

Unsupervised Coreference Resolution in a Nonparametric Bayesian Model



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Coreference Resolution

The Weir Group , whose headquarters is in the U.S , is a large specialized corporation . This power plant , which , will be situated in Jiangsu , has a large generation capacity.

Coreference Resolution

The **Weir Group**, whose **headquarters** is in the **U.S**, is a large specialized **corporation**. This **power plant**, **which**, will be situated in **Jiangsu**, has a large generation capacity.

Coreference Resolution

Weir Group whose headquarters

U.S

corporation

power plant which

Jiangsu

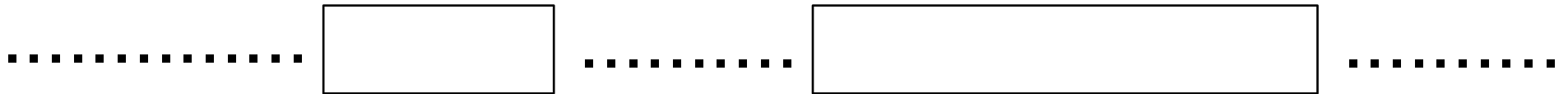
Coreference Resolution



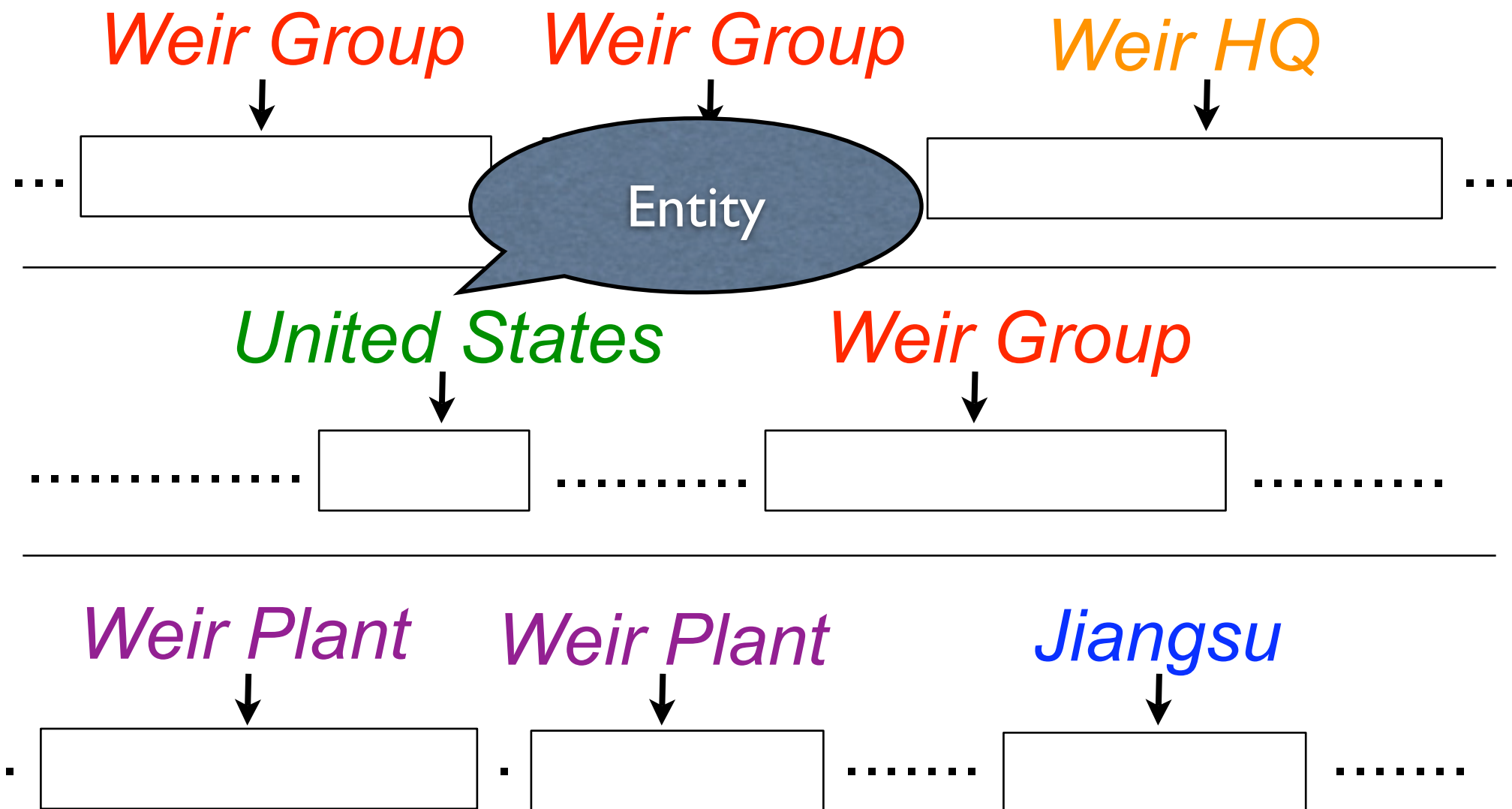
Generative Story



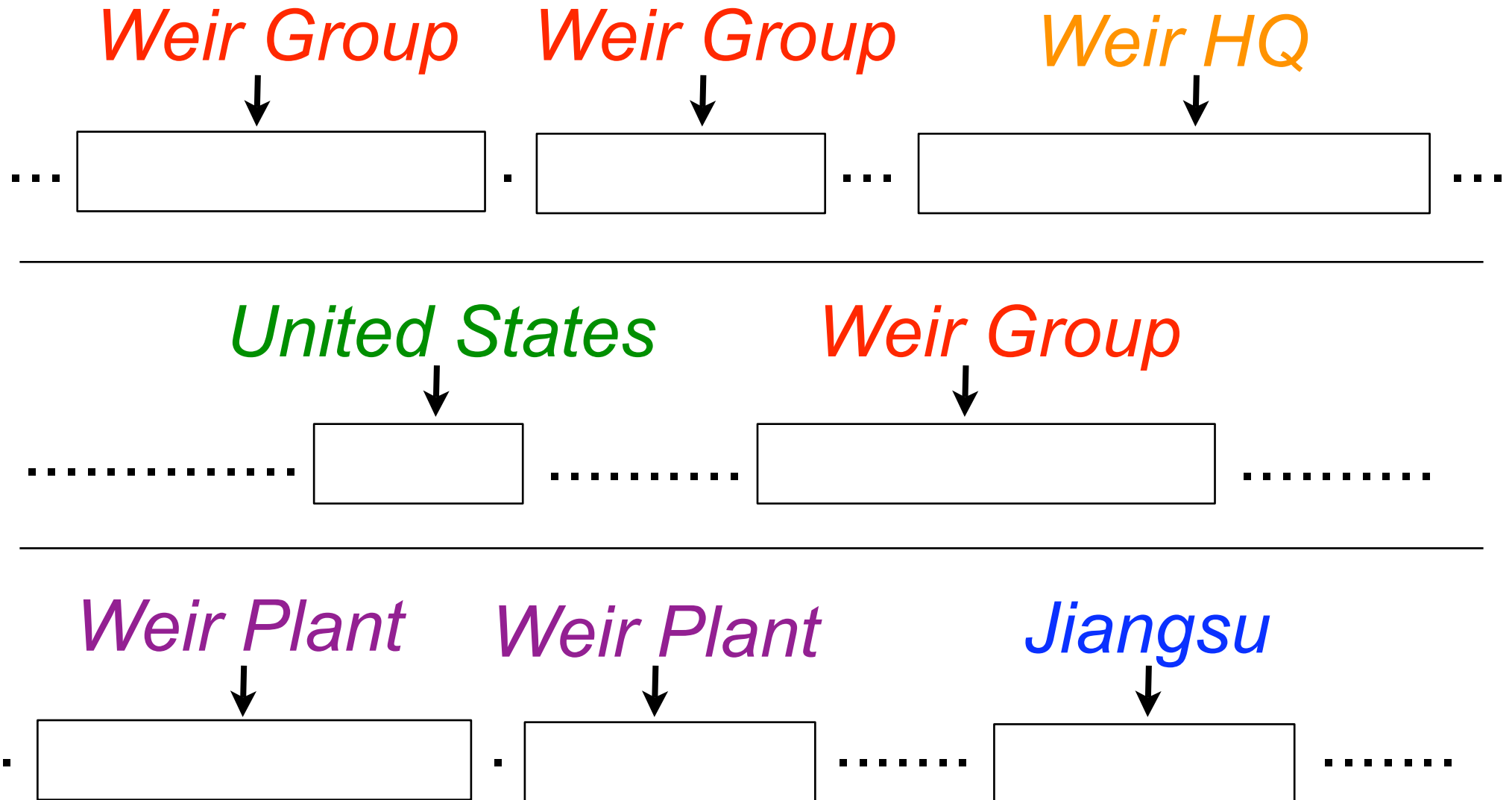
Coreference Resolution



Coreference Resolution



Coreference Resolution



Coreference Resolution

Weir Group *Weir Group* *Weir HQ*
↓ ↓ ↓
... “Weir group” . “whose” ... “headquarters” ...

United States *Weir Group*
↓ ↓
..... “U.S” “corporation”

Weir Plant *Weir Plant* *Jiangsu*
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· “power plant” · “which” “Jiangsu”

Coreference Resolution

Weir Group *Weir Group* *Weir HQ*

↓ ↓ ↓

... “Weir group” . “whose” ... “headquarters” ...

United States *Weir Group* Mention

↓ ↓ ↓

..... “U.S” “corporation”

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Coreference Resolution

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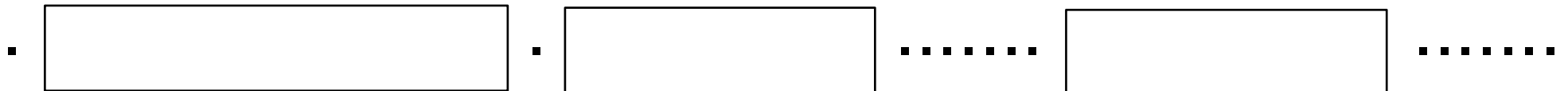
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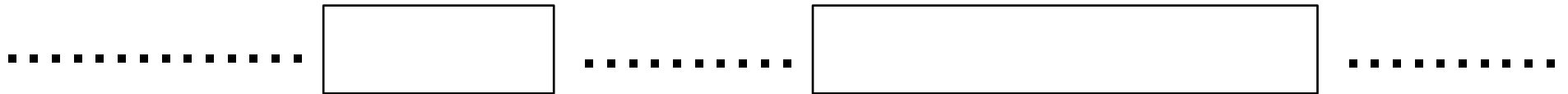
Coreference Resolution



Inference Time



Coreference Resolution



Coreference Resolution

... “Weir group” . “whose” ... “headquarters” ...

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Coreference Resolution

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↓ ↓ ↓
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Finite Mixture Model



Finite Mixture Model

$Z_1 =$
Weir Group

$Z_2 =$
Weir Group

$Z_3 =$
Weir HQ

Finite Mixture Model

Entity Distribution

$$P(\textit{Weir Group}) = 0.2,$$

.....

$$P(\textit{Weir HQ}) = 0.5,$$

Z₁=

Weir Group

Z₂=

Weir Group

Z₃=

Weir HQ

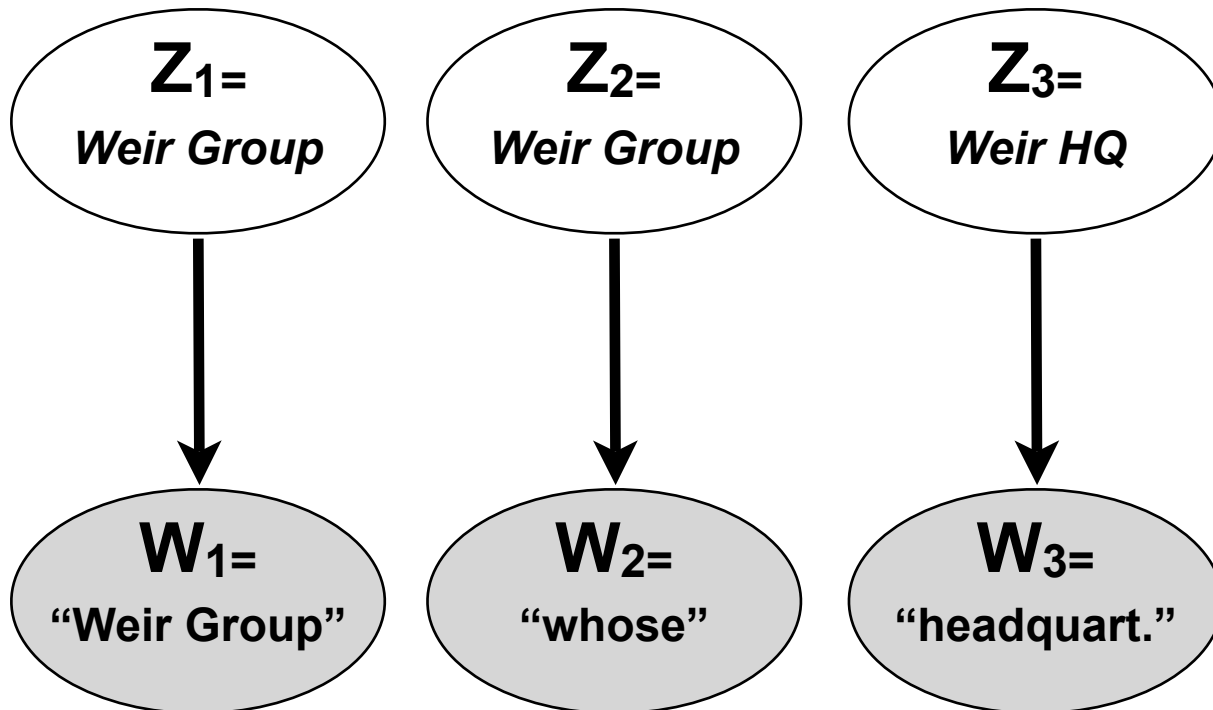
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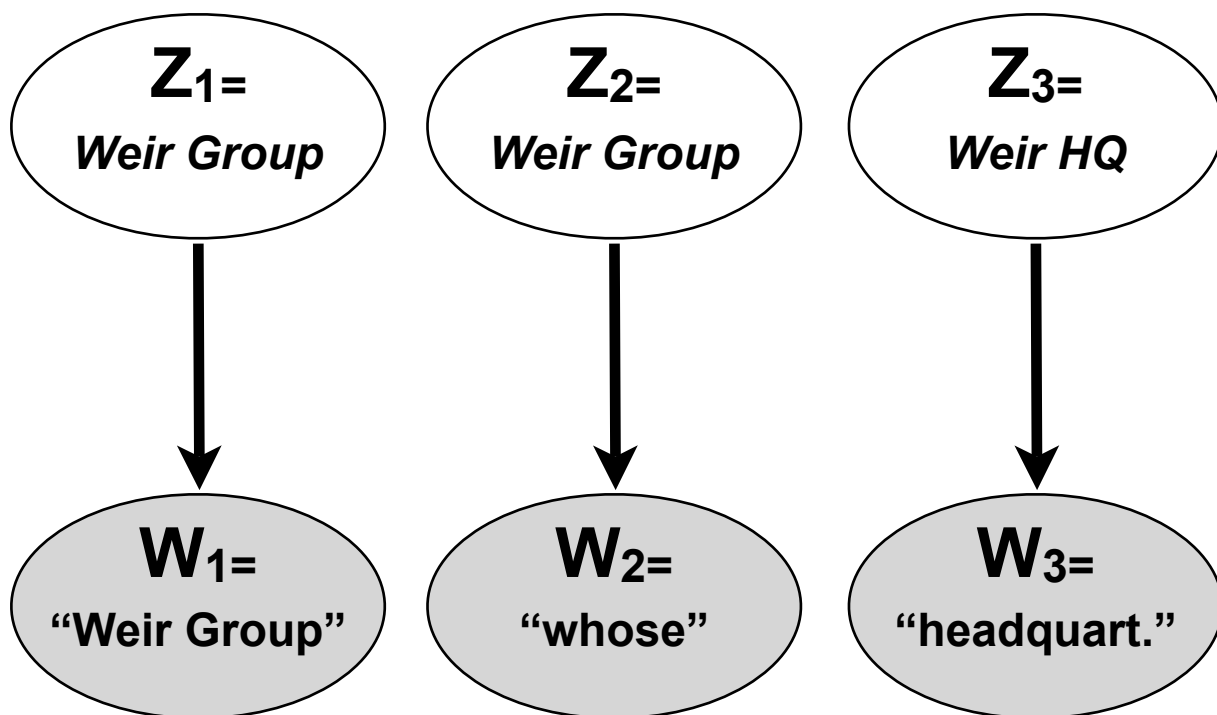
Mention Distribution

$$P(W \mid \textit{Weir Group}):$$

$$\text{"Weir Group"} = 0.4,$$

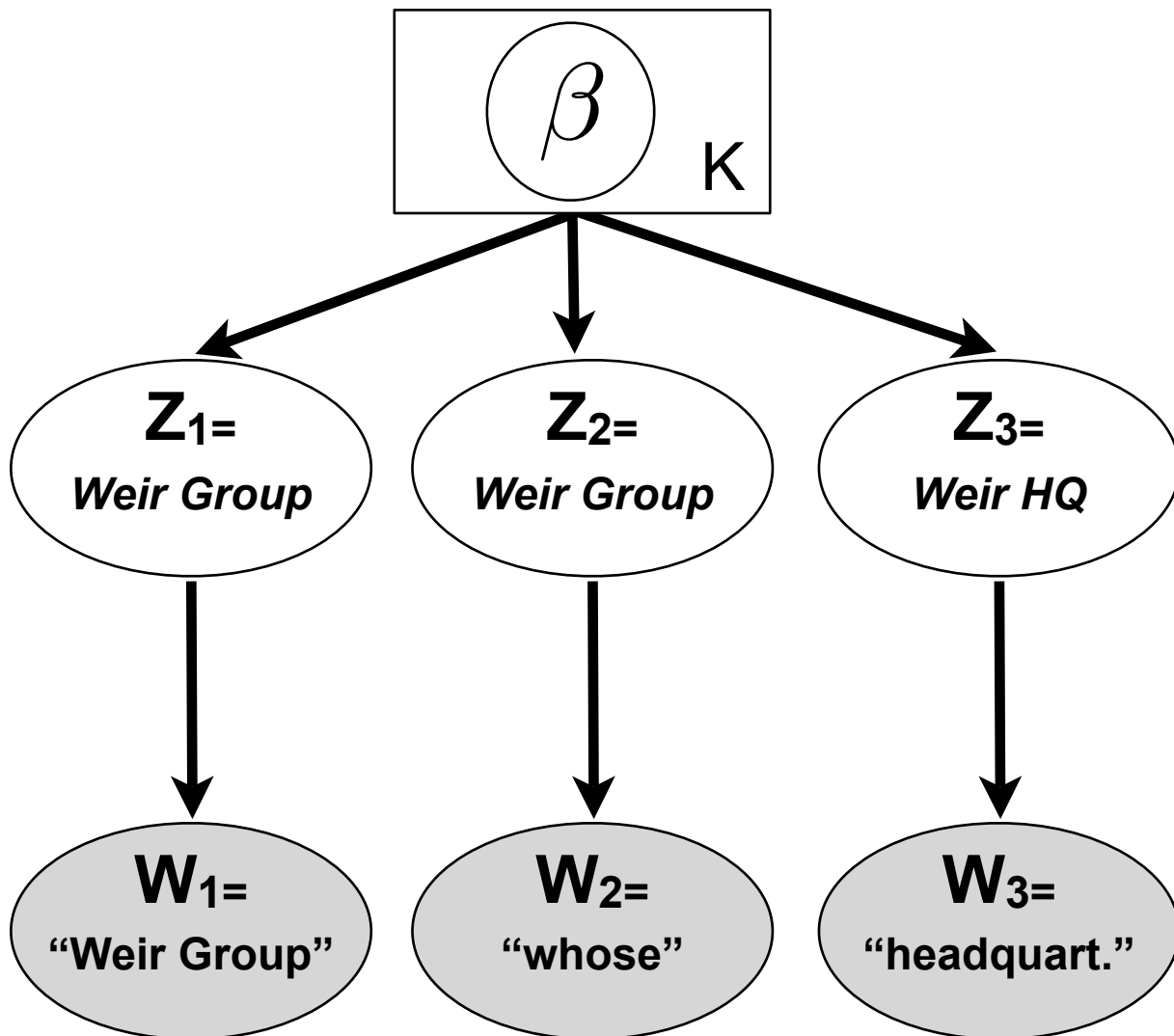
$$\text{"whose"} = 0.2,$$

.....



