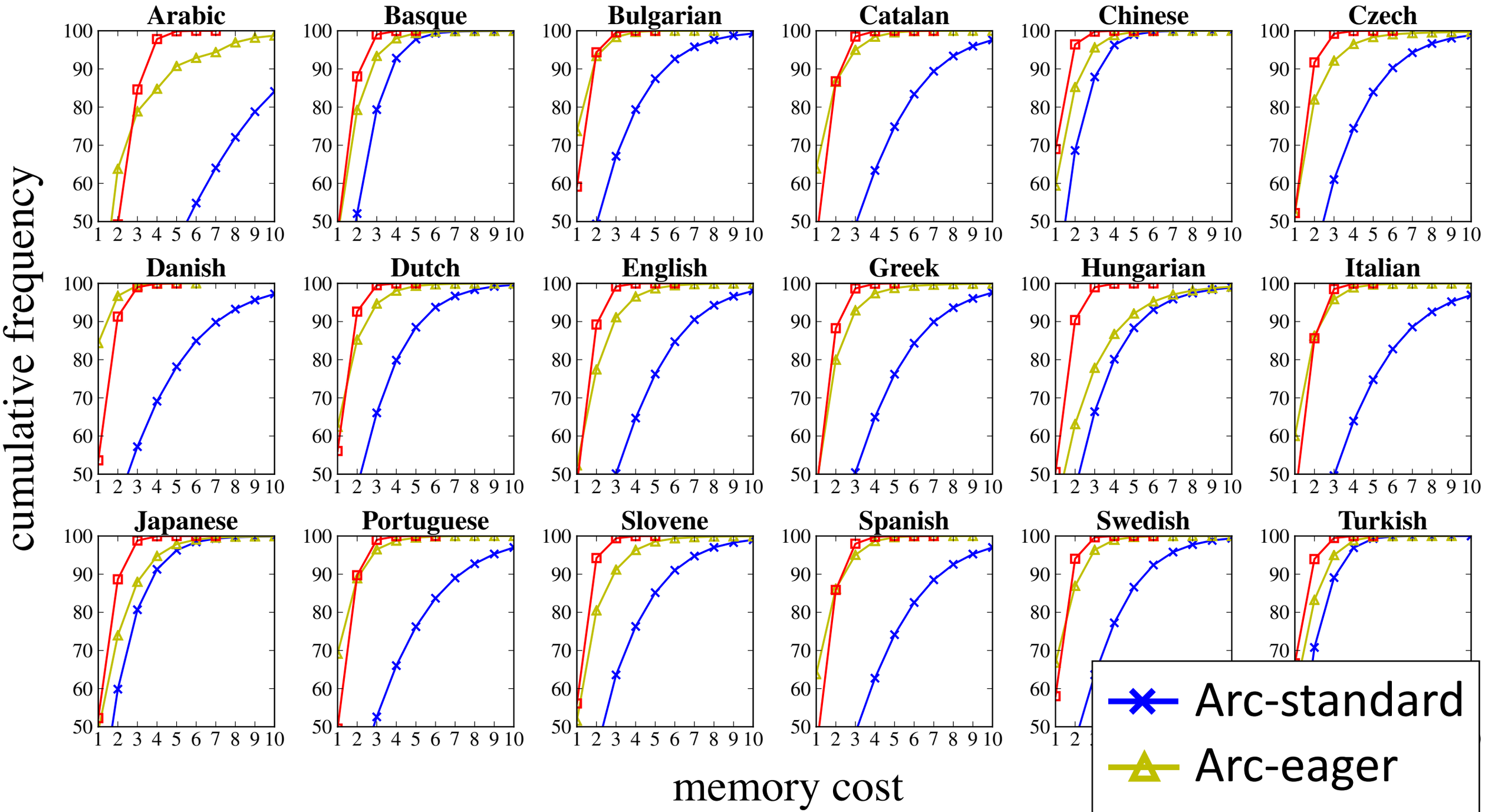

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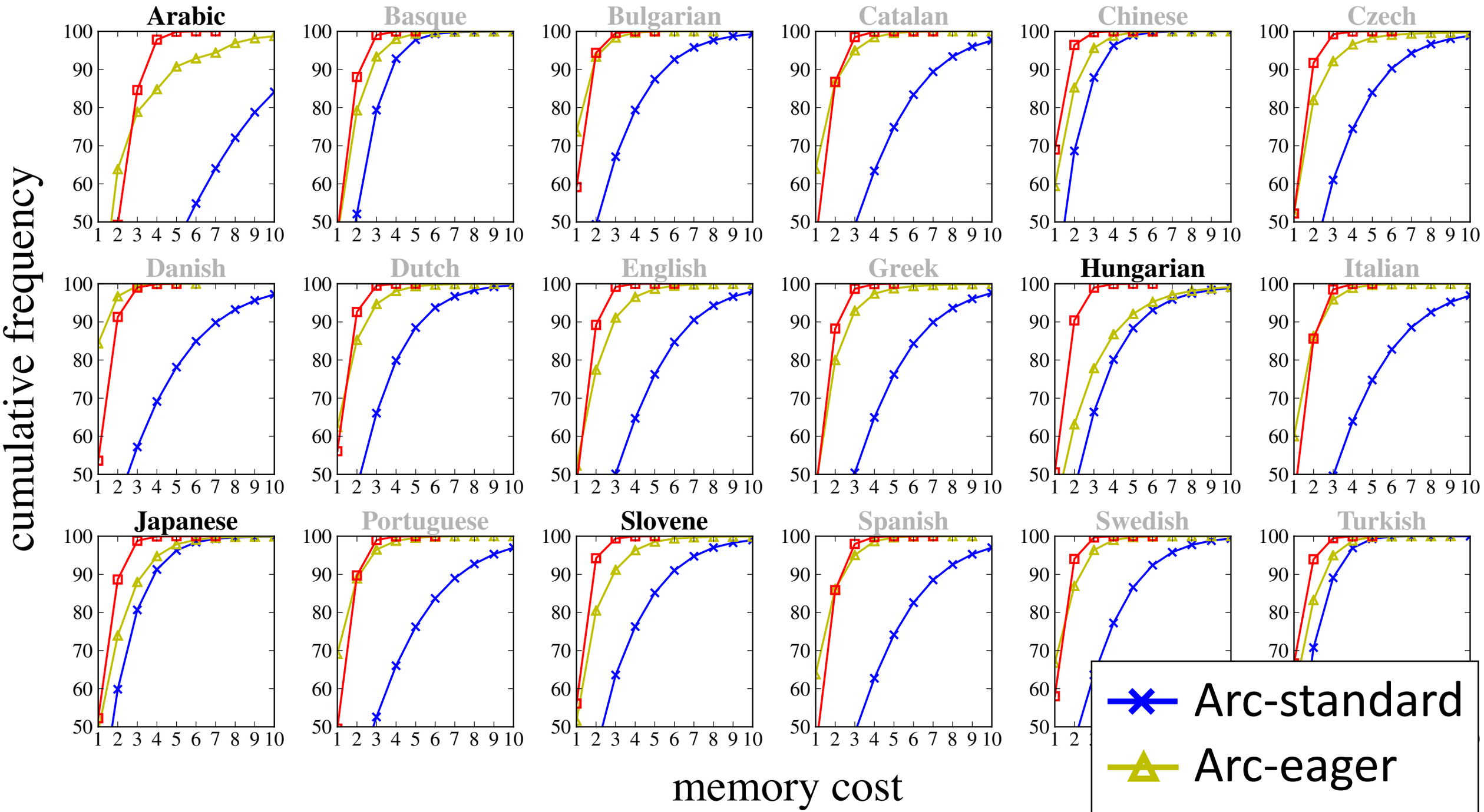

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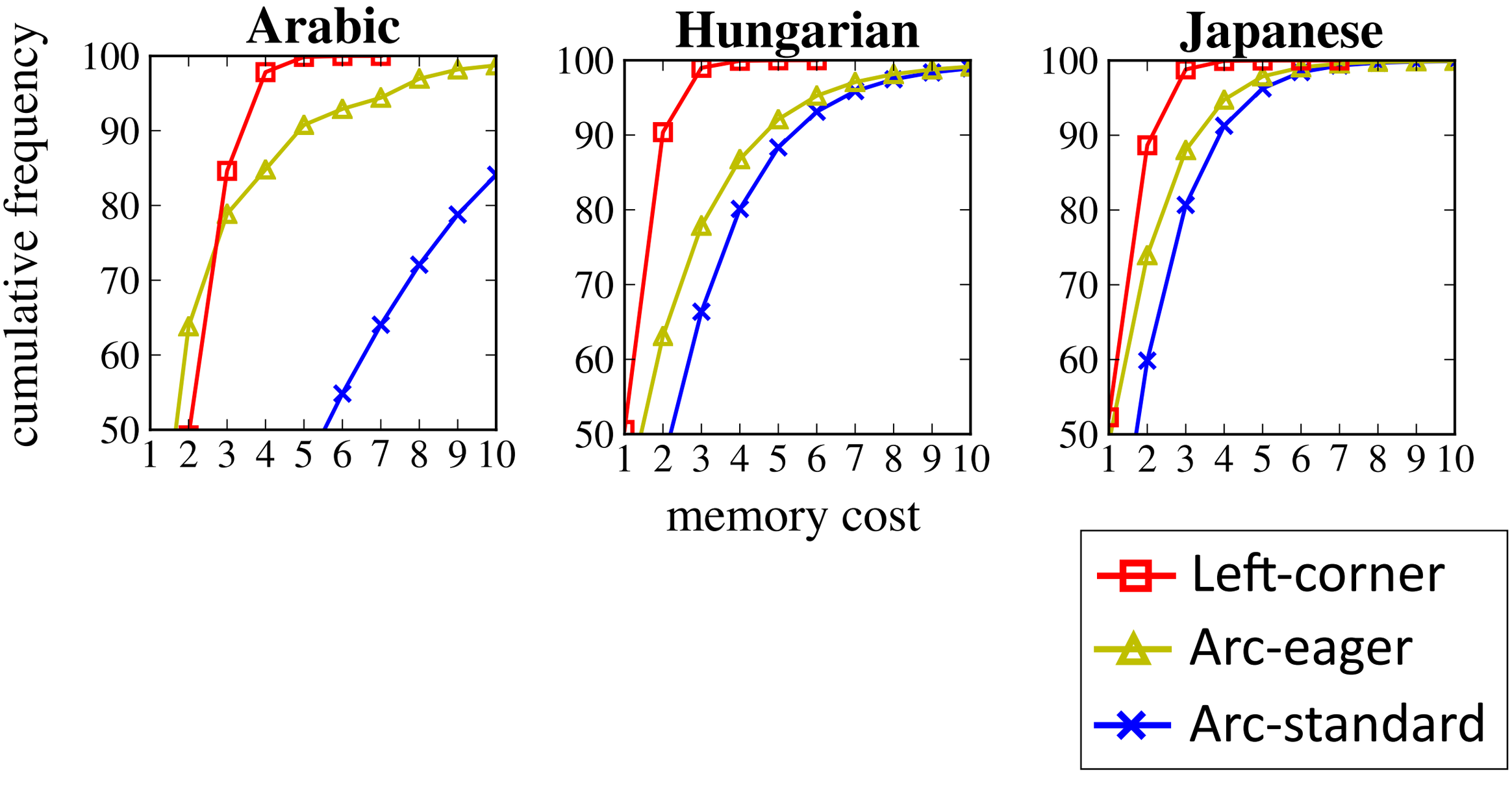
Universality