Bayesian Finite Mixture Model

Entity Distribution

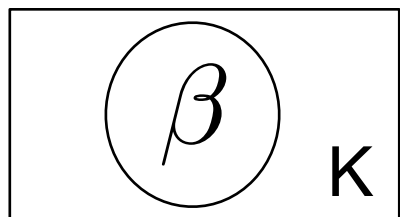


Mention Distribution

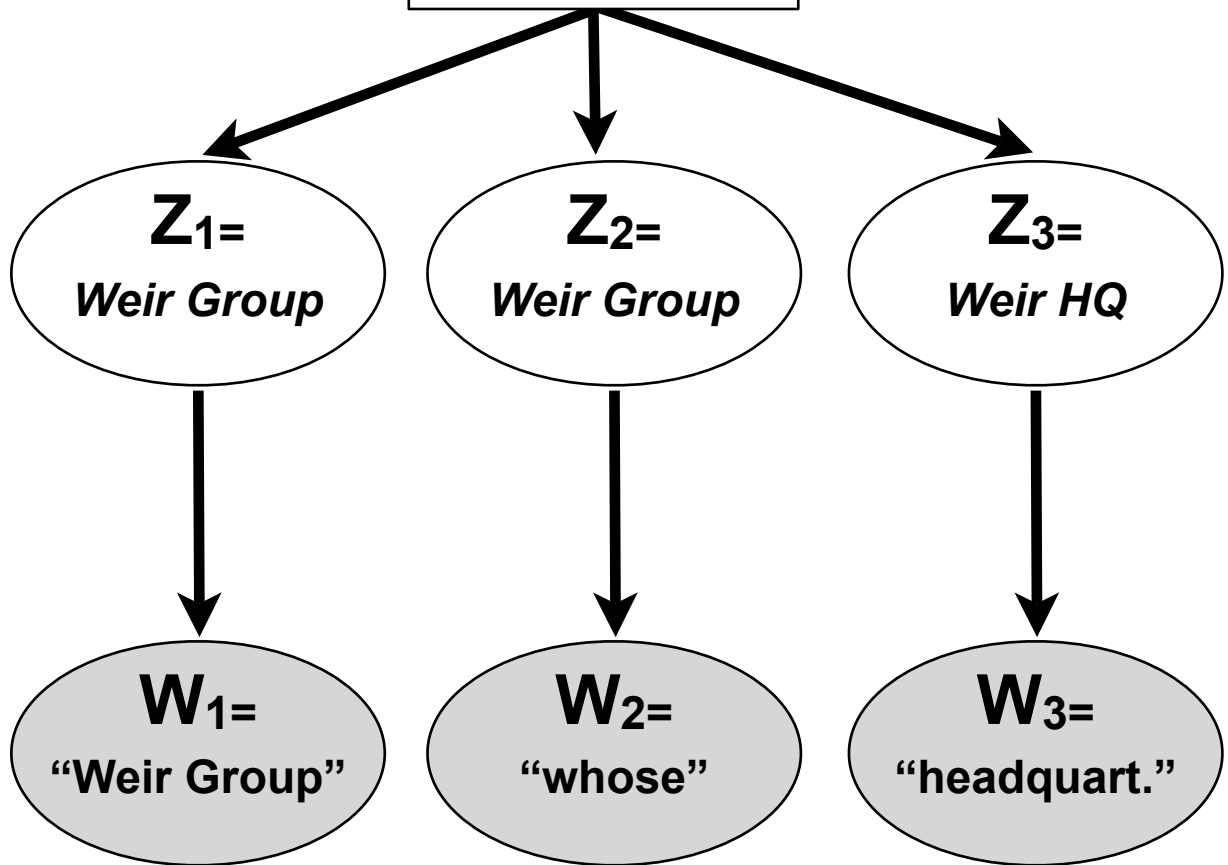
$P(W \mid \text{Weir Group})$:
 "Weir Group"=0.4,
 "whose"=0.2,

Bayesian Finite Mixture Model

Entity Distribution



This is how many entities there are

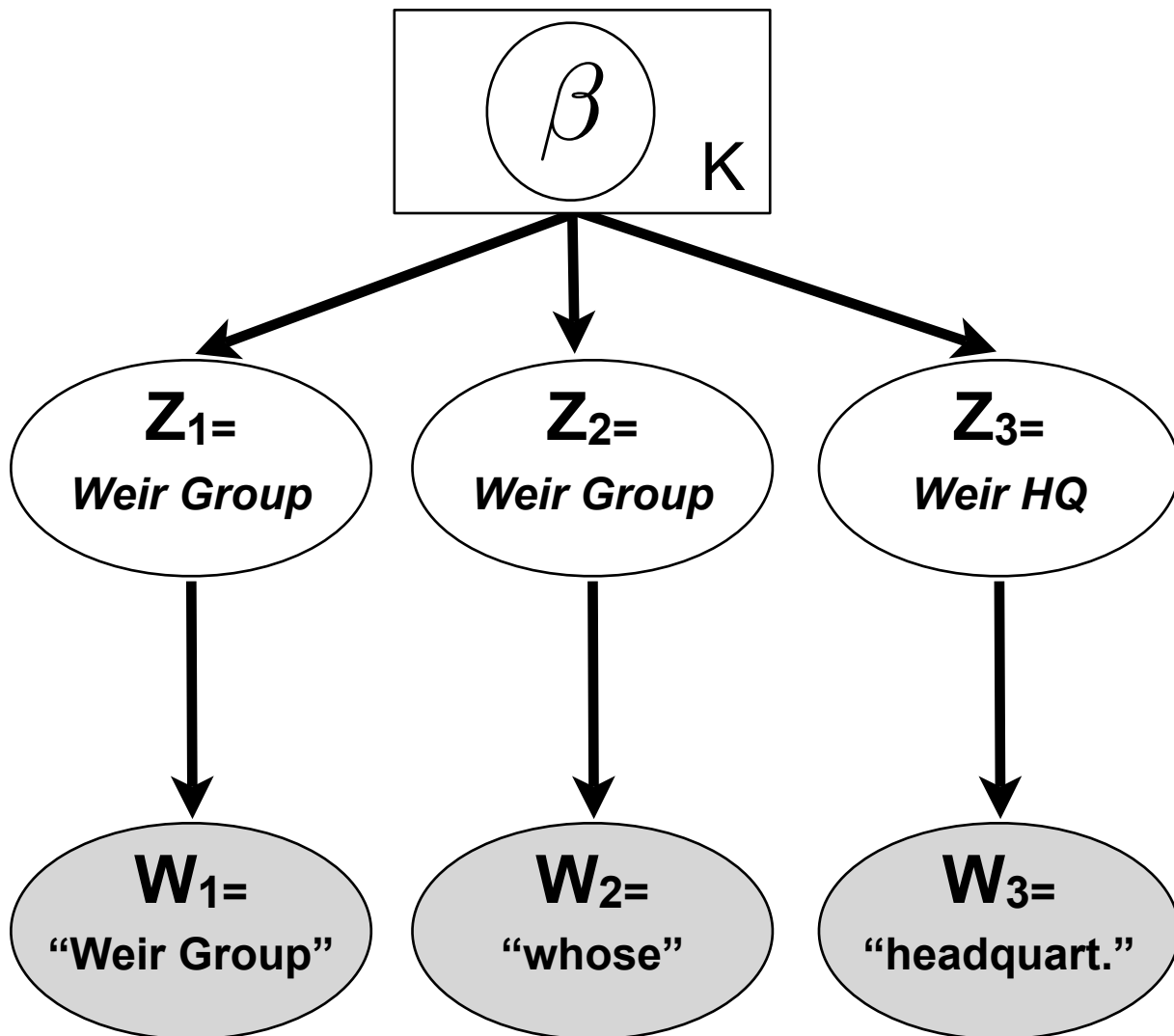


Mixture Distribution

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Bayesian Finite Mixture Model

Entity Distribution

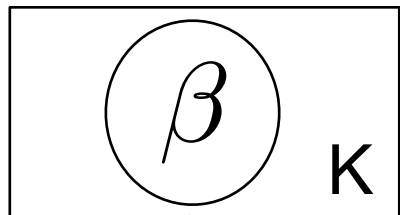


Mention Distribution

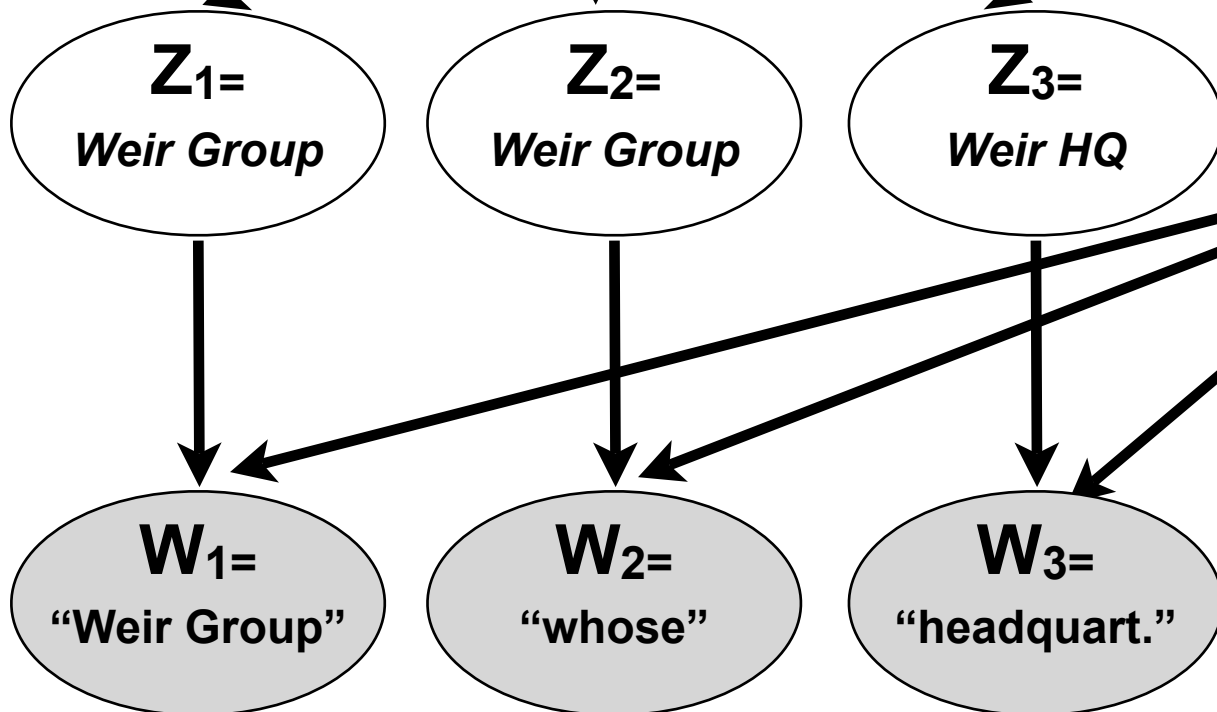
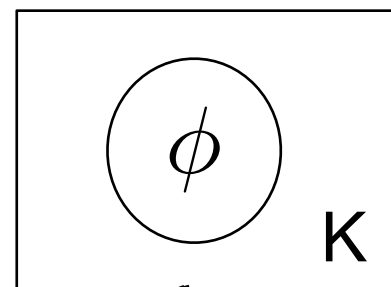
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Bayesian Finite Mixture Model

Entity Distribution

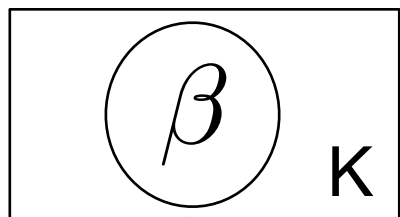


Mention Distribution



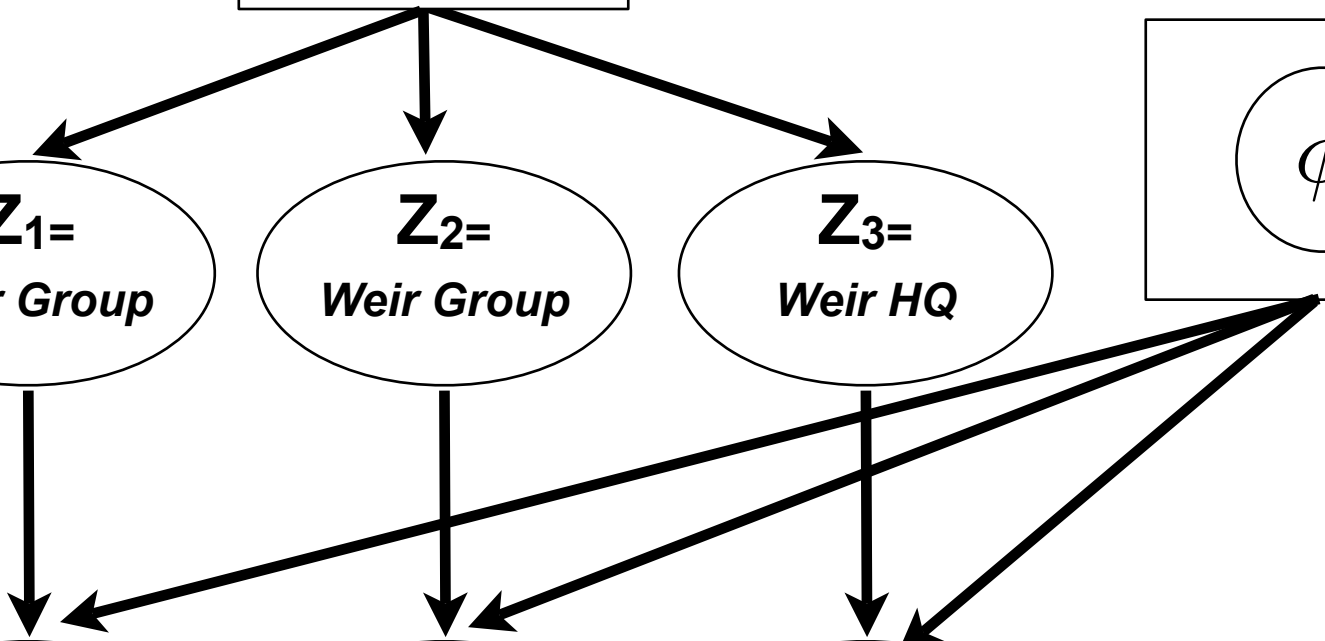
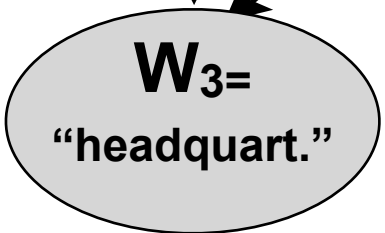
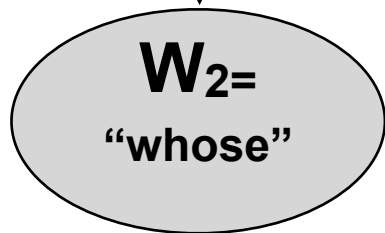
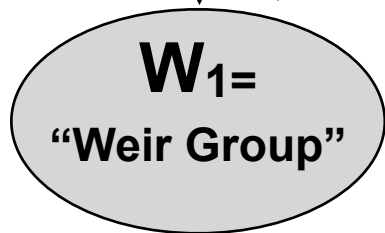
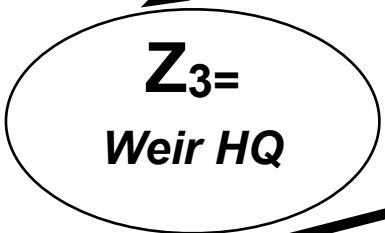
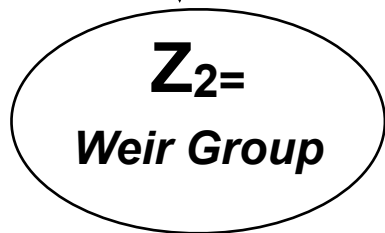
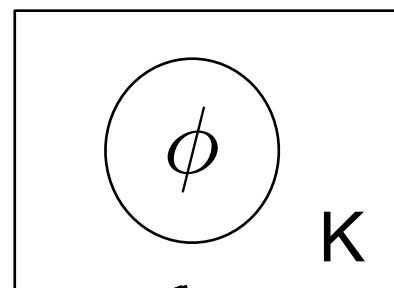
Bayesian Finite Mixture Model

Entity Distribution



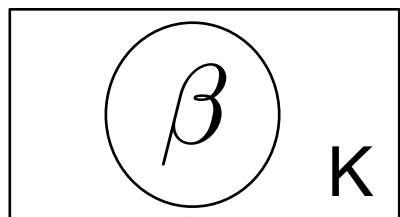
How do you choose K ?

Mixture Distribution

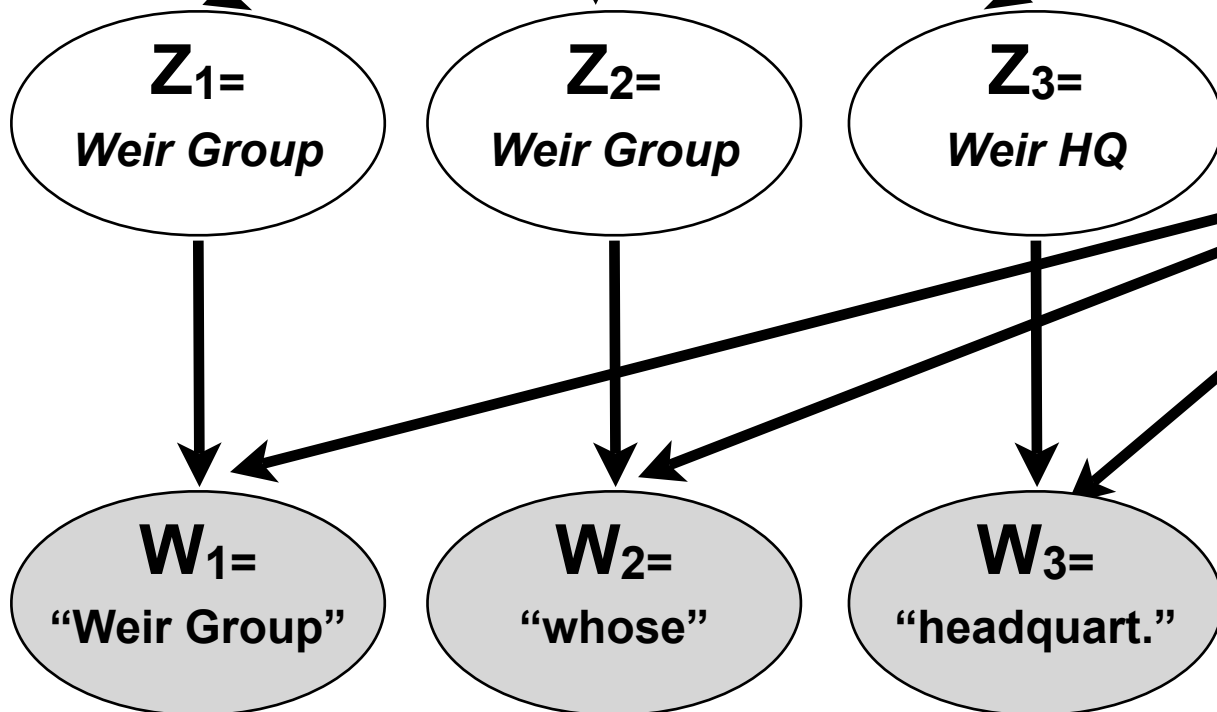
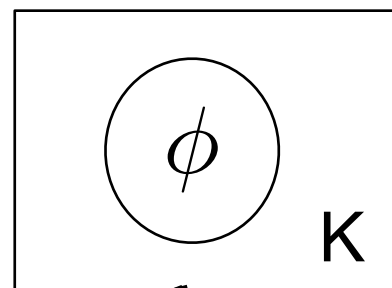


Bayesian Finite Mixture Model

Entity Distribution

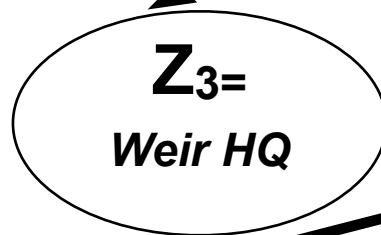
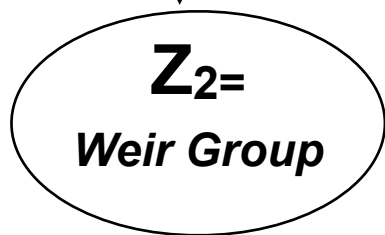
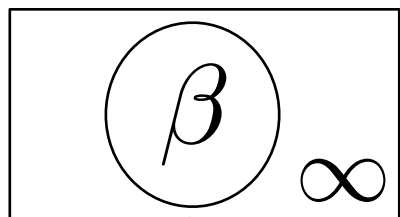


Mention Distribution

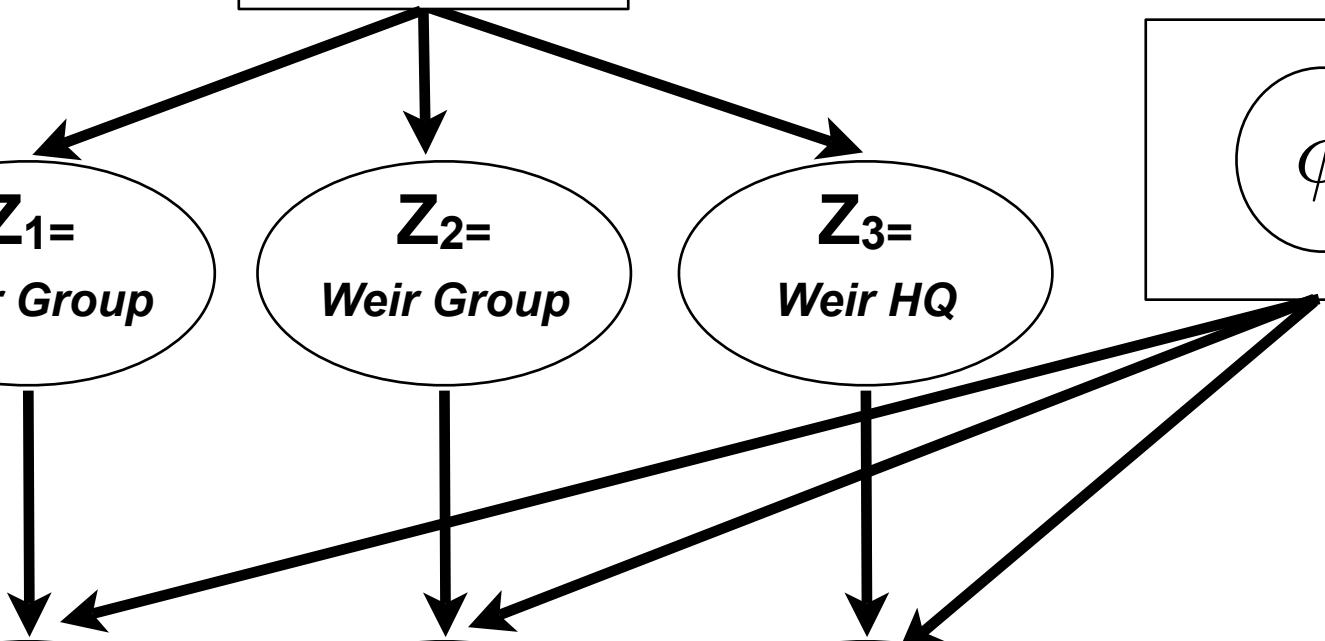
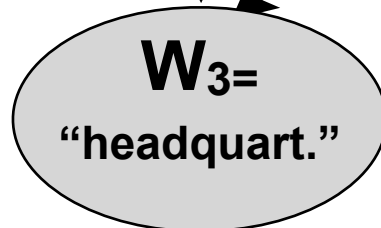
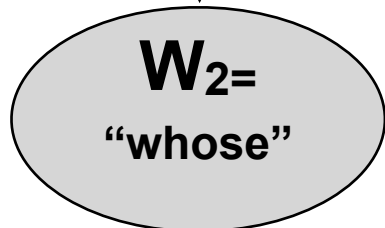
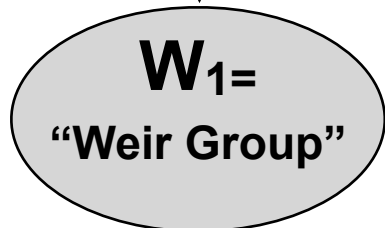
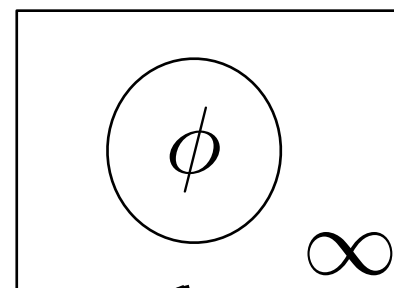


Infinite Mixture Model

Entity Distribution



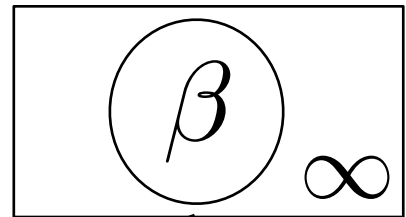
Mention Distribution



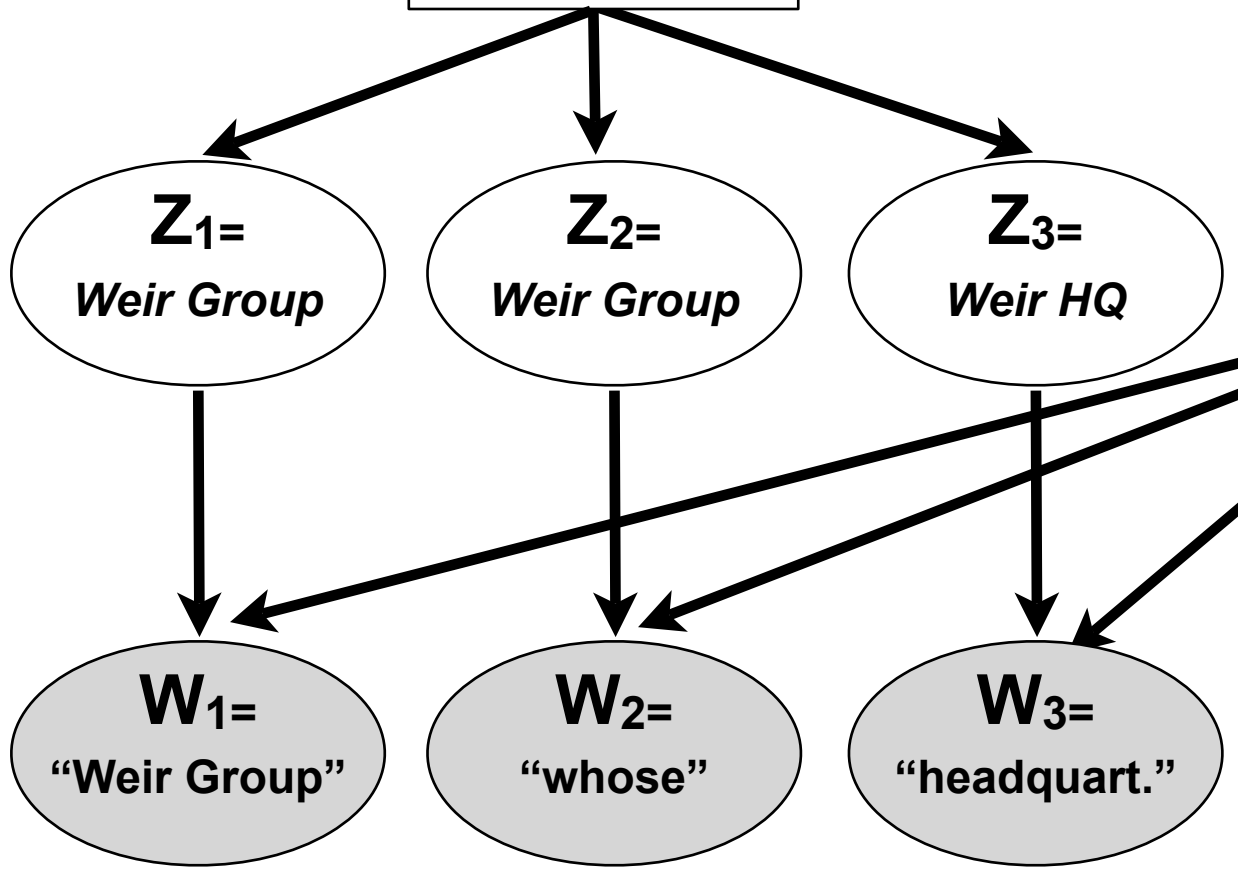
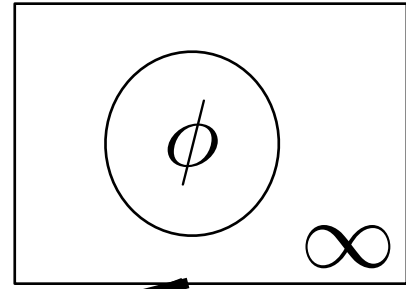
Infinite Mixture Model

Drawn from a Dirichlet Process (DP) prior [Teh et al., 2006]

Entity Distribution

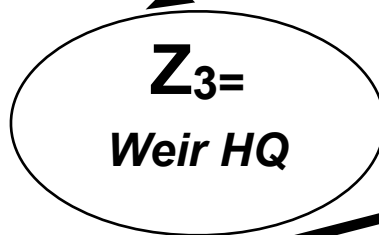
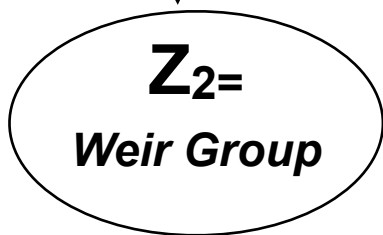
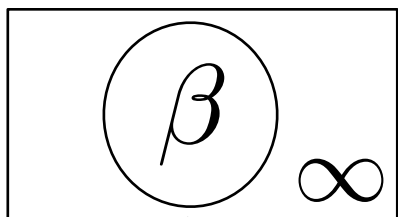


Mention Distribution

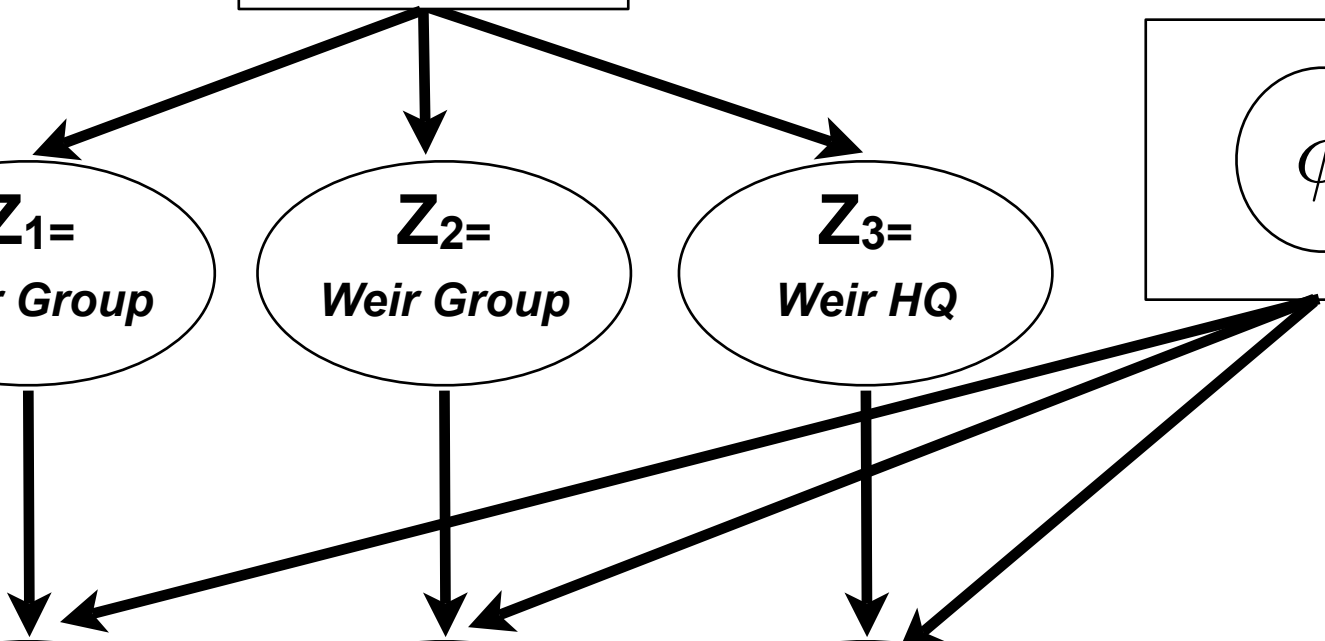
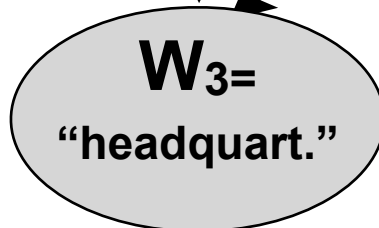
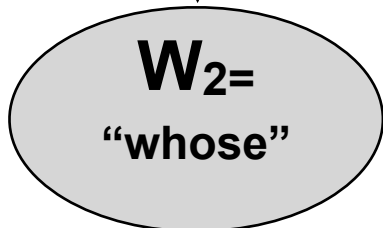
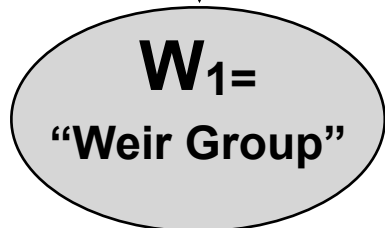
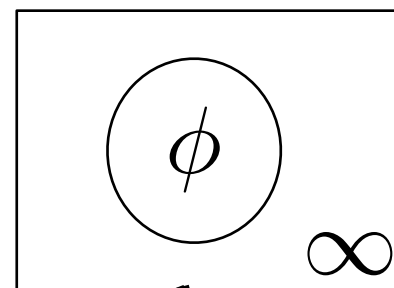


Infinite Mixture Model

Entity Distribution



Mention Distribution





Experimental Setup

Experimental Setup

- ACE 2004 English translations of Arabic and Chinese Treebanks

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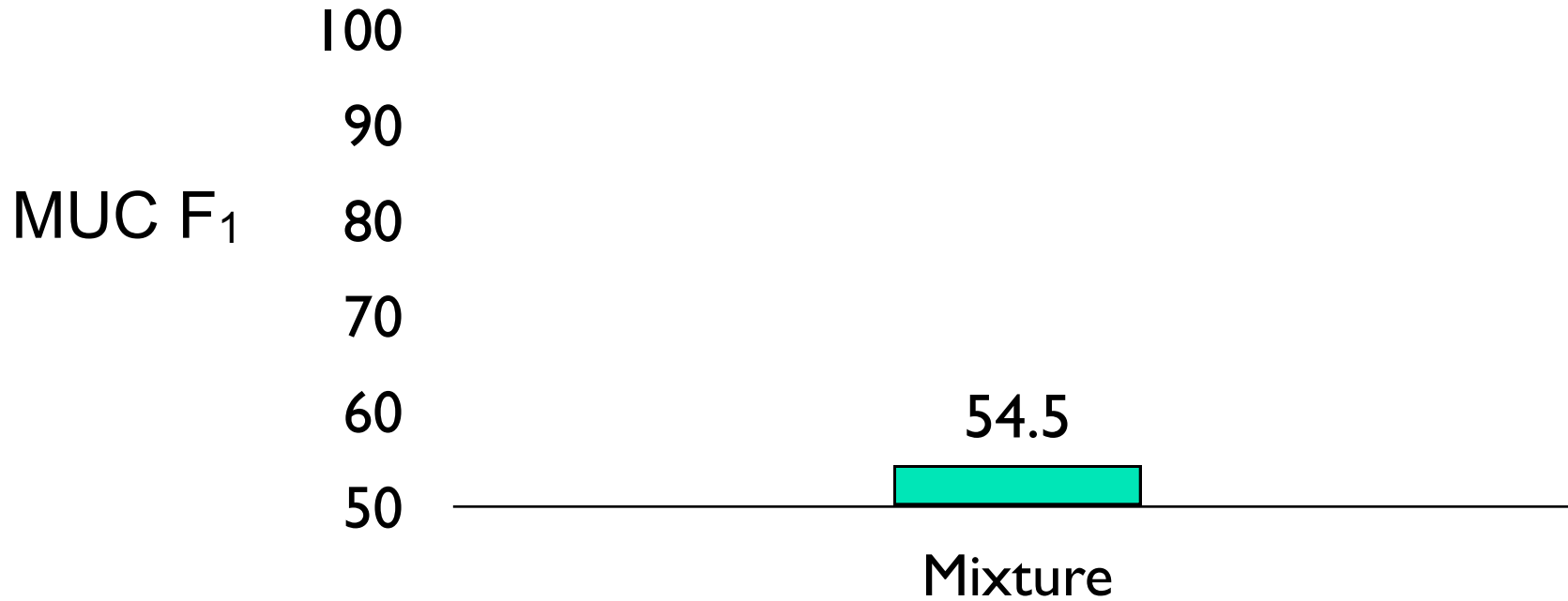
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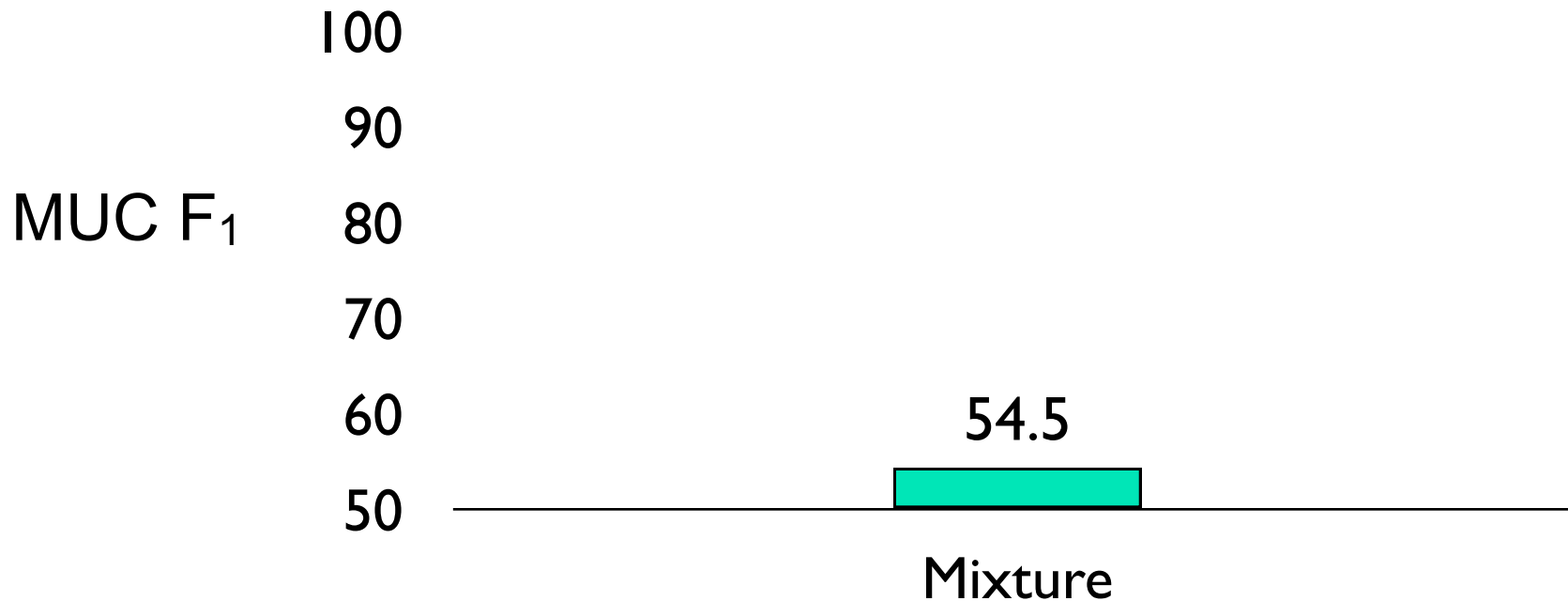
Experimental Setup

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- Given mention boundaries
- Evaluate on MUC F_1 Measure

Infinite Mixture Model

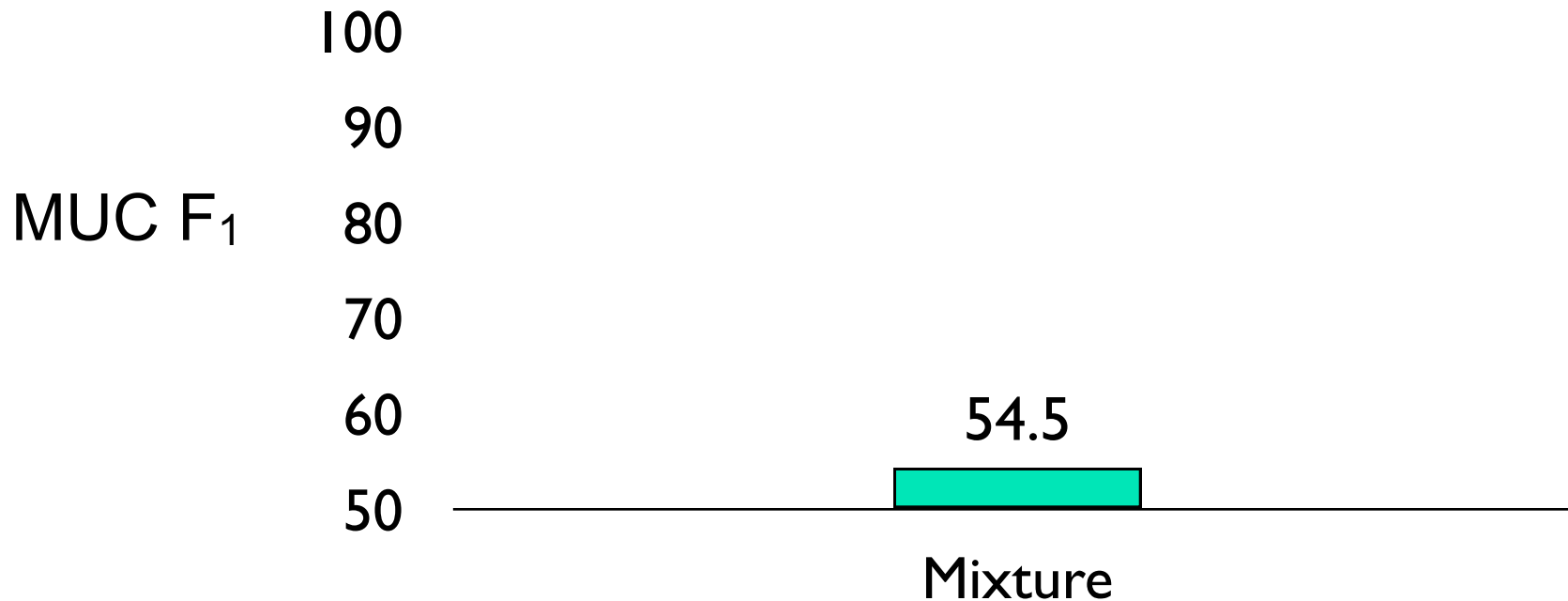


Infinite Mixture Model



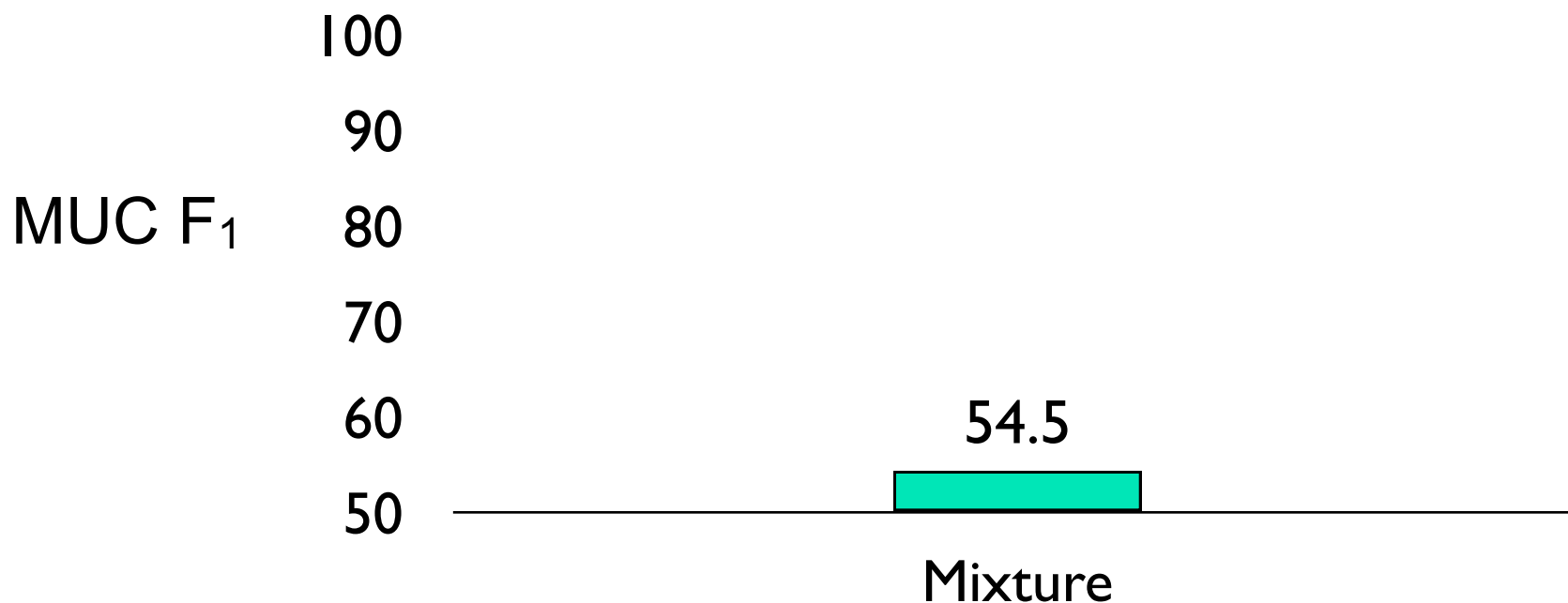
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Infinite Mixture Model



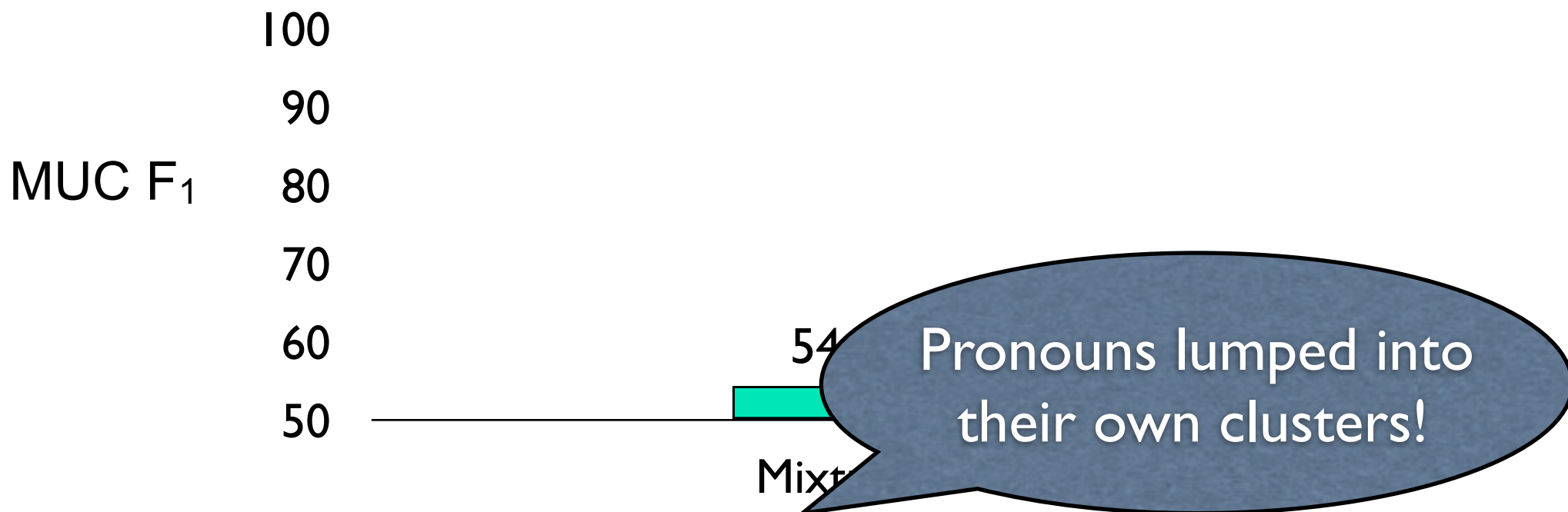
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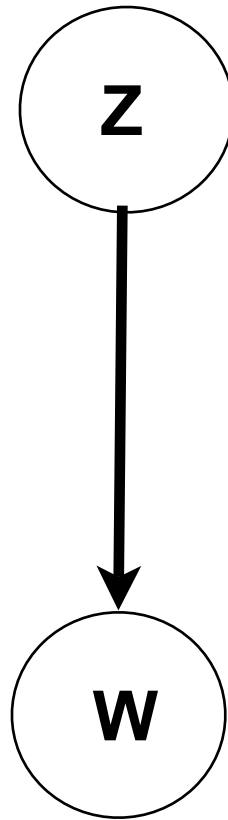
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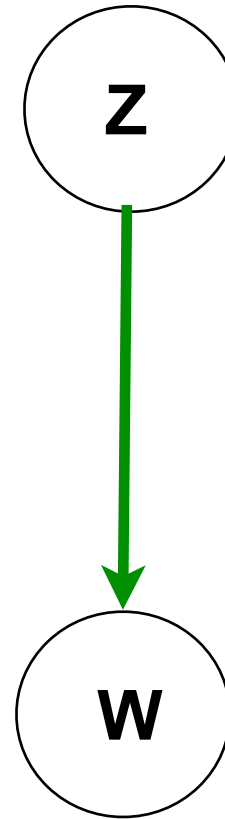
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Enriching Mention Model



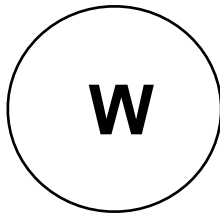
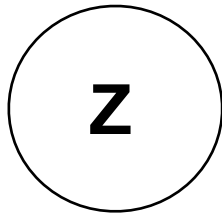
Enriching Mention Model

Non-Pronoun

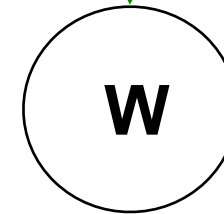
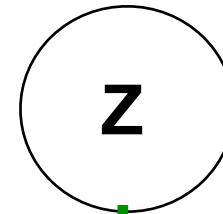