Arc-eager performs poorly in some languages

Left-corner's behavior is more consistent across languages



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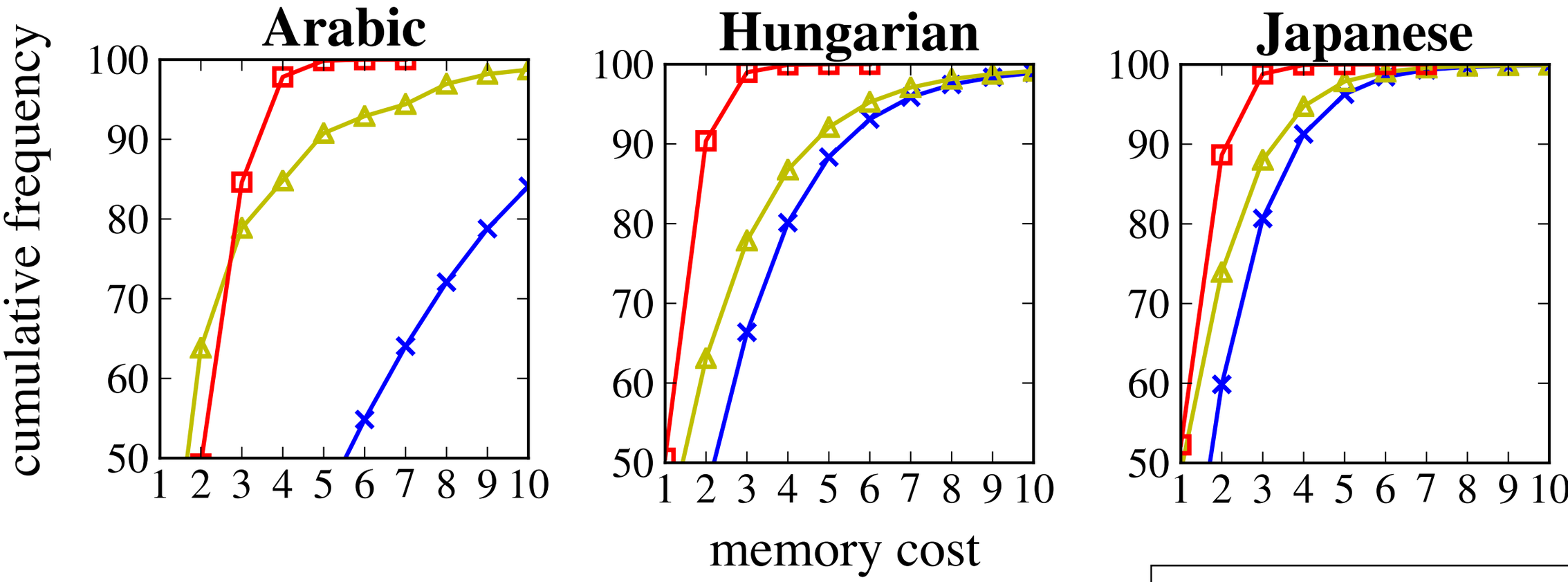

Indicate left-corner is cross-linguistically cognitively plausible in terms of memory cost

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So far...

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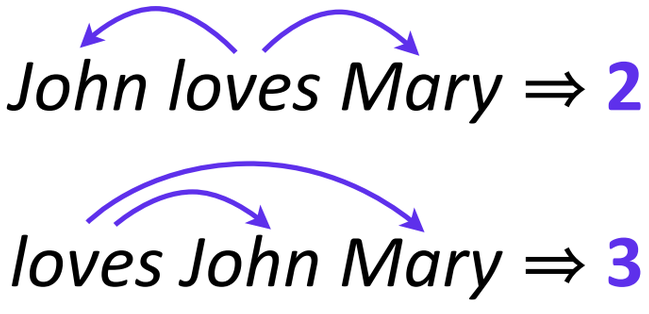

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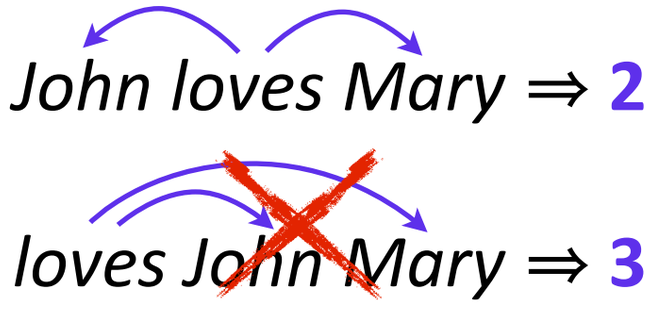

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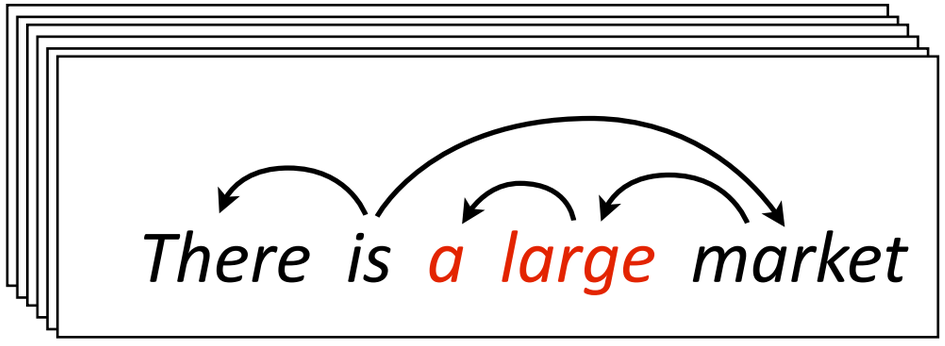