Enriching Mention Model

Pronoun

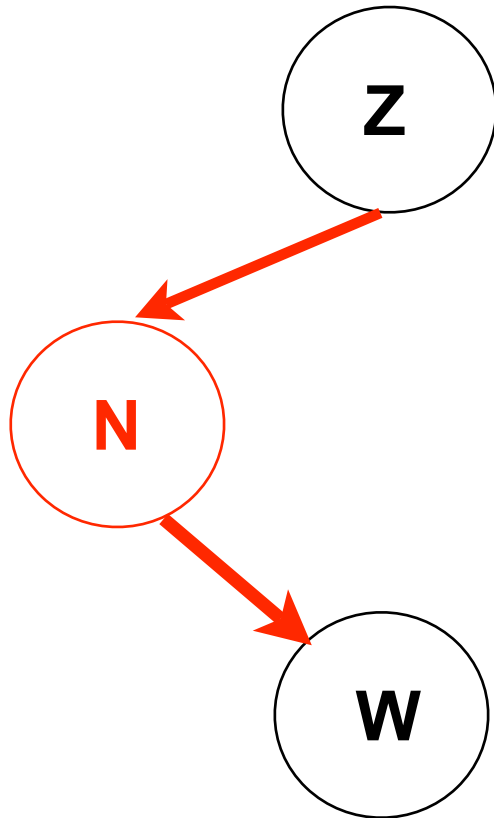


Non-Pronoun

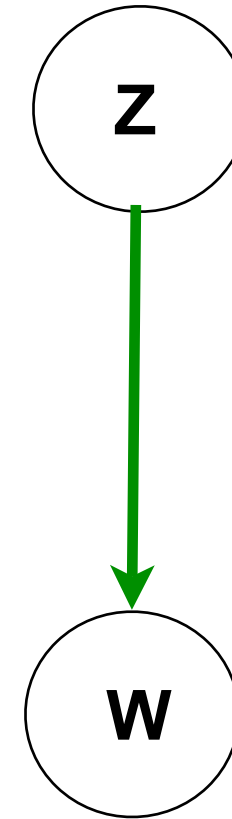


Enriching Mention Model

Pronoun

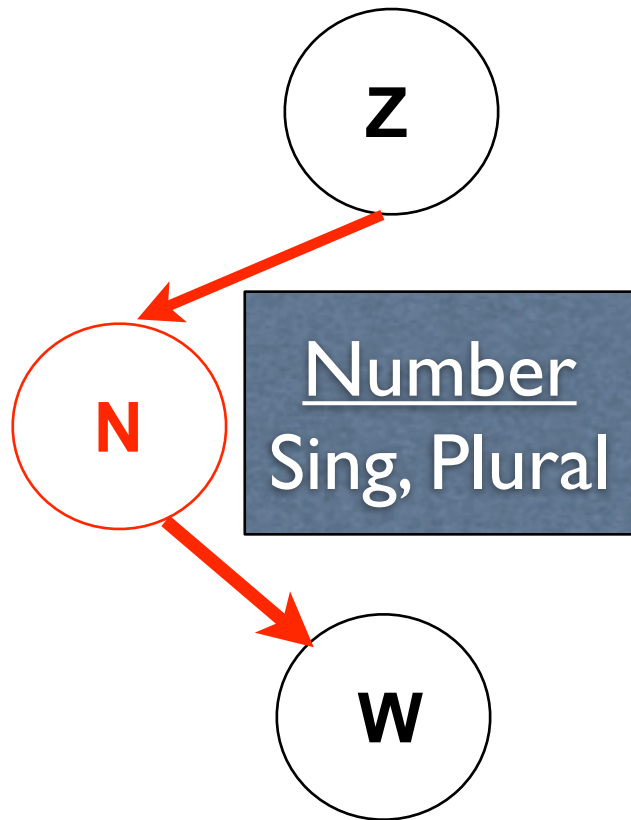


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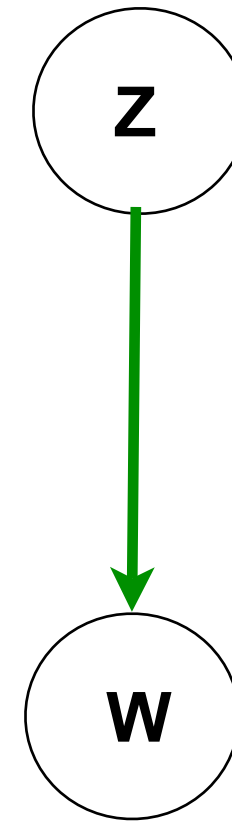


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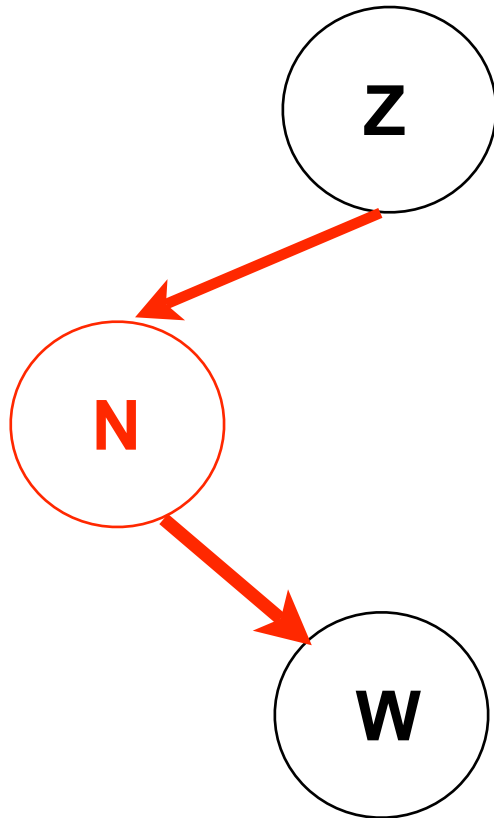


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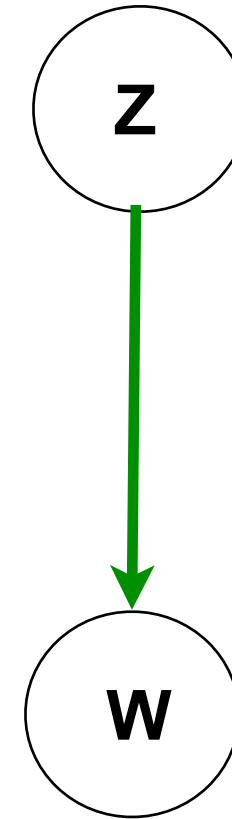


Enriching Mention Model

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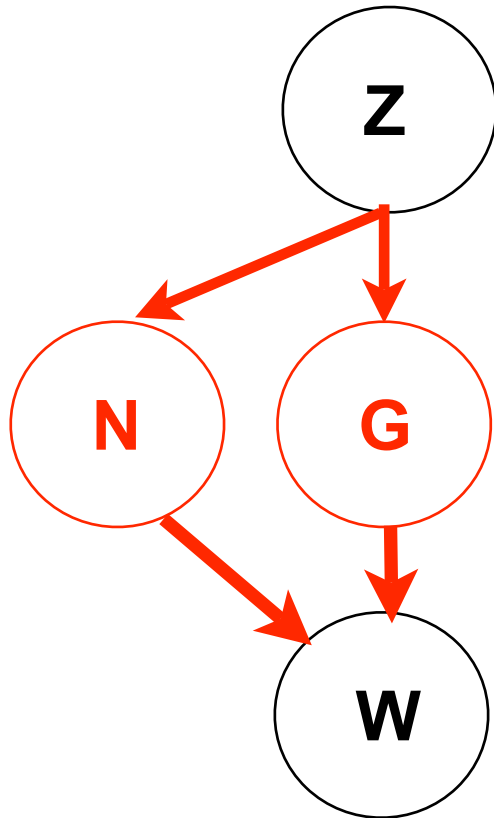


Non-Pronoun

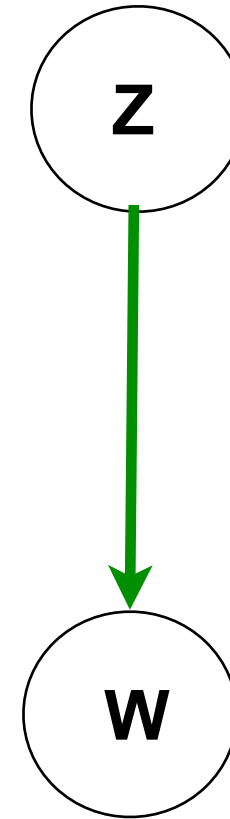


Enriching Mention Model

Pronoun

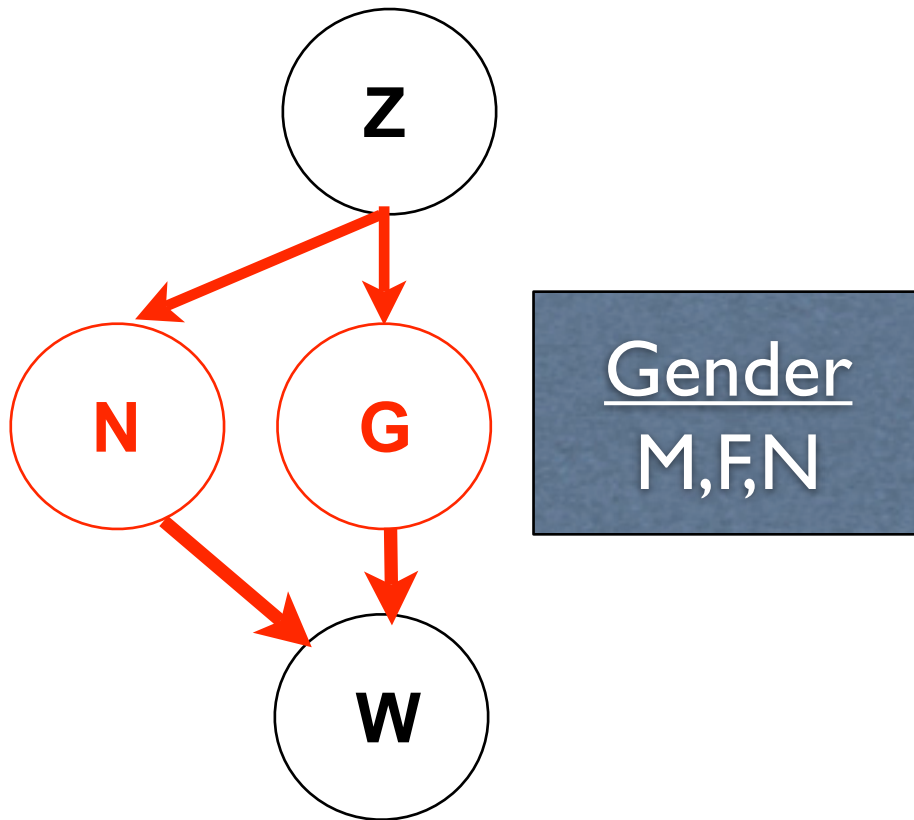


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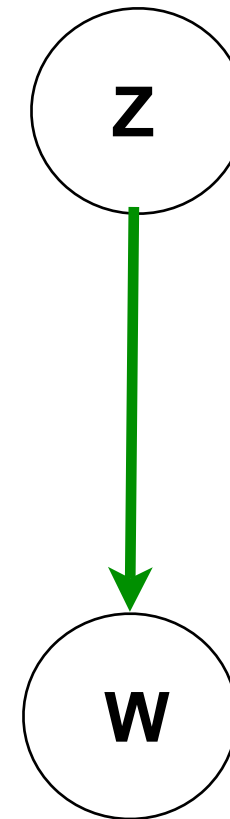


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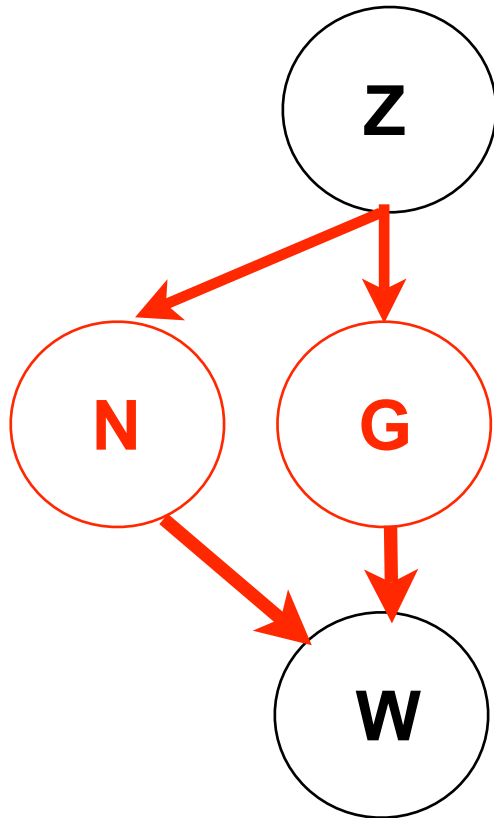


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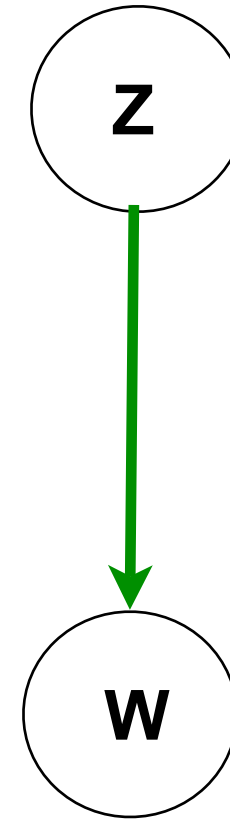


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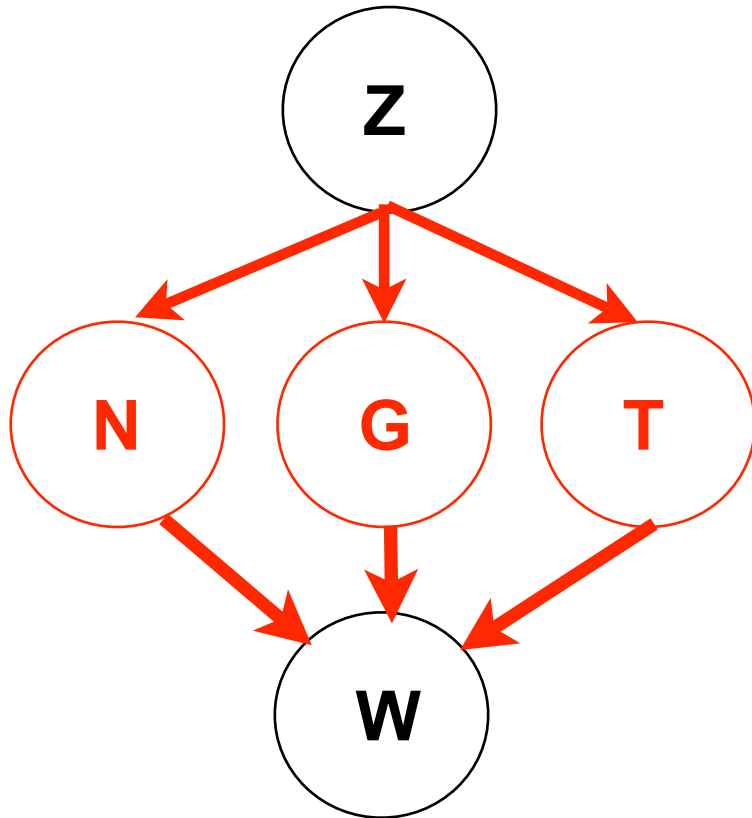


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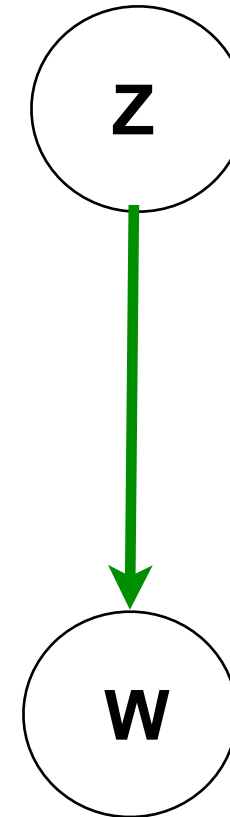


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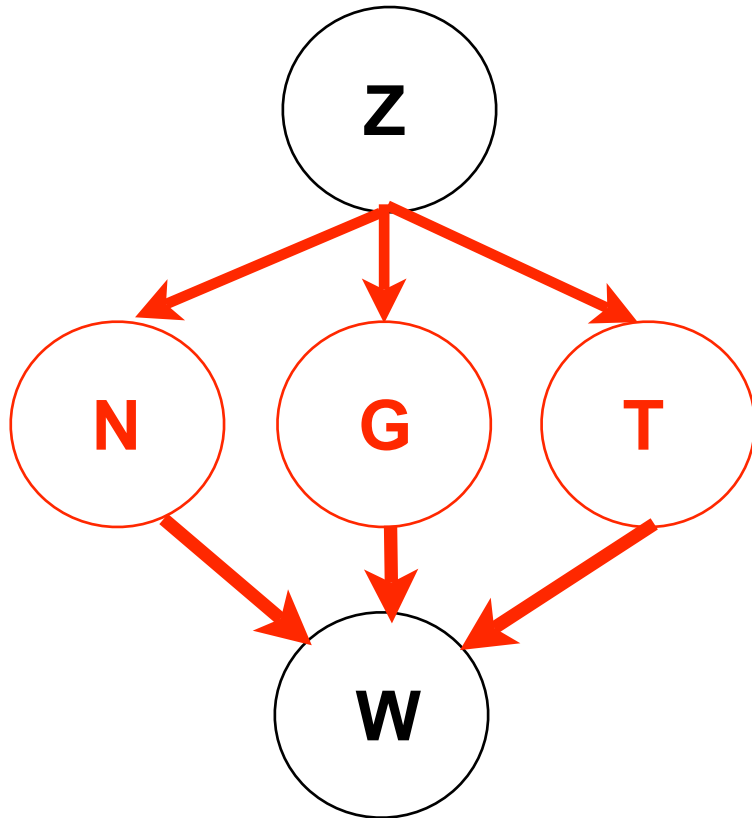


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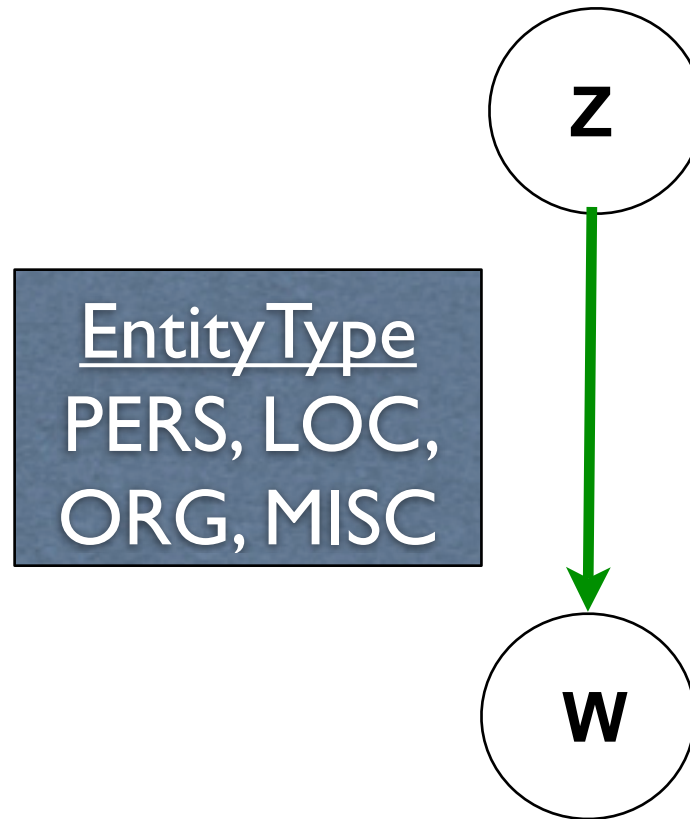


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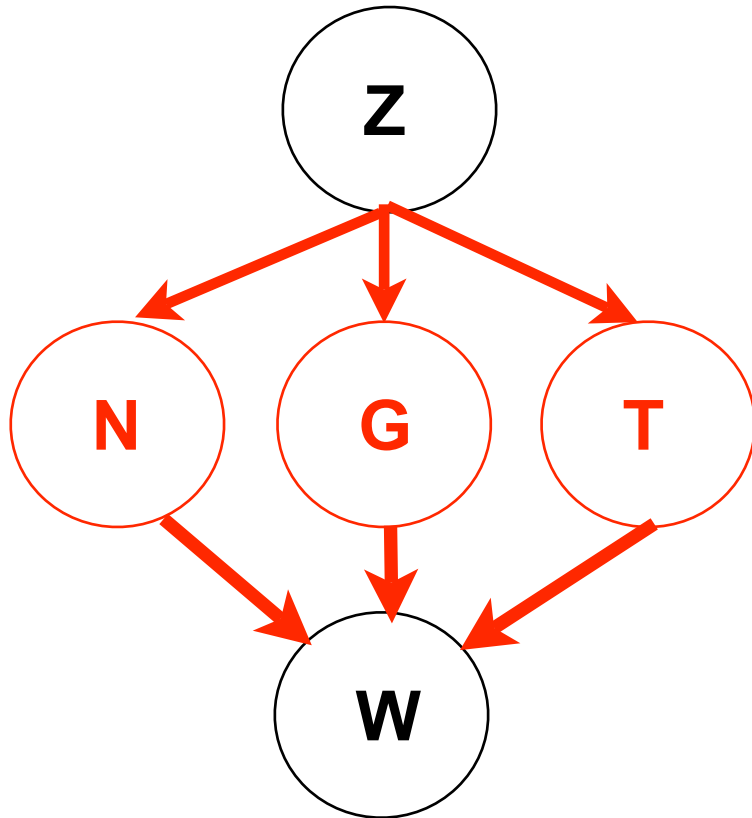


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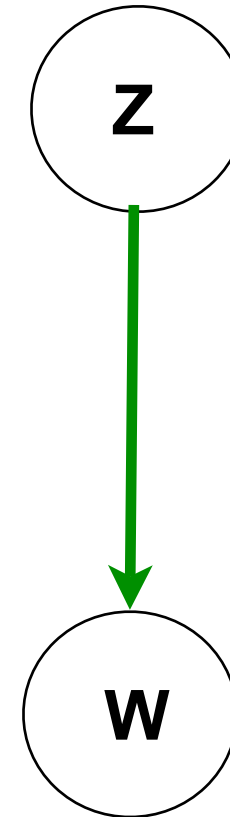


Enriching Mention Model

Pronoun

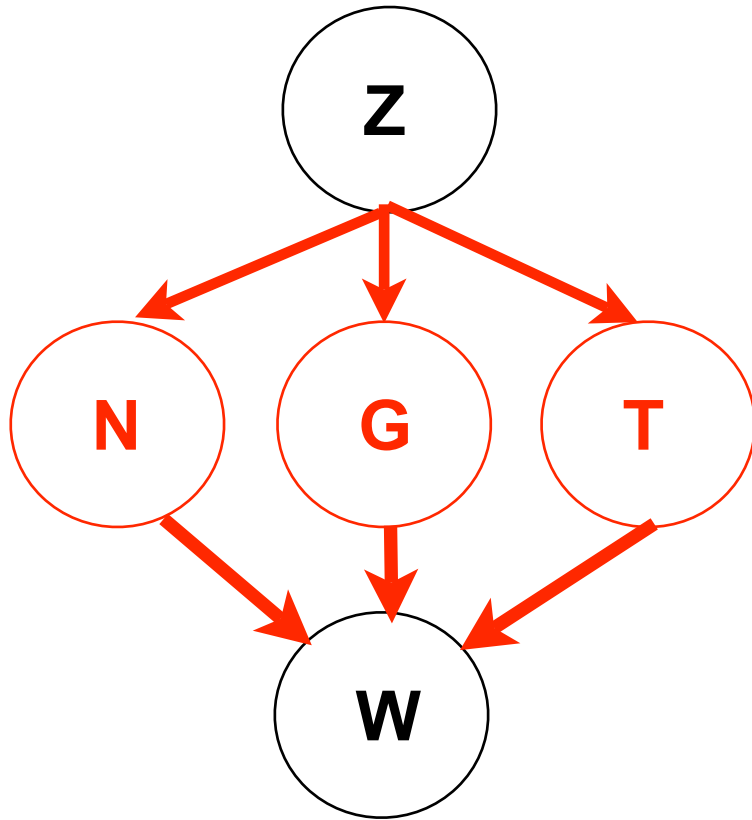


Non-Pronoun



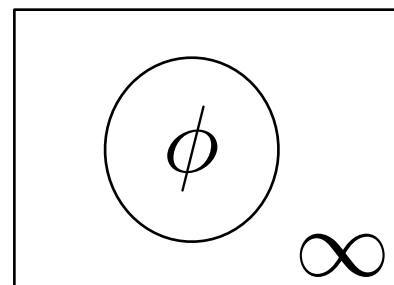
Enriching Mention Model

Pronoun

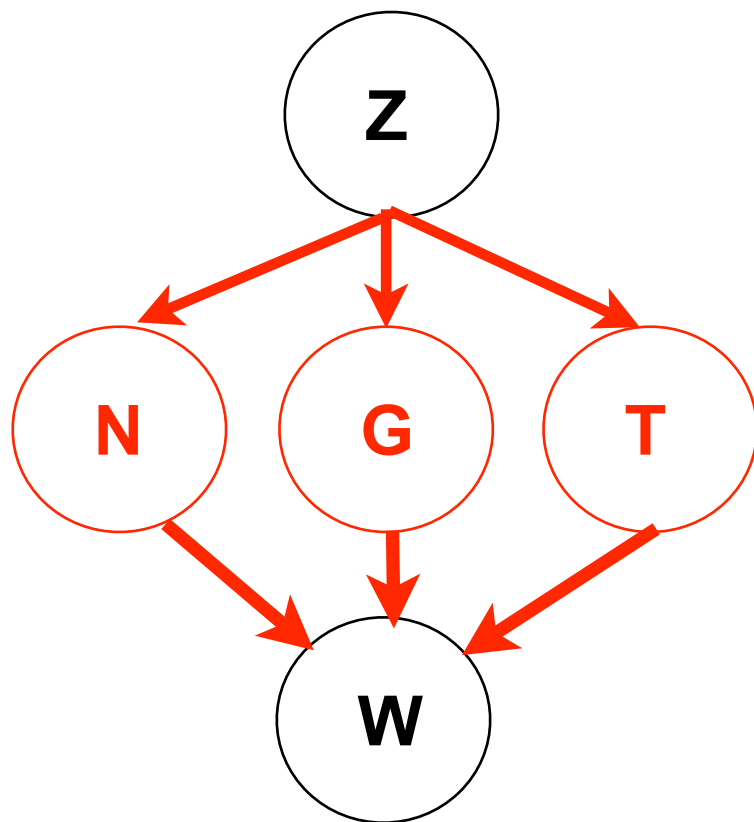


Enriching Mention Model

Entity Parameters

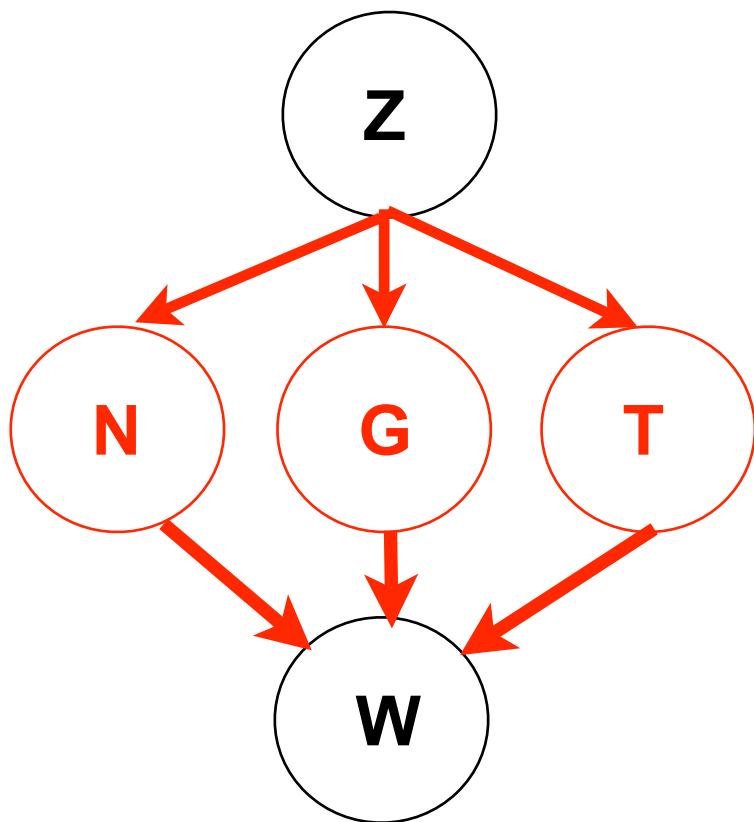


Pronoun

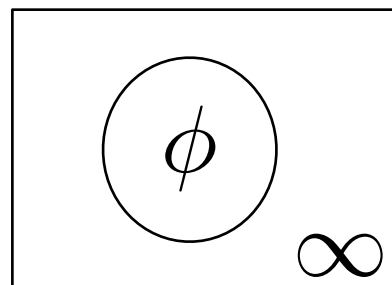


Enriching Mention Model

Pronoun



Entity Parameters



Pronoun Parameters

W | SING, MALE, PERS

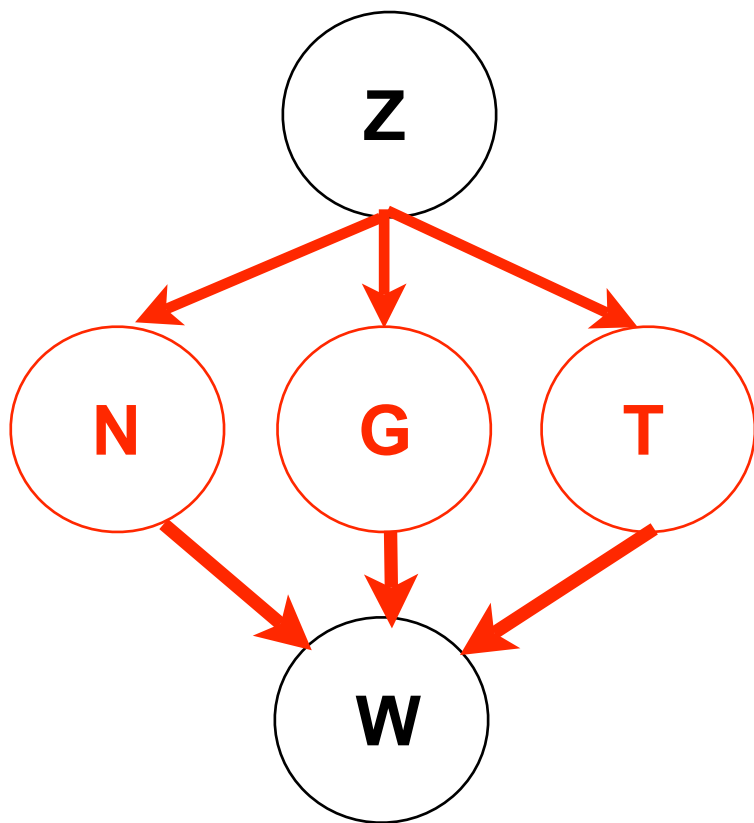
“he”:0.5, “him”: 0.3,...

W | PL, NEUT, ORG

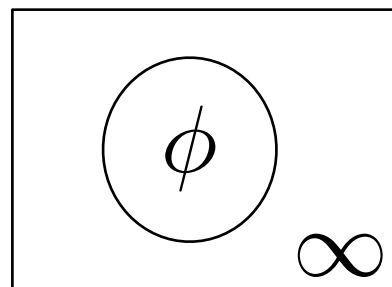
“they”:0.3, “it”: 0.2,...