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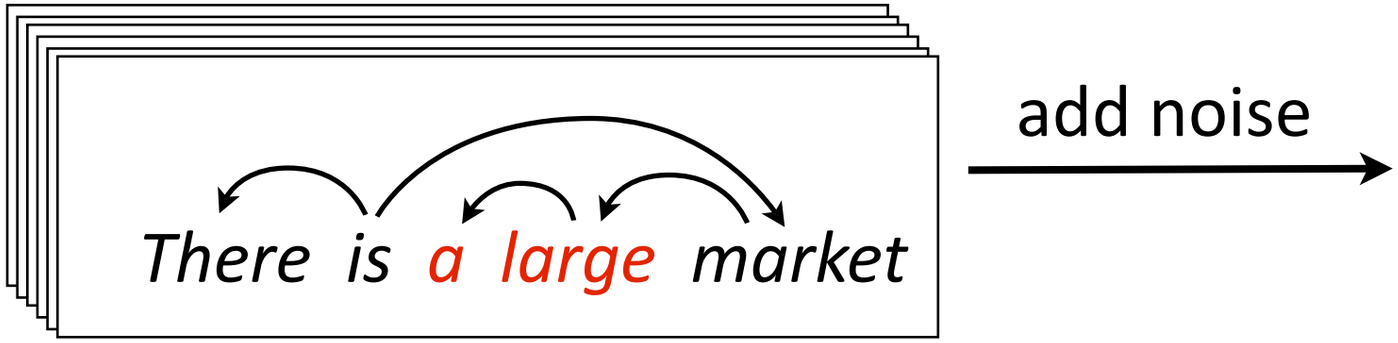

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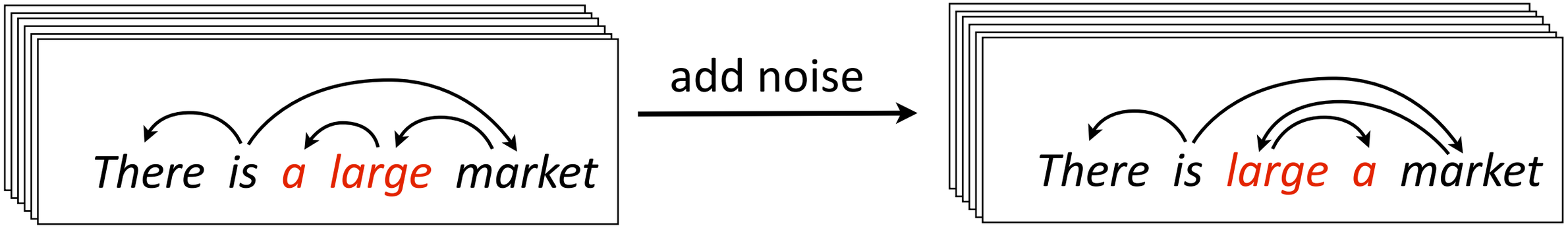

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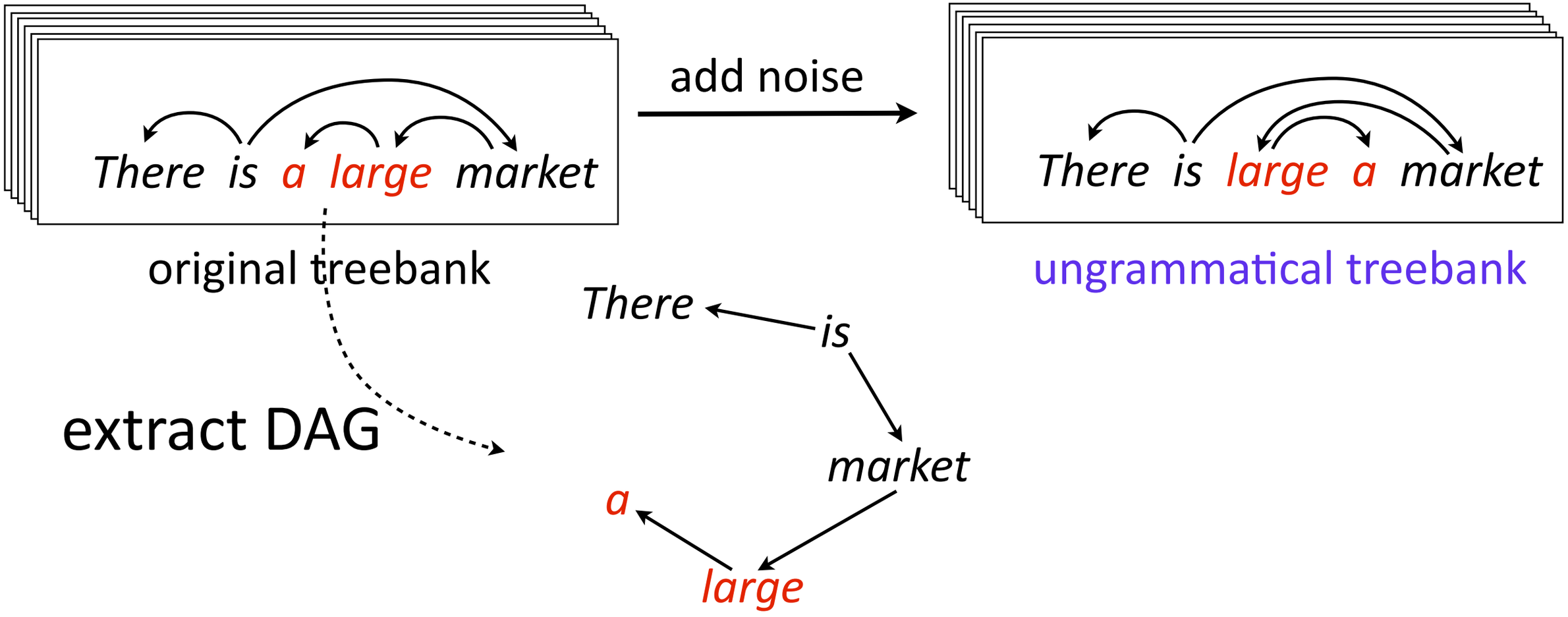