Enriching Mention Model

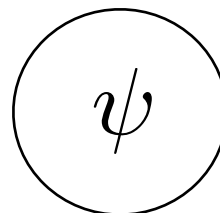
Pronoun



Entity Parameters

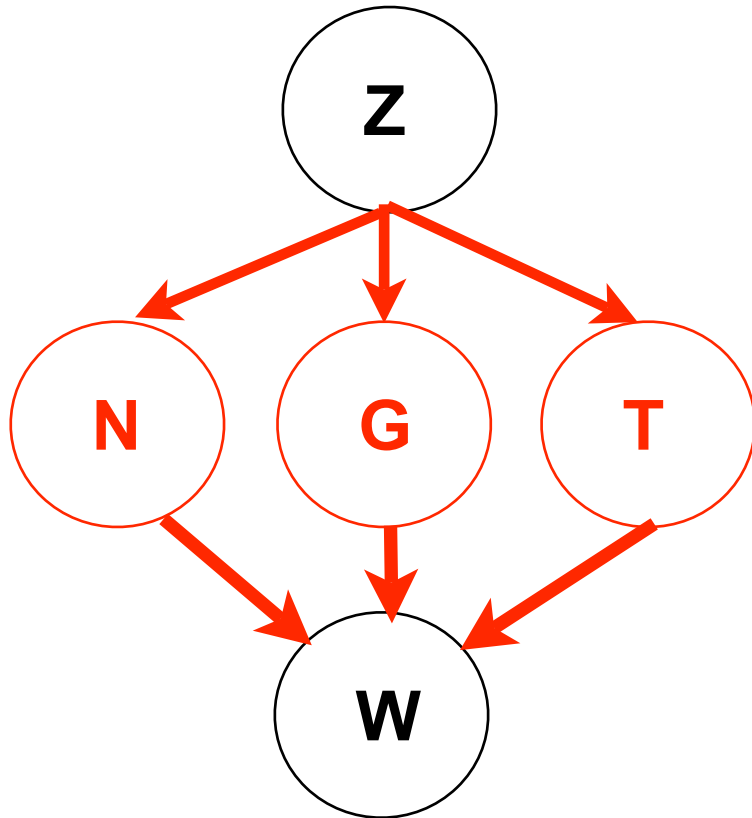


Pronoun Parameters

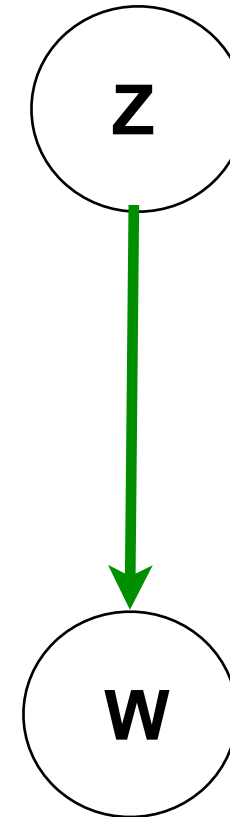


Enriching Mention Model

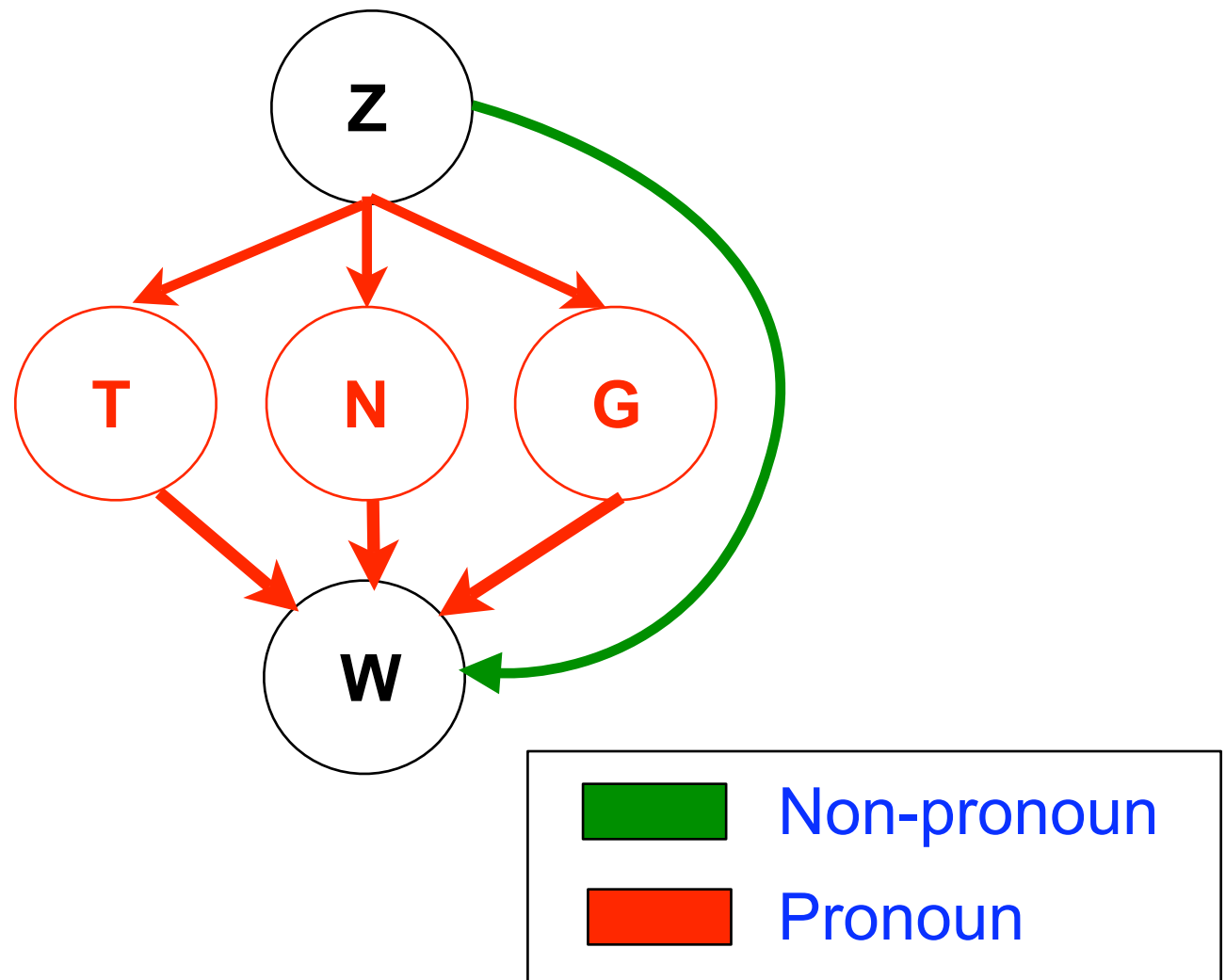
Pronoun



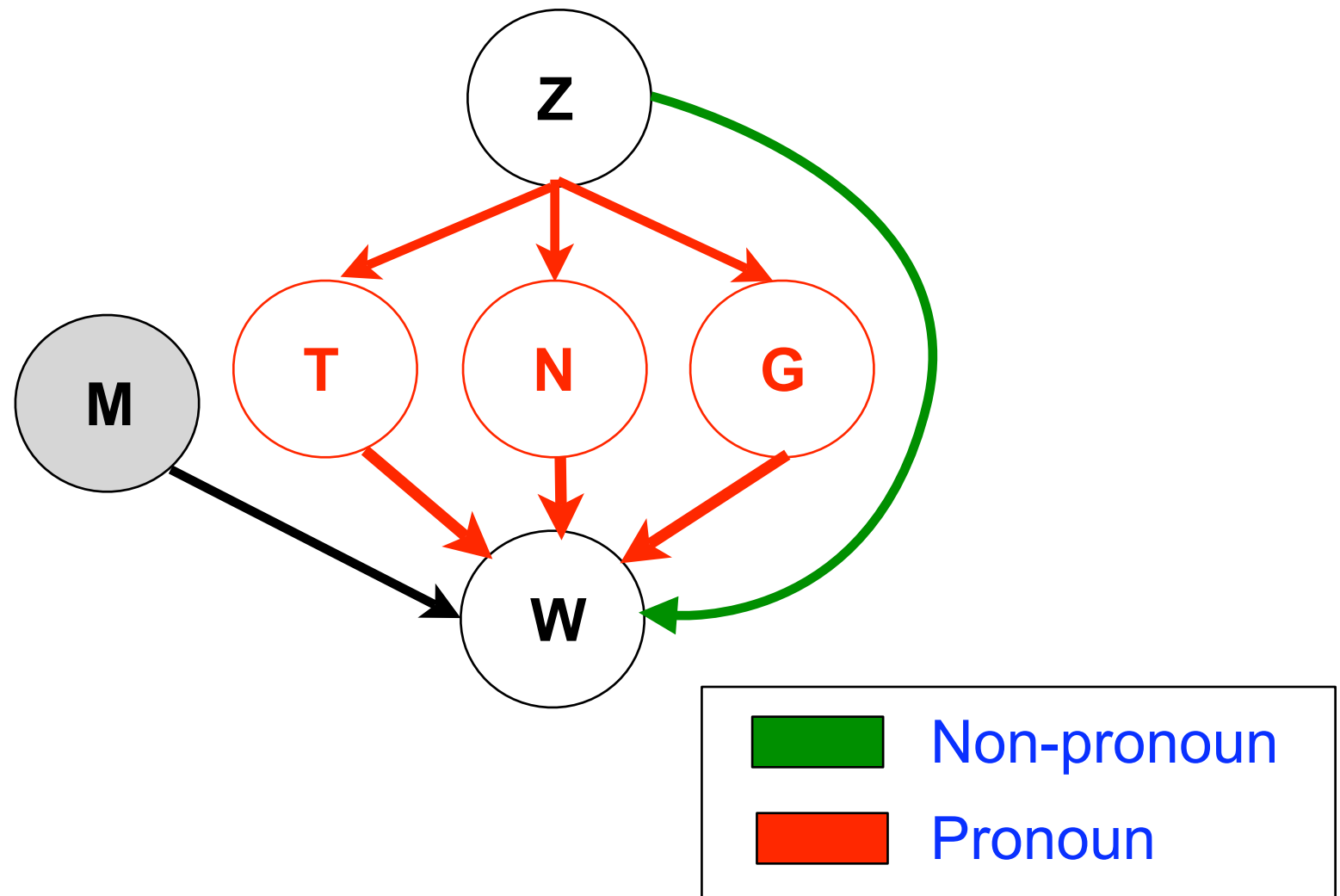
Non-Pronoun



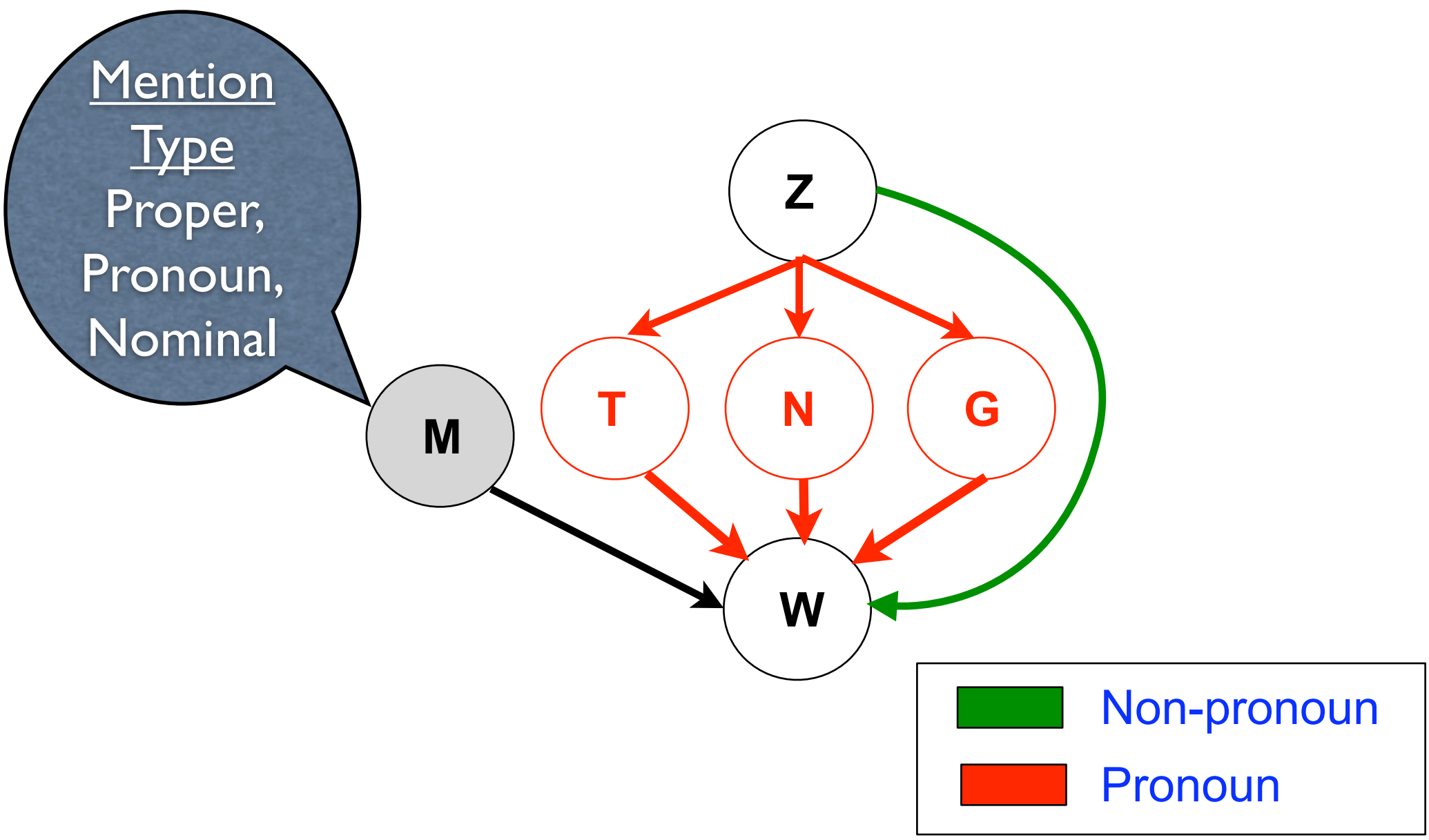
Enriching Mention Model



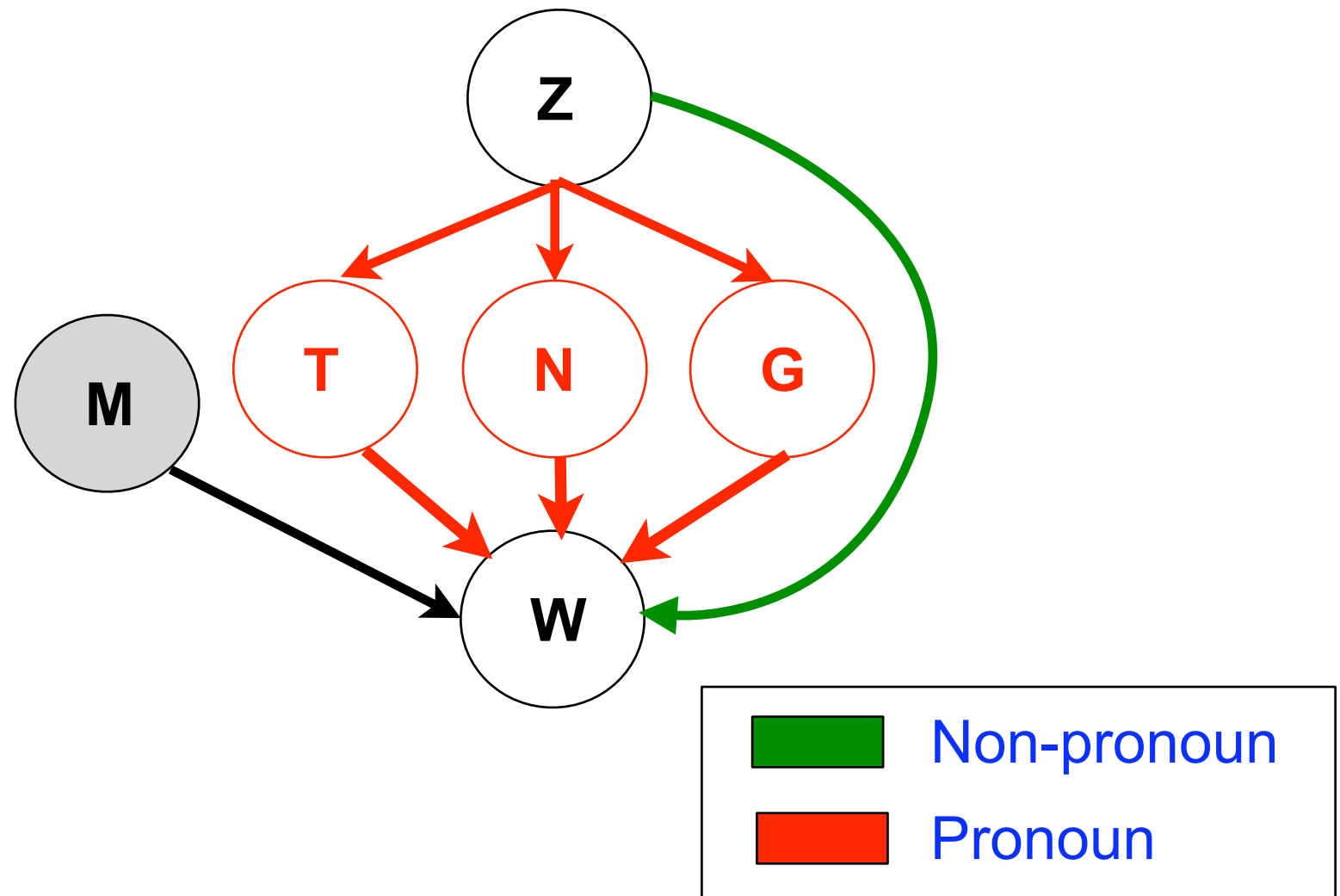
Enriching Mention Model



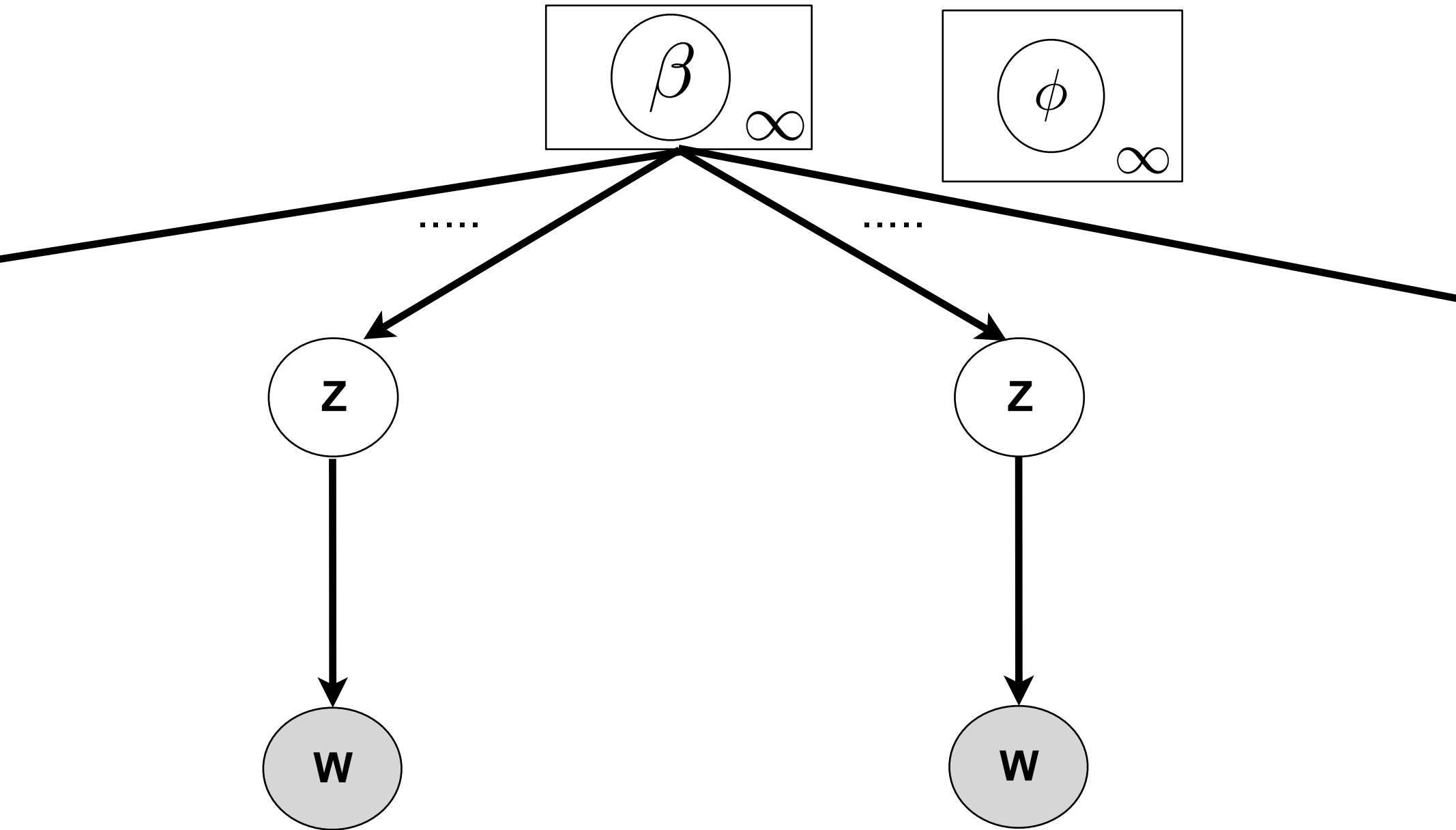
Enriching Mention Model



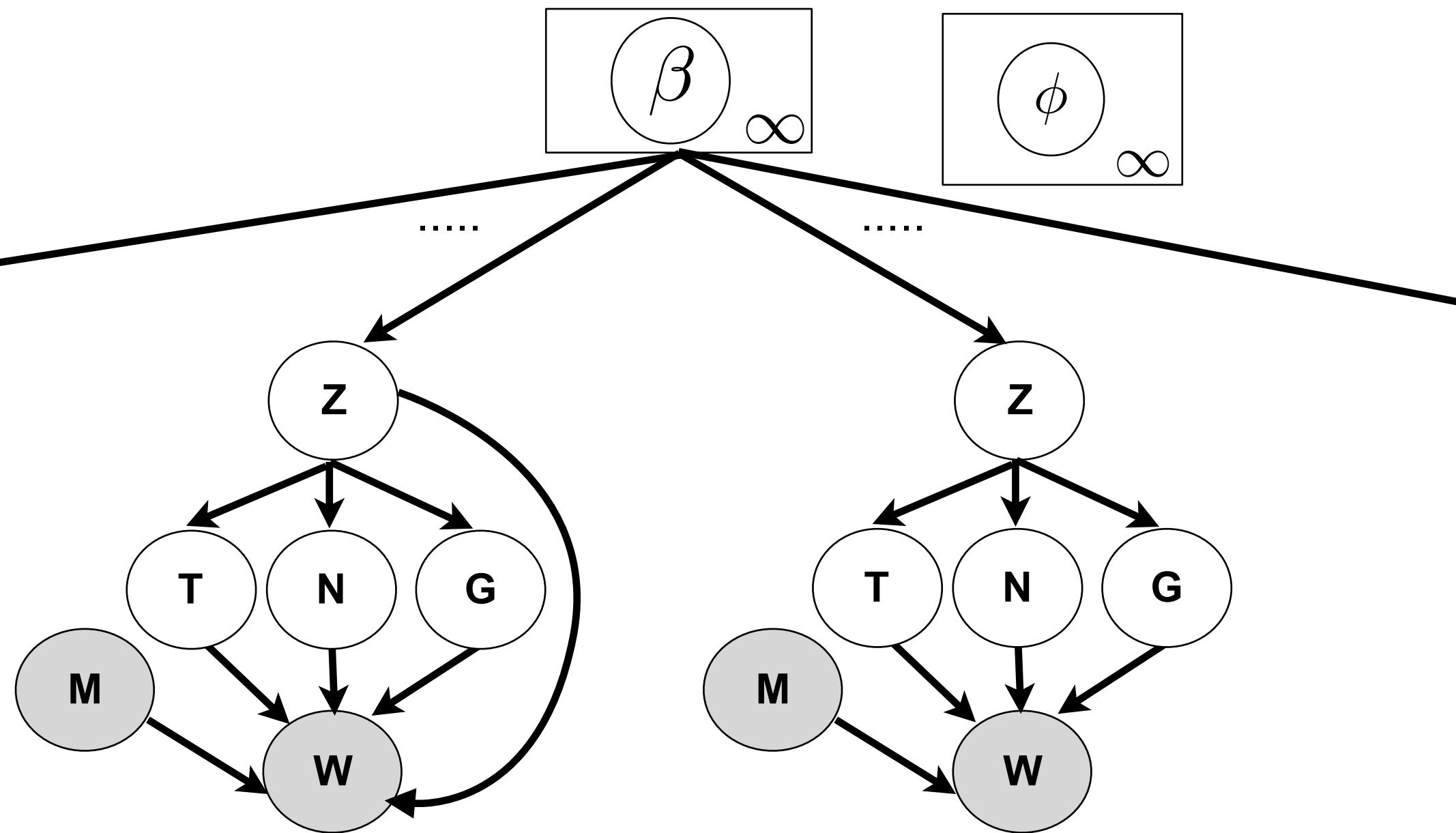
Enriching Mention Model



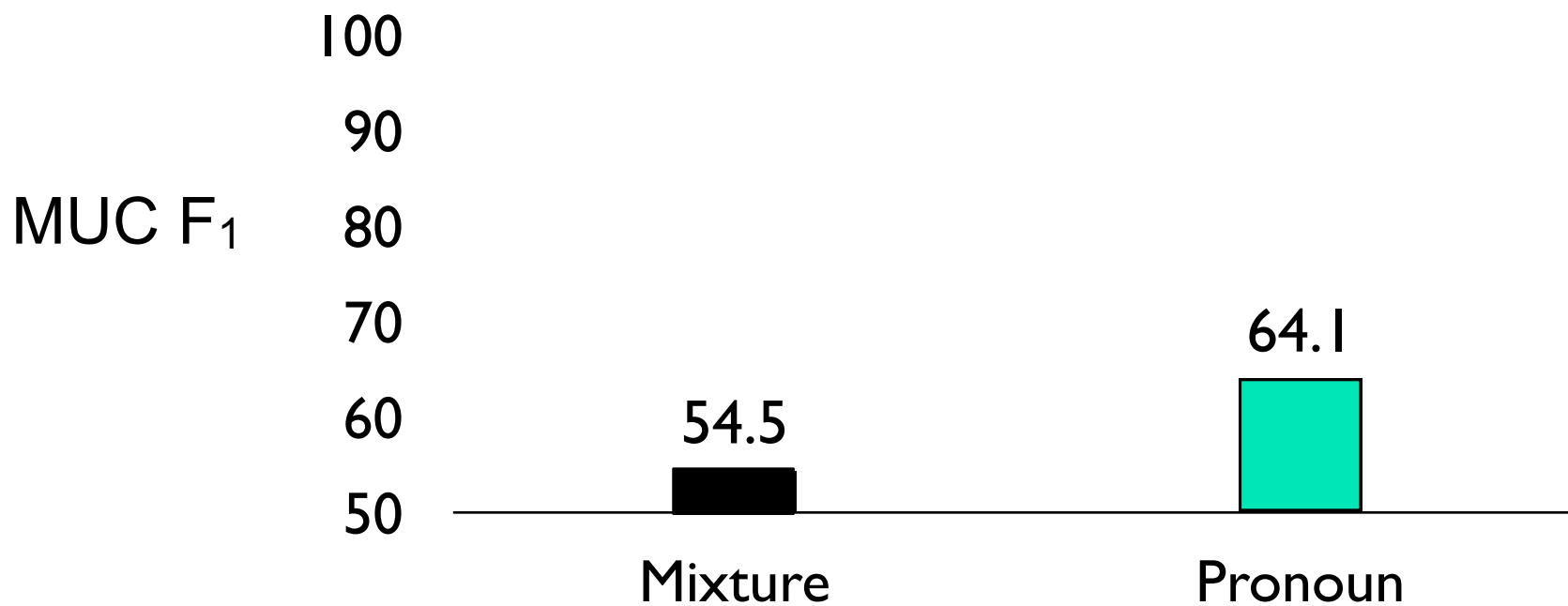
Enriching Mention Model



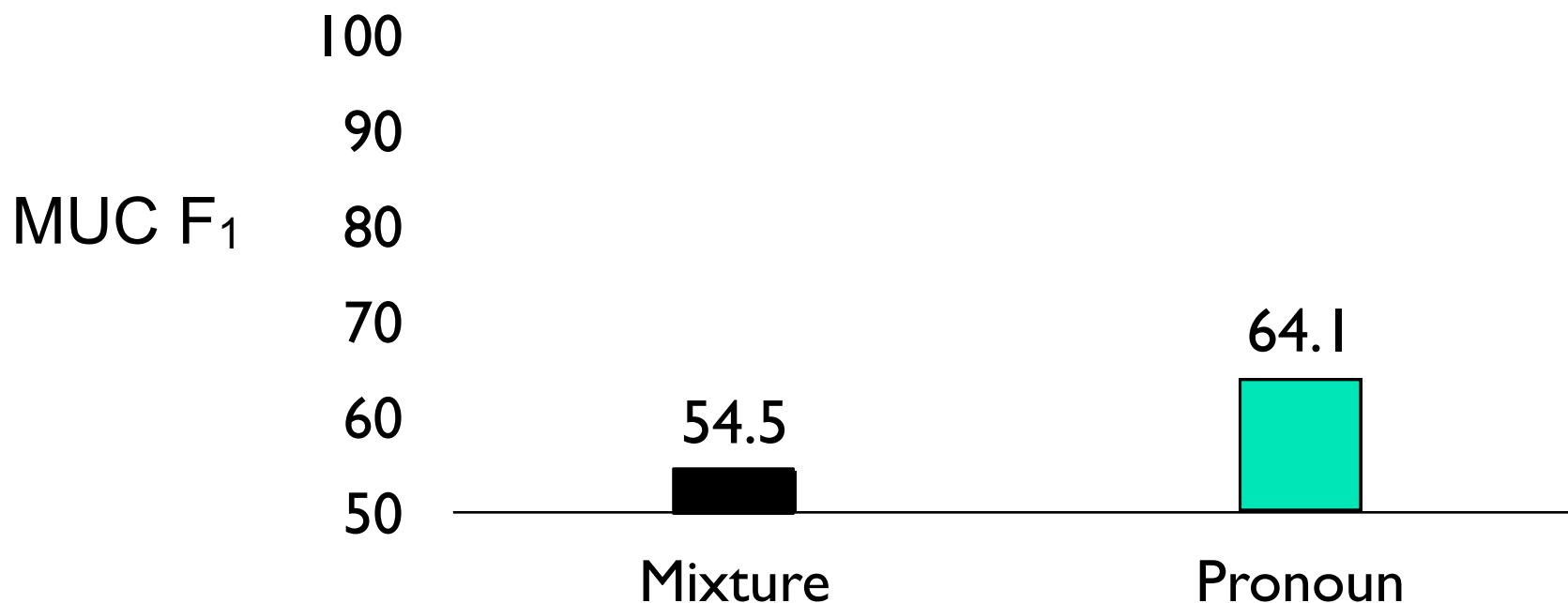
Enriching Mention Model



Pronoun Head Model

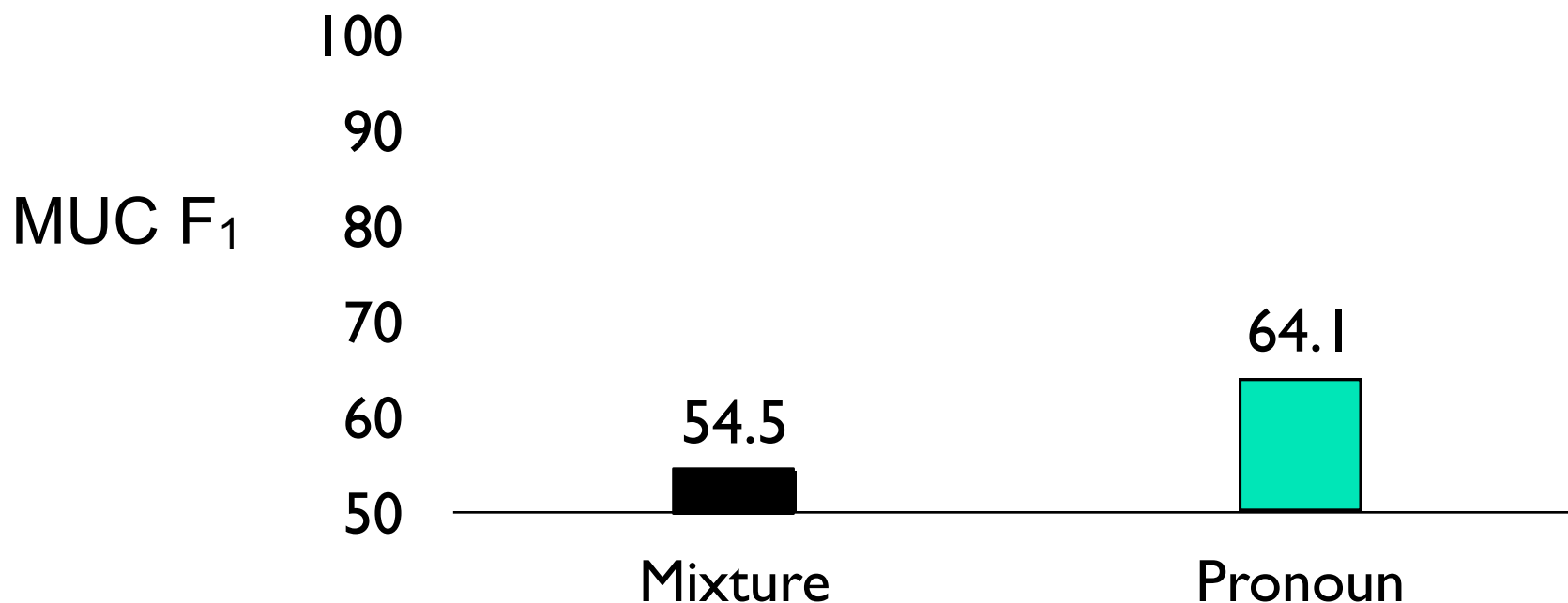


Pronoun Head Model



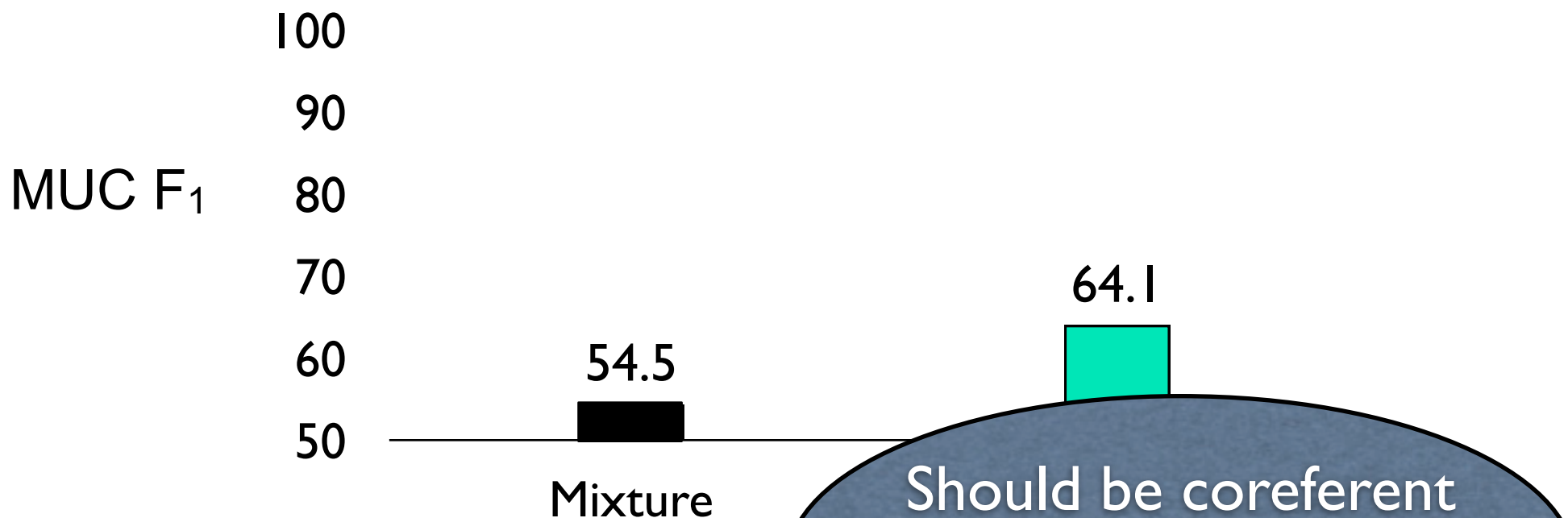
The **Weir Group**, whose headquarters is in the **U.S** is a large specialized corporation. This power plant, which, will be situated in **Jiangsu**, has a large generation capacity.

Pronoun Head Model



The **Weir Group** , whose headquarters is in the **U.S** is a large specialized corporation. This power plant , **which** , will be situated in **Jiangsu** , has a large generation capacity.

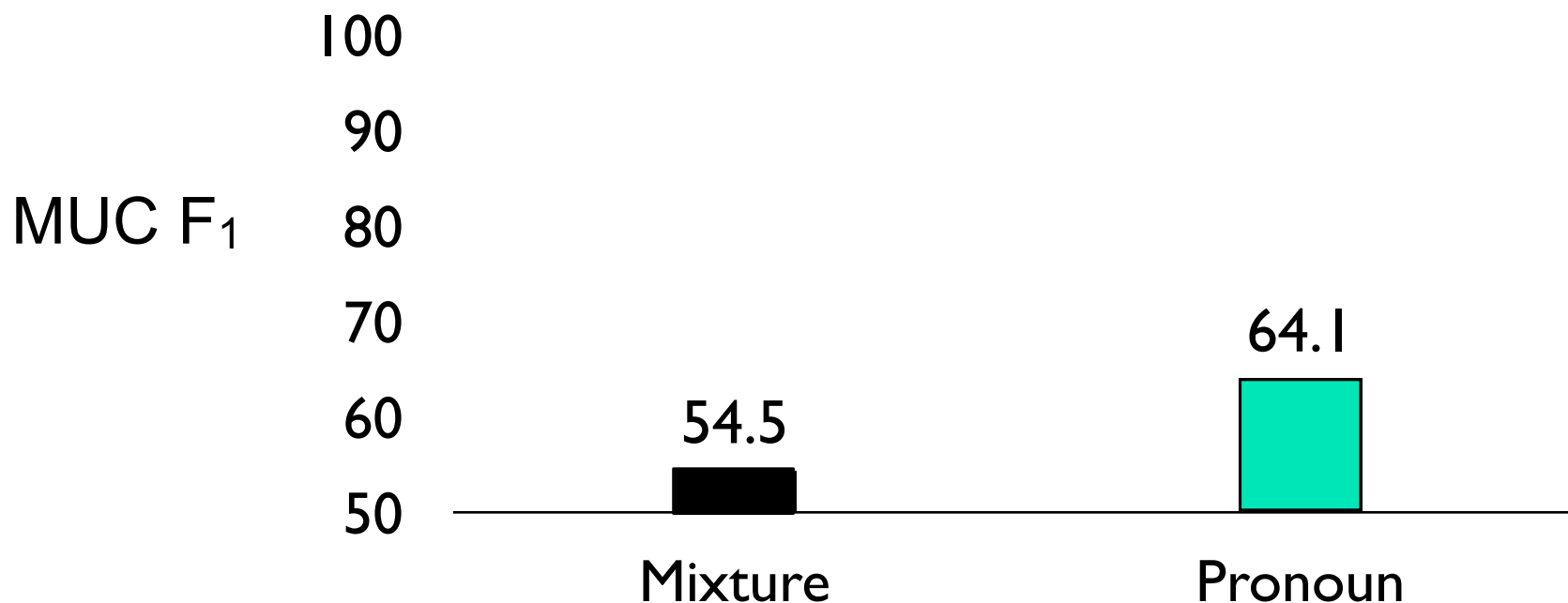
Pronoun Head Model



Should be coreferent with recent "power plant" entity.