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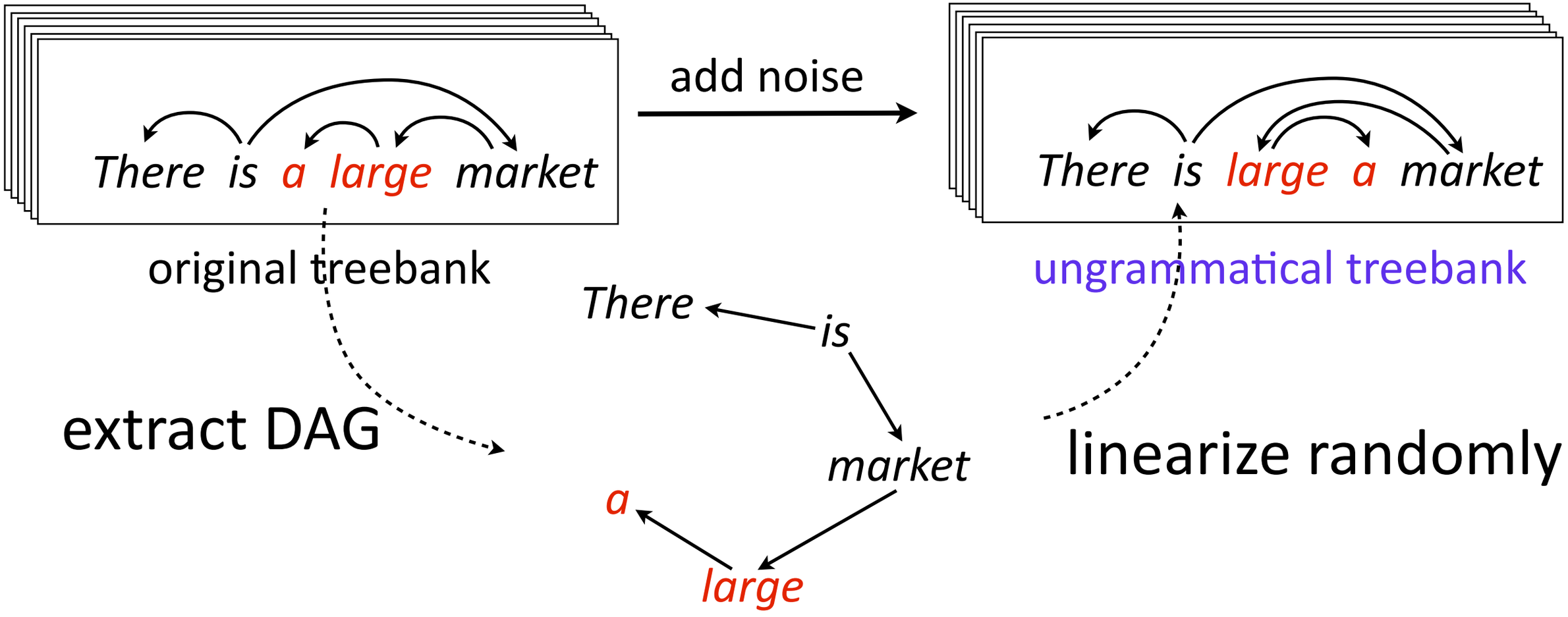

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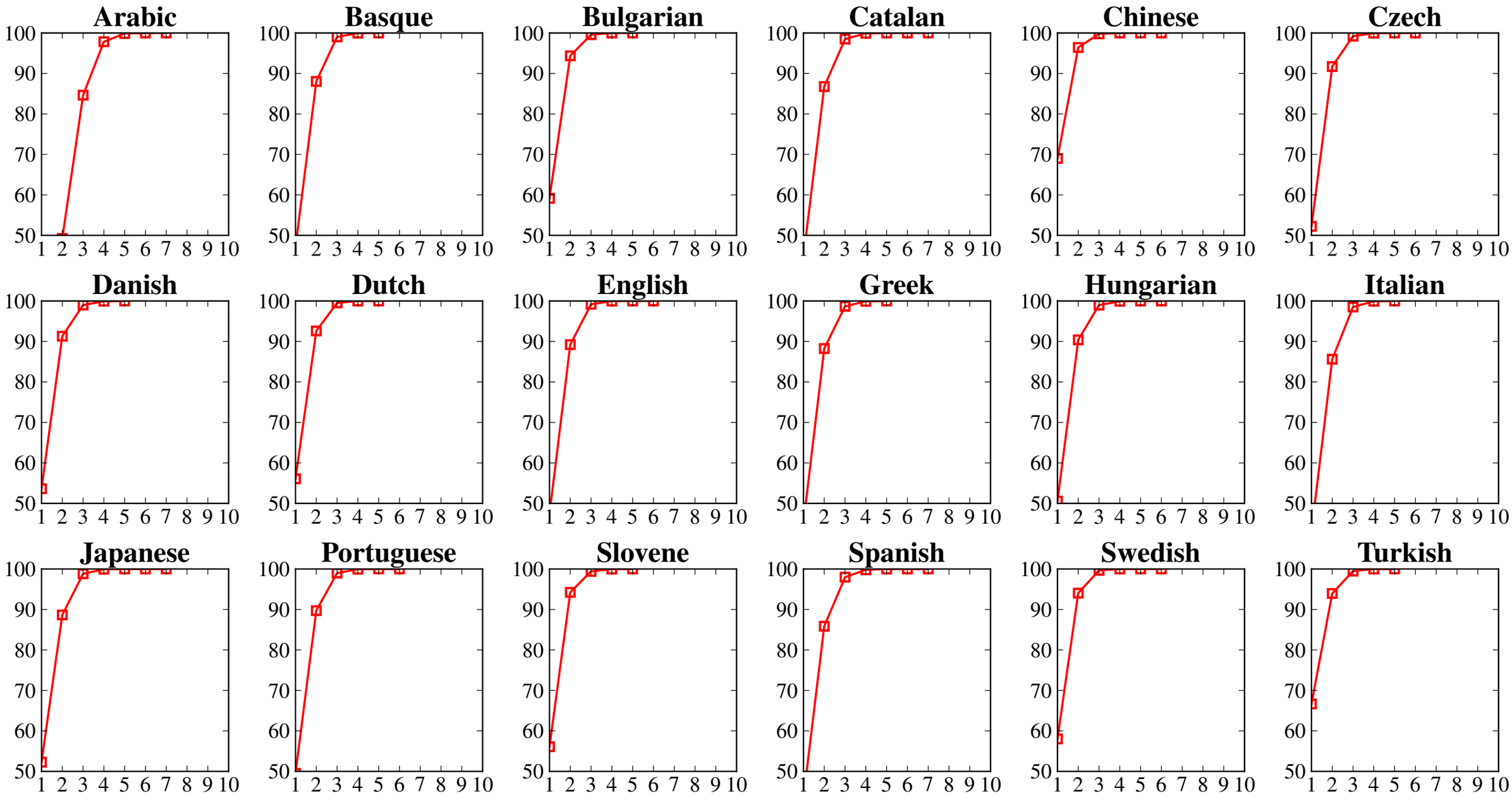

memory cost

Left-corner (origina

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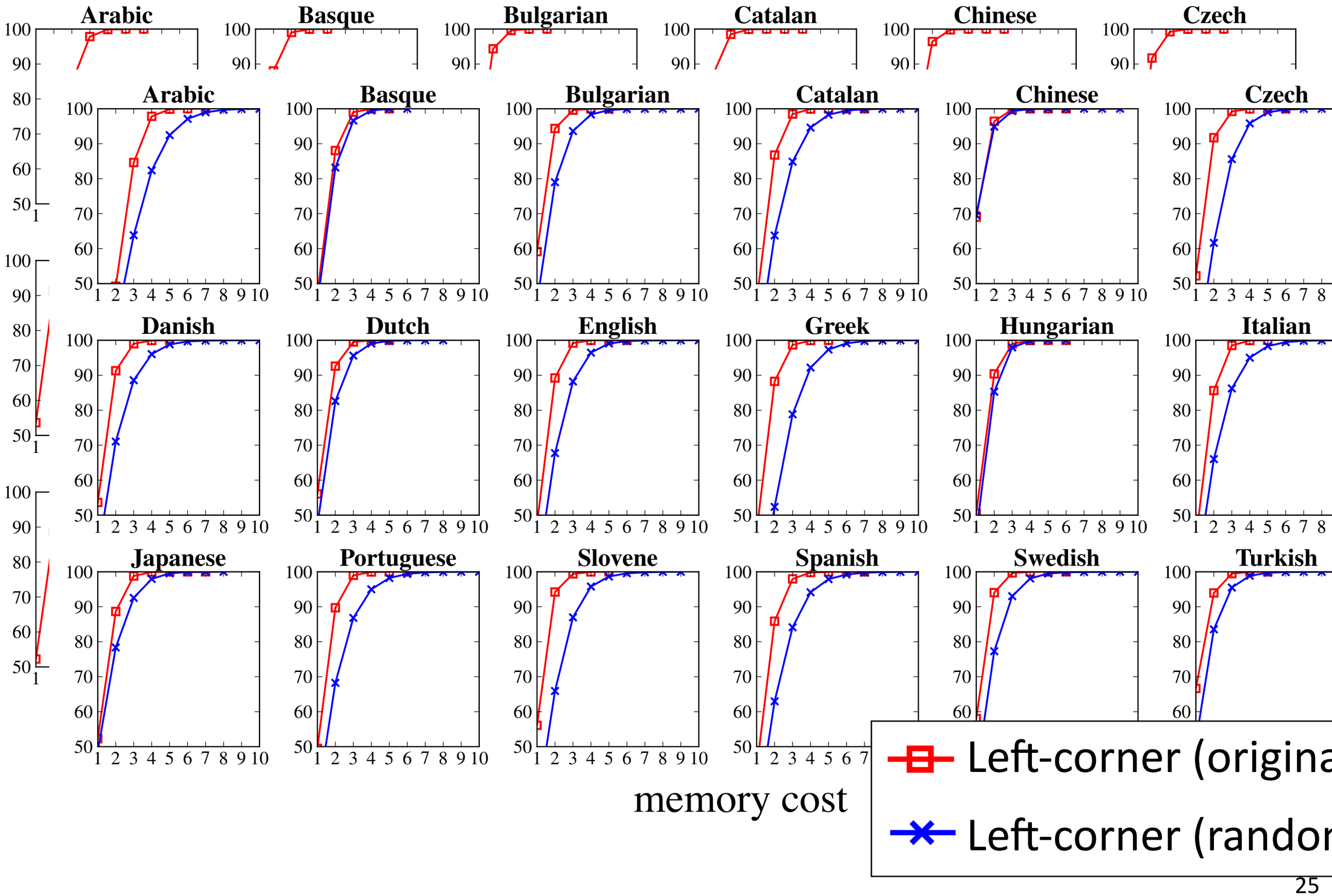