The **Weir Group**, whose **U.S** is a large specialized **power plant**.
 This **power plant**, **which**, will be situated in **Jiangsu**, has a large generation capacity.

Pronoun Head Model



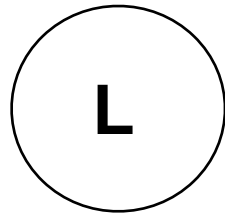
The **Weir Group**, whose headquarters is in the **U.S** is a large specialized corporation. This power plant, **which**, will be situated in **Jiangsu**, has a large generation capacity.



Saliency Model

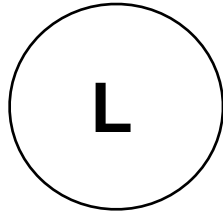


Saliency Model



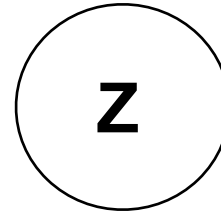
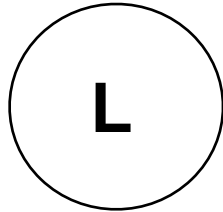
Saliency Model

Entity	Activation
1	1.0
2	0.0



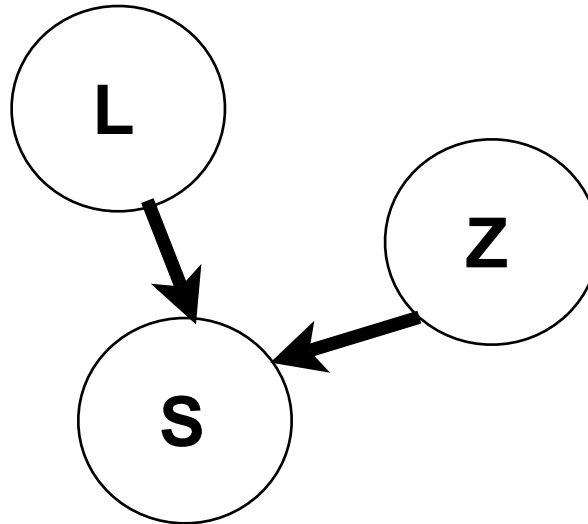
Saliency Model

Entity	Activation
1	1.0
2	0.0



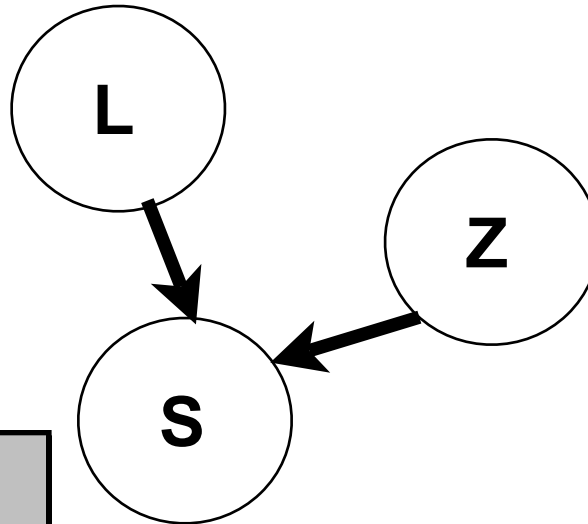
Saliency Model

Entity	Activation
1	1.0
2	0.0



Saliency Model

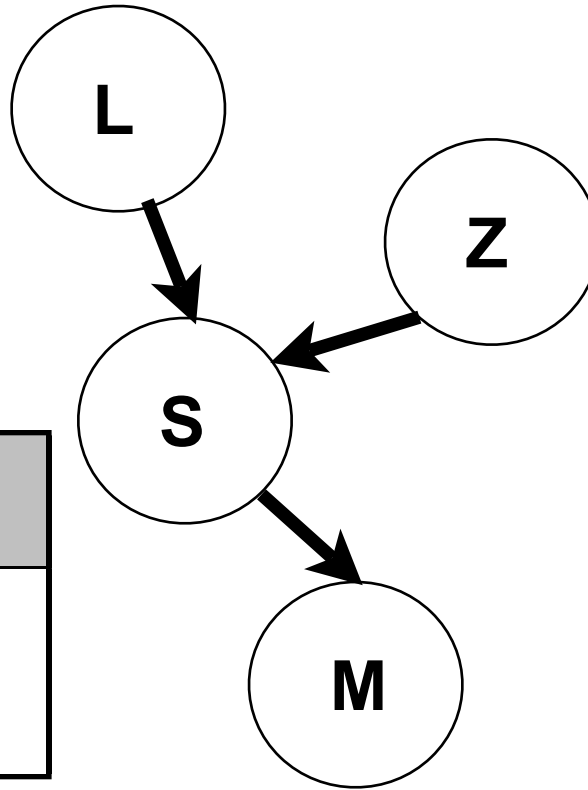
Entity	Activation
1	1.0
2	0.0



Saliency Values
TOP, HIGH, MED, LOW, NONE

Saliency Model

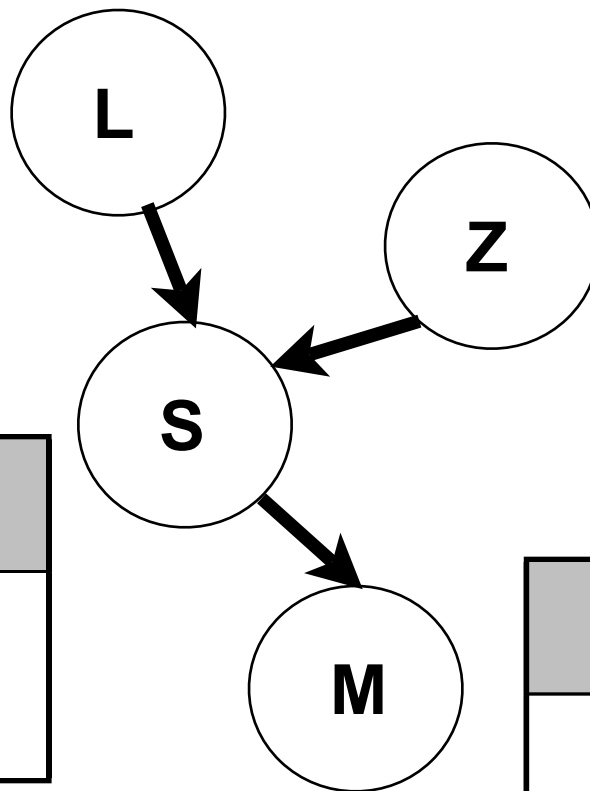
Entity	Activation
1	1.0
2	0.0



Saliency Values
TOP, HIGH, MED, LOW, NONE

Saliience Model

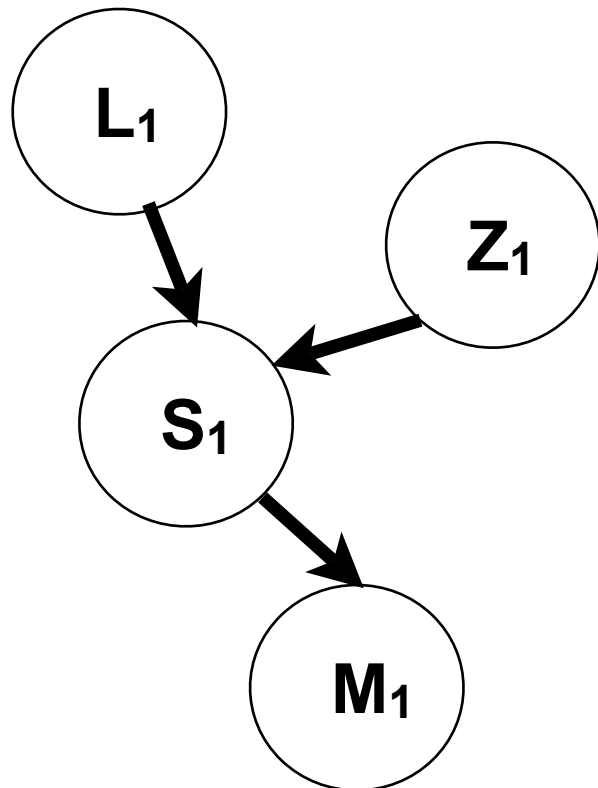
Entity	Activation
1	1.0
2	0.0



Saliience Values
TOP, HIGH, MED, LOW, NONE

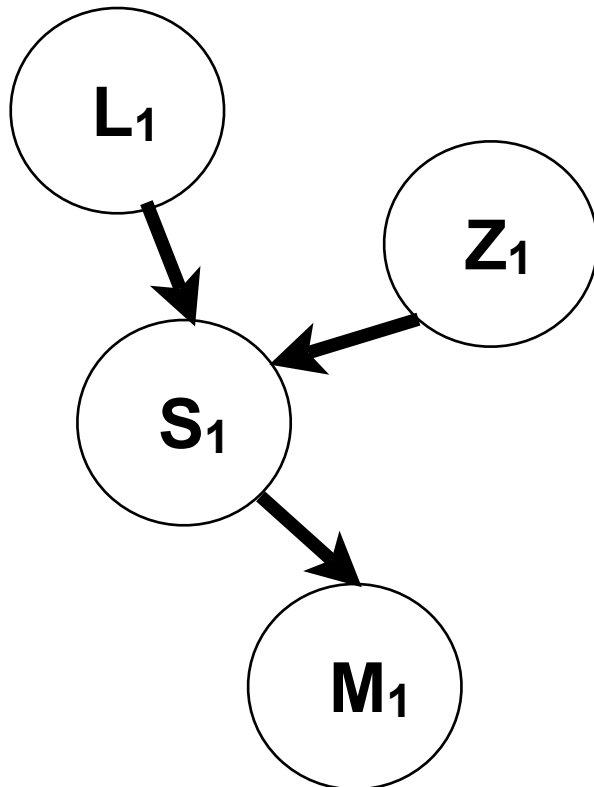
Mention Type
Proper, Pronoun, Nominal

Saliency Model



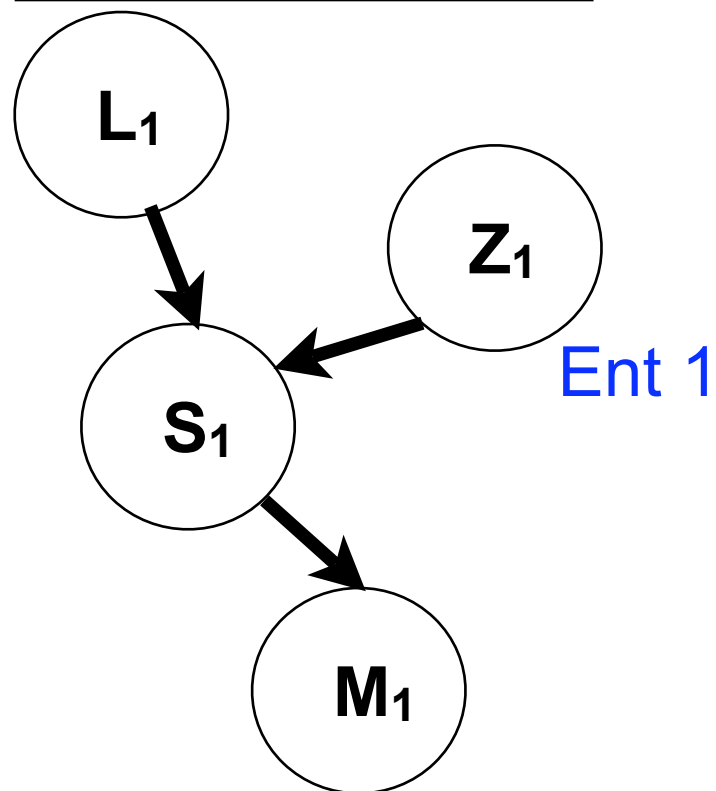
Saliency Model

Entity	Activation