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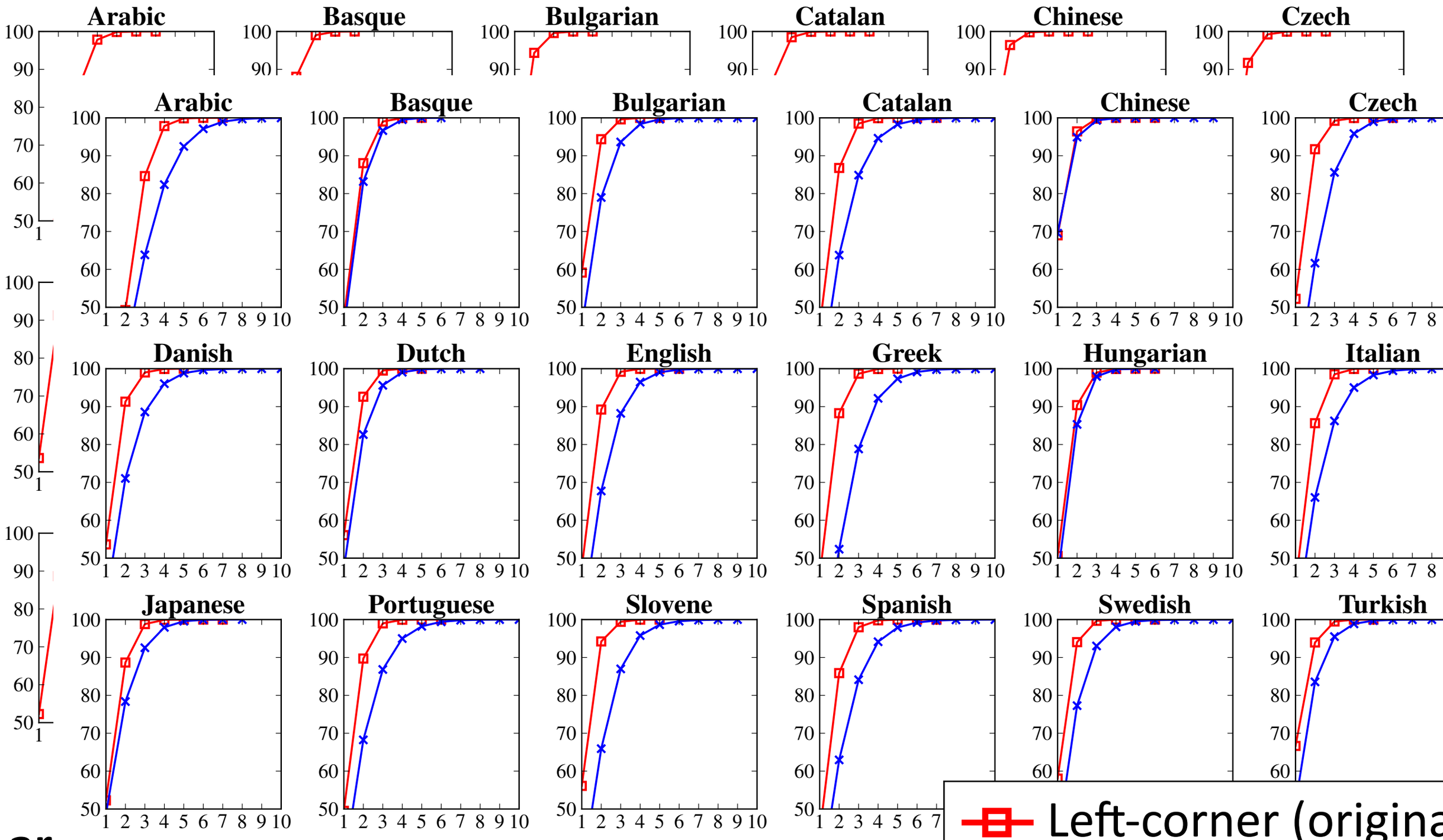

- **Large differences in most languages**
- Small differences in Basque, Chinese, and Hur

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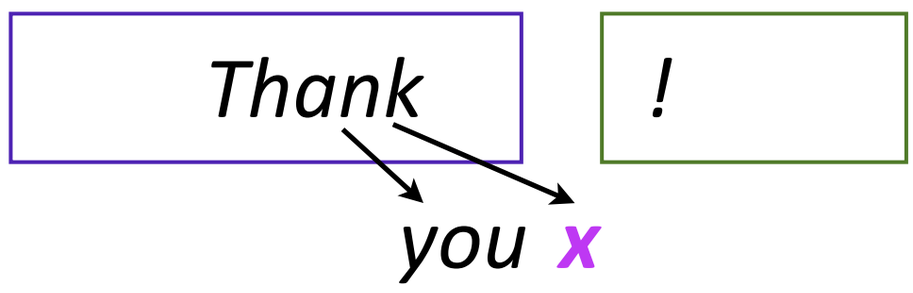

Prediction and CNF interpretation

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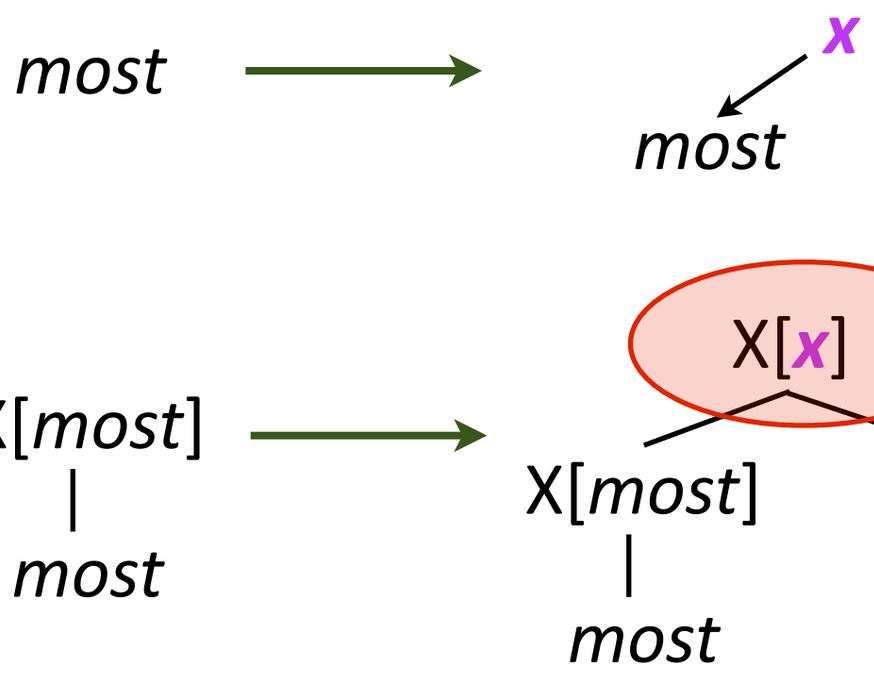

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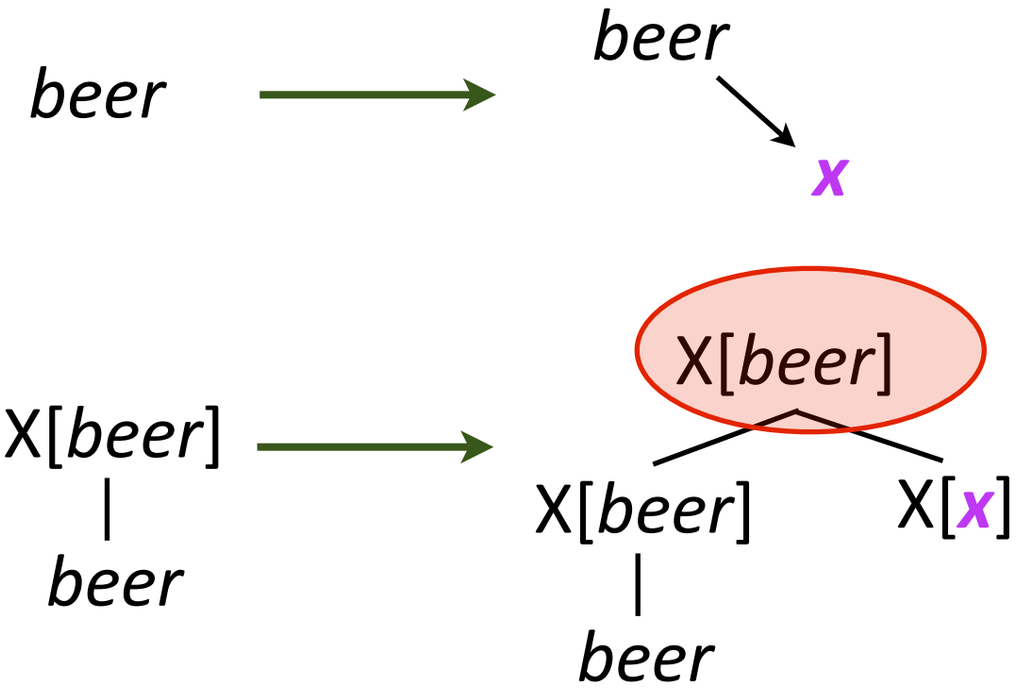
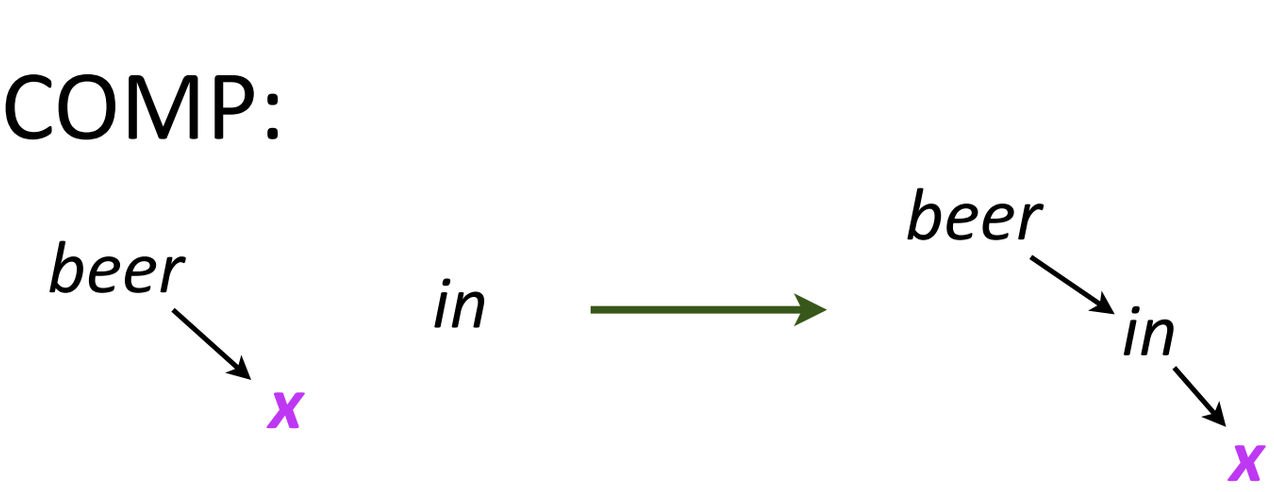


The same form as **prediction** in original left-corner parser

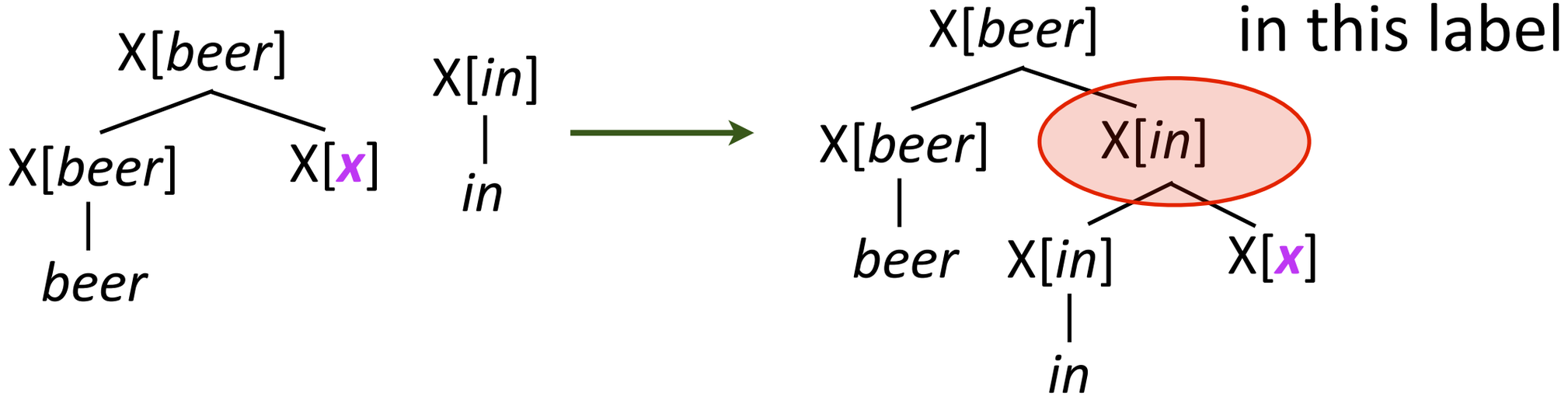
Difference: predicted parent label
(Which child is the head child?)

Composition and CNF interpretation

RIGHT-COMP:



LEFT-COMP differs in this label



The same form as original **composition** [Resnik, 1992]

Important result: Our parser implicitly recognizes a CNF tree as the original left-corner parser would do