1	0.0
2	0.0



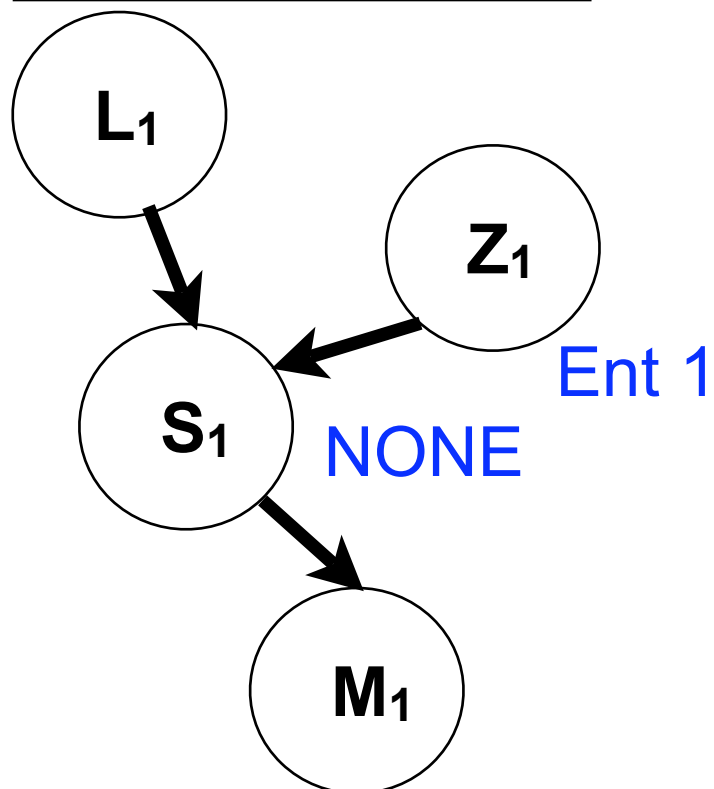
Saliency Model

Entity	Activation
1	0.0
2	0.0



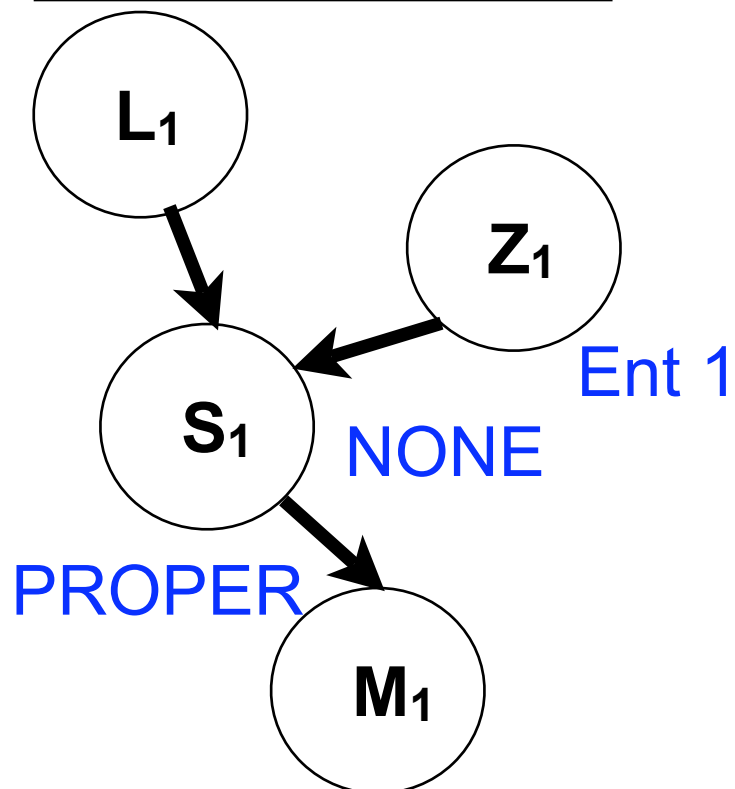
Saliency Model

Entity	Activation
1	0.0
2	0.0



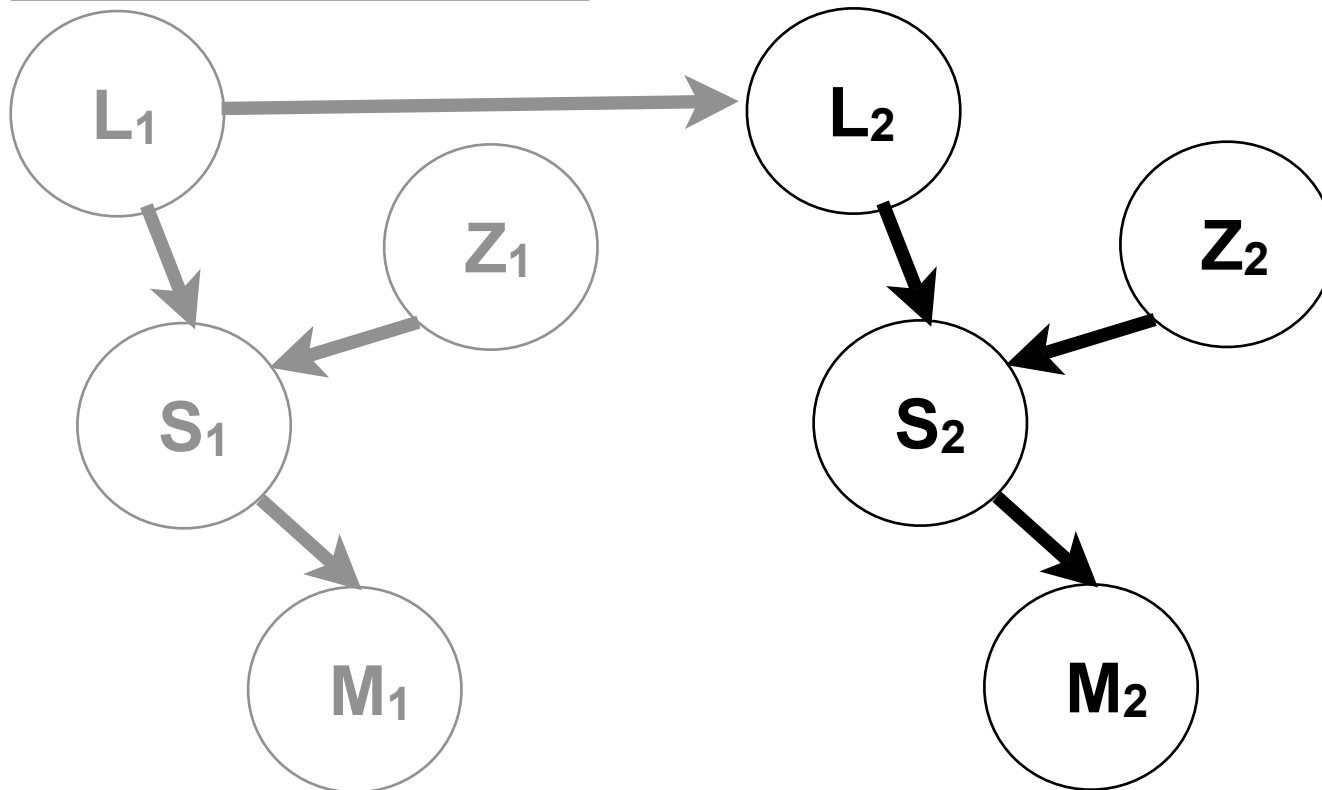
Saliency Model

Entity	Activation
1	0.0
2	0.0



Saliency Model

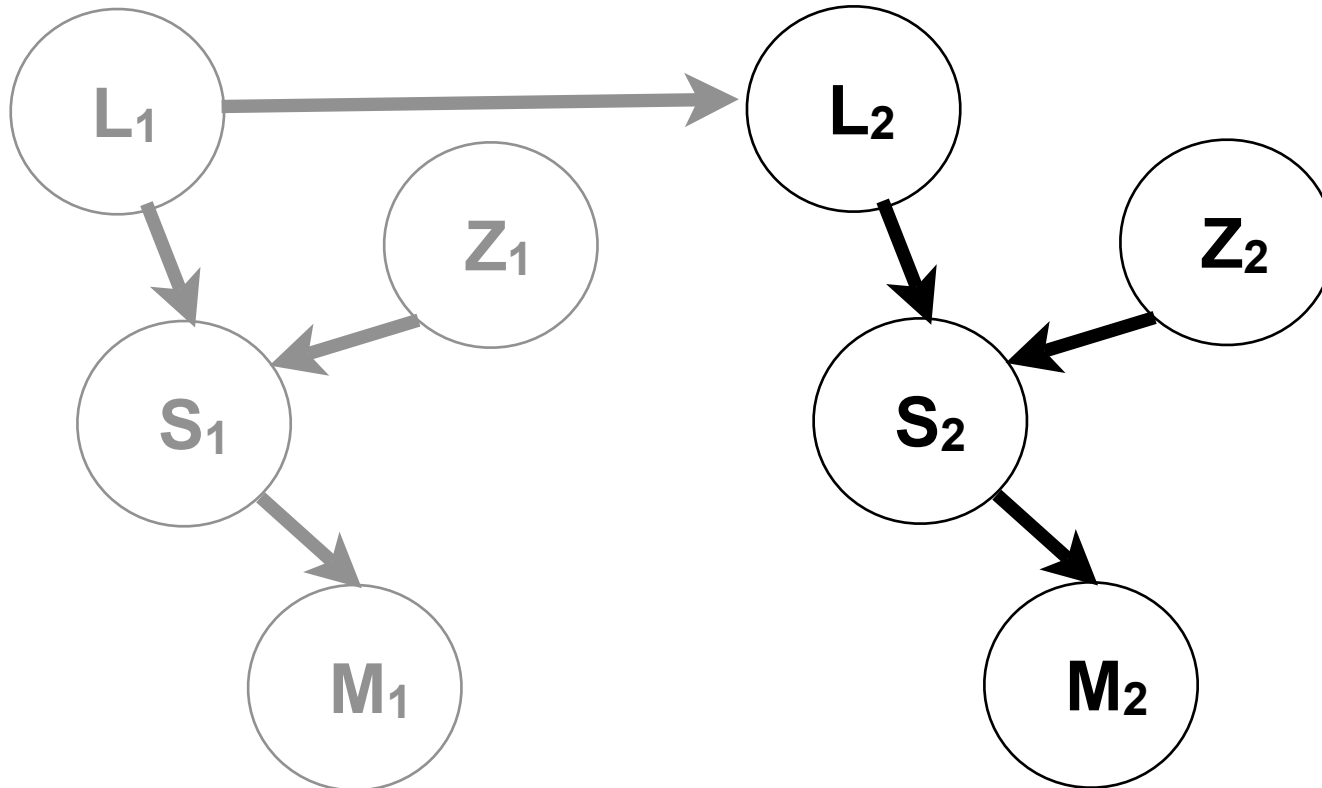
Entity	Activation
1	0.0
2	0.0



Saliency Model

Entity	Activation
1	0.0
2	0.0

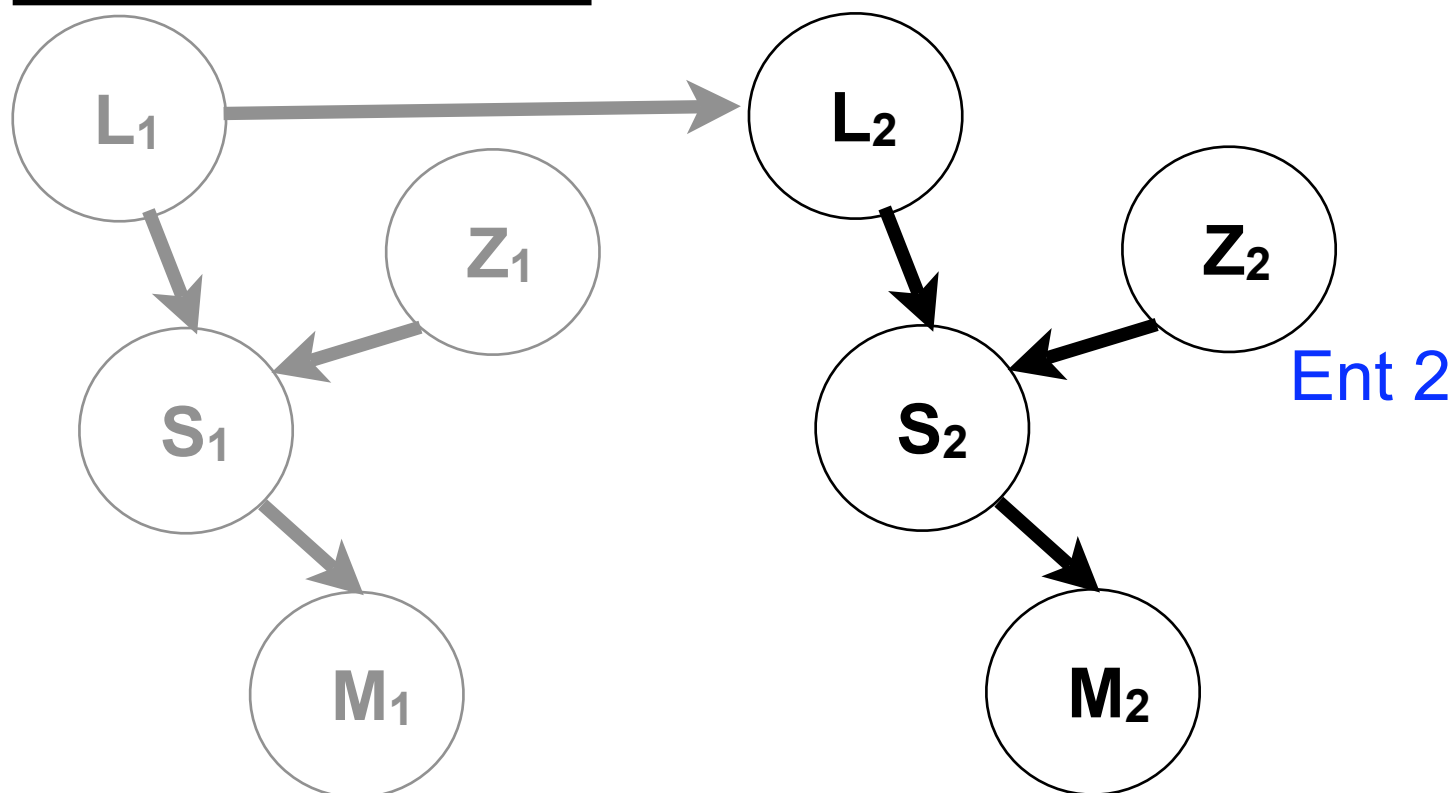
Entity	Activation
1	1.0
2	0.0



Saliency Model

Entity	Activation
1	0.0
2	0.0

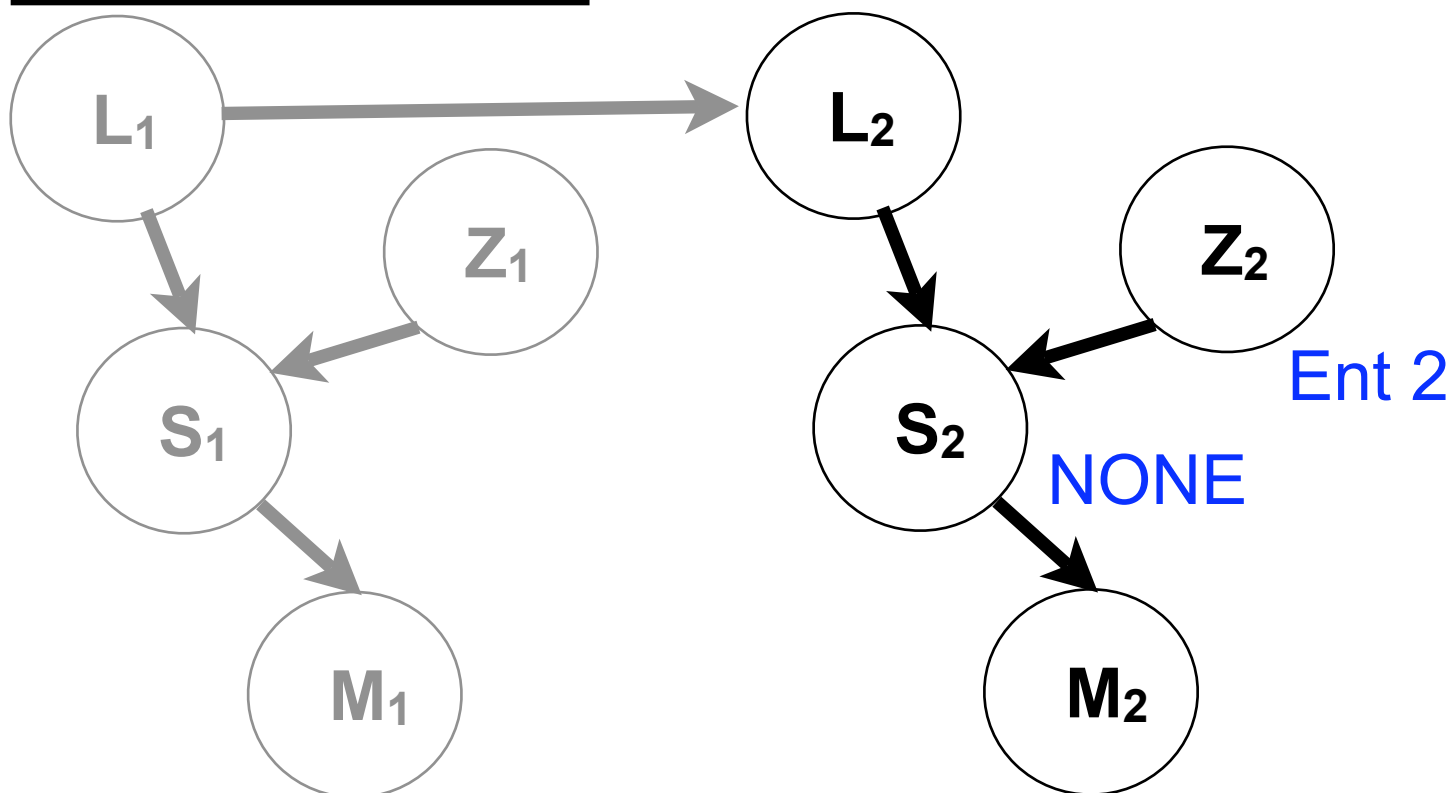
Entity	Activation
1	1.0
2	0.0



Saliency Model

Entity	Activation
1	0.0
2	0.0

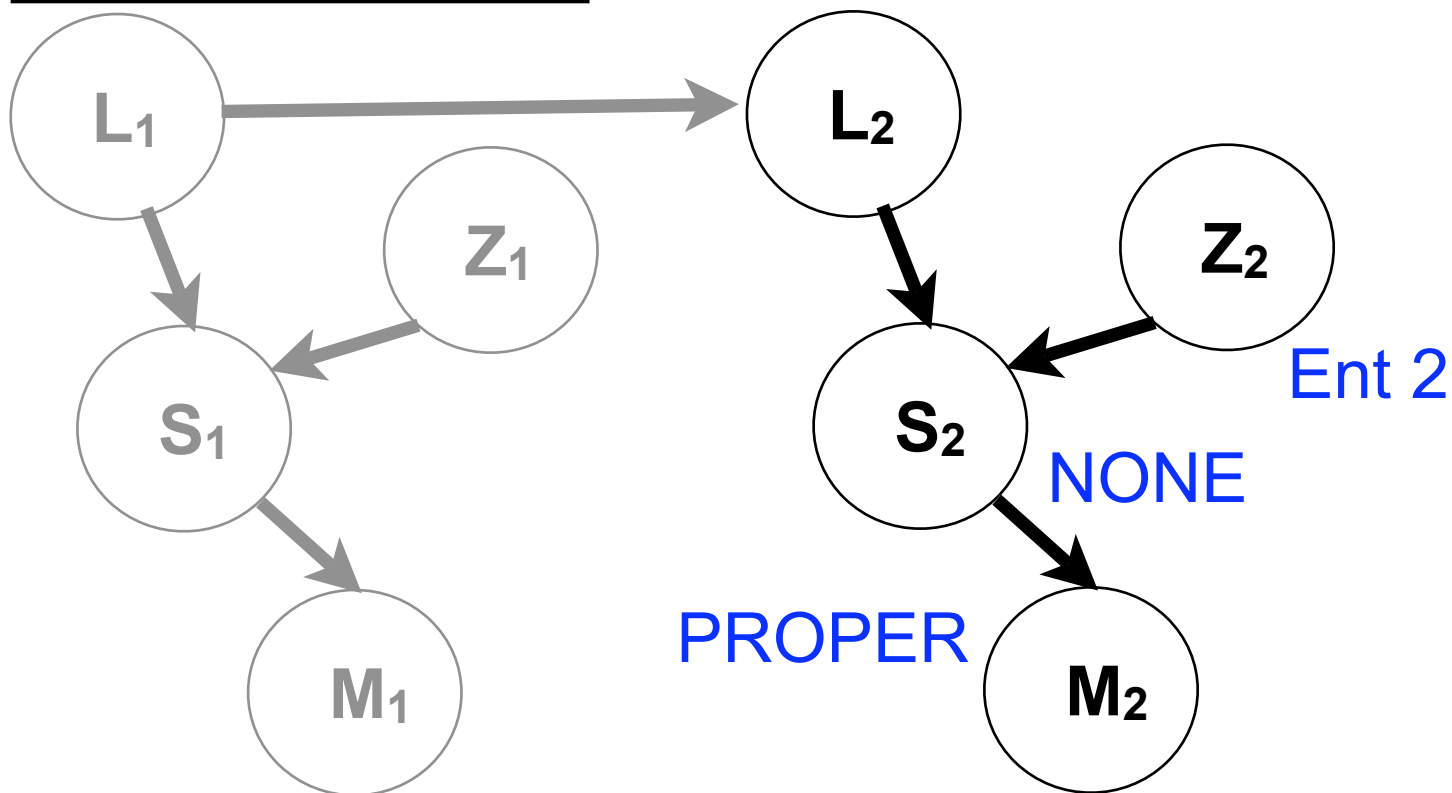
Entity	Activation
1	1.0
2	0.0



Saliency Model

Entity	Activation
1	0.0
2	0.0

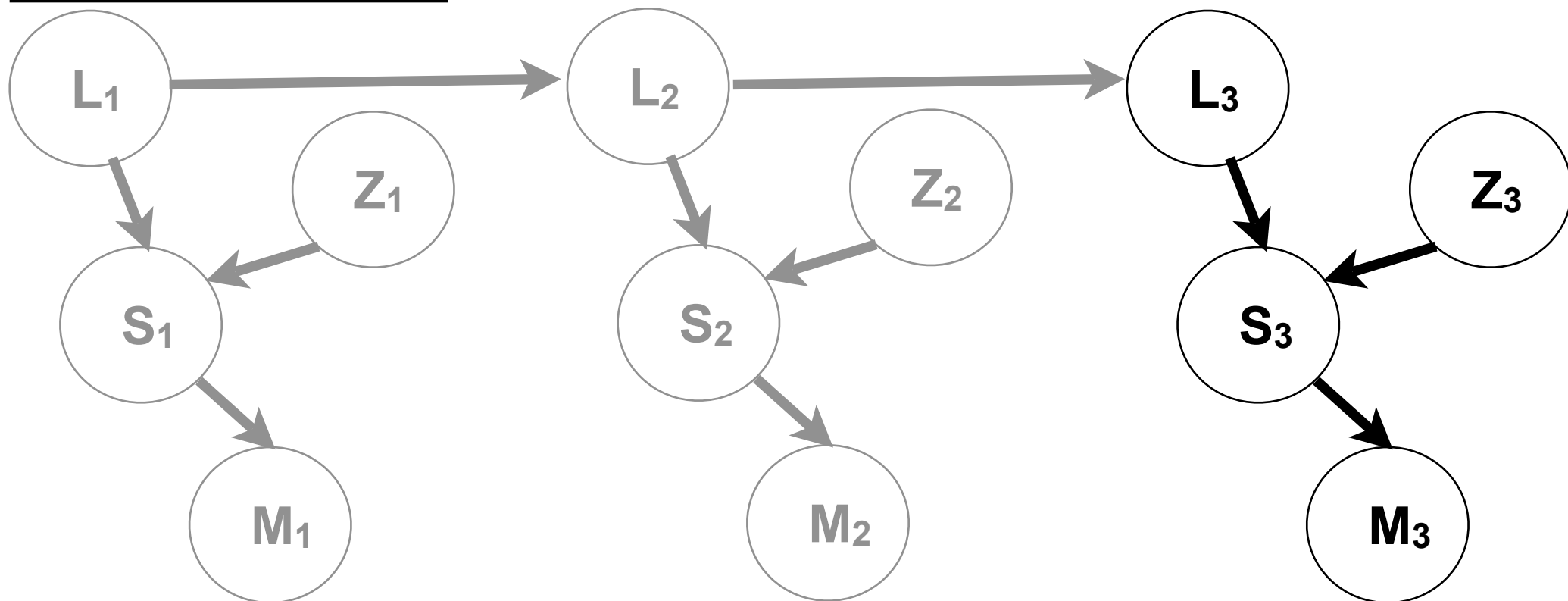
Entity	Activation
1	1.0
2	0.0



Saliency Model

Entity	Activation
1	0.0
2	0.0

Entity	Activation
1	1.0
2	0.0

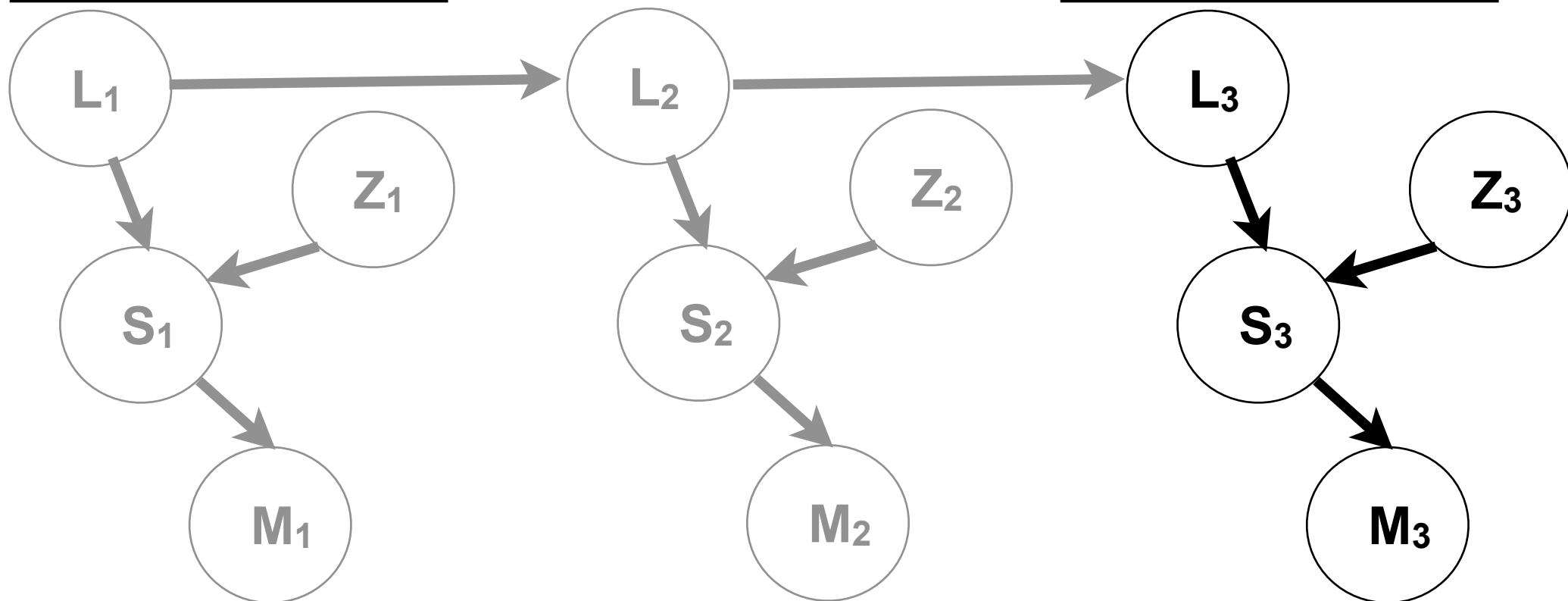


Saliency Model

Entity	Activation
1	0.0
2	0.0

Entity	Activation
1	1.0
2	0.0

Entity	Activation
1	0.5
2	1.0

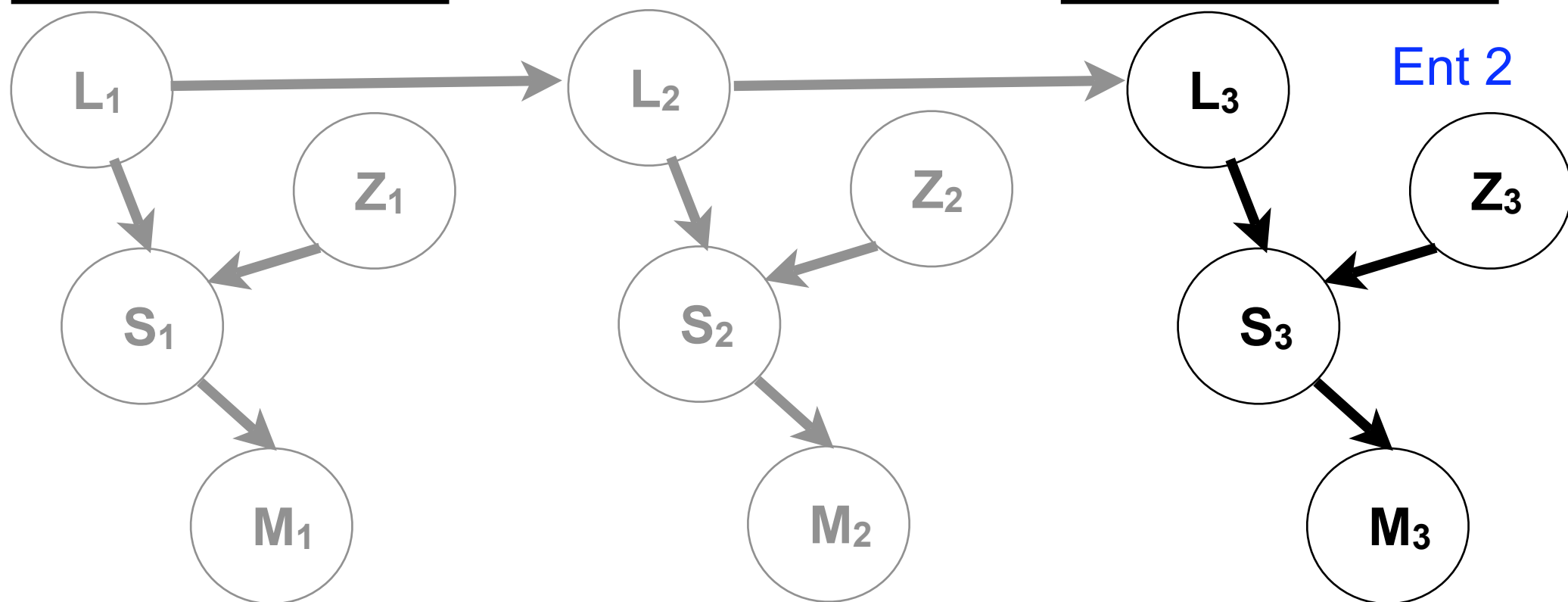


Saliency Model

Entity	Activation
1	0.0
2	0.0

Entity	Activation
1	1.0
2	0.0

Entity	Activation
1	0.5
2	1.0

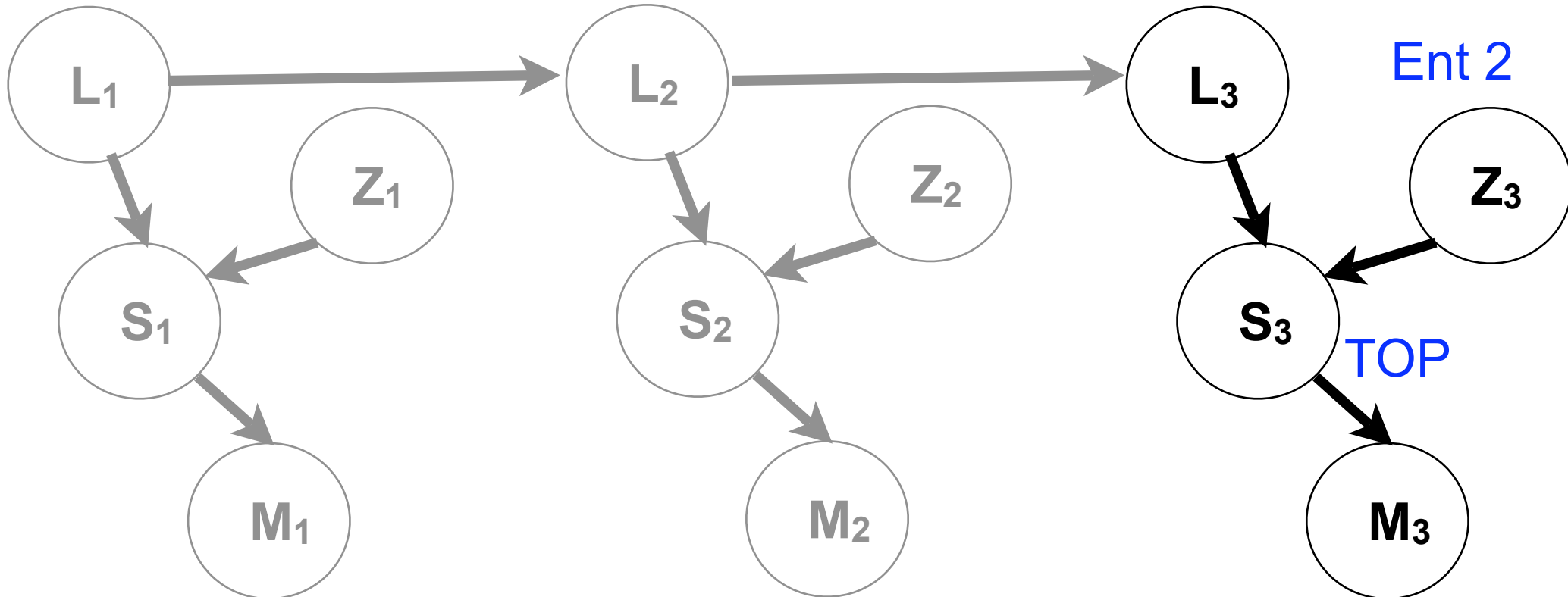


Saliency Model

Entity	Activation
1	0.0
2	0.0

Entity	Activation
1	1.0
2	0.0

Entity	Activation
1	0.5
2	1.0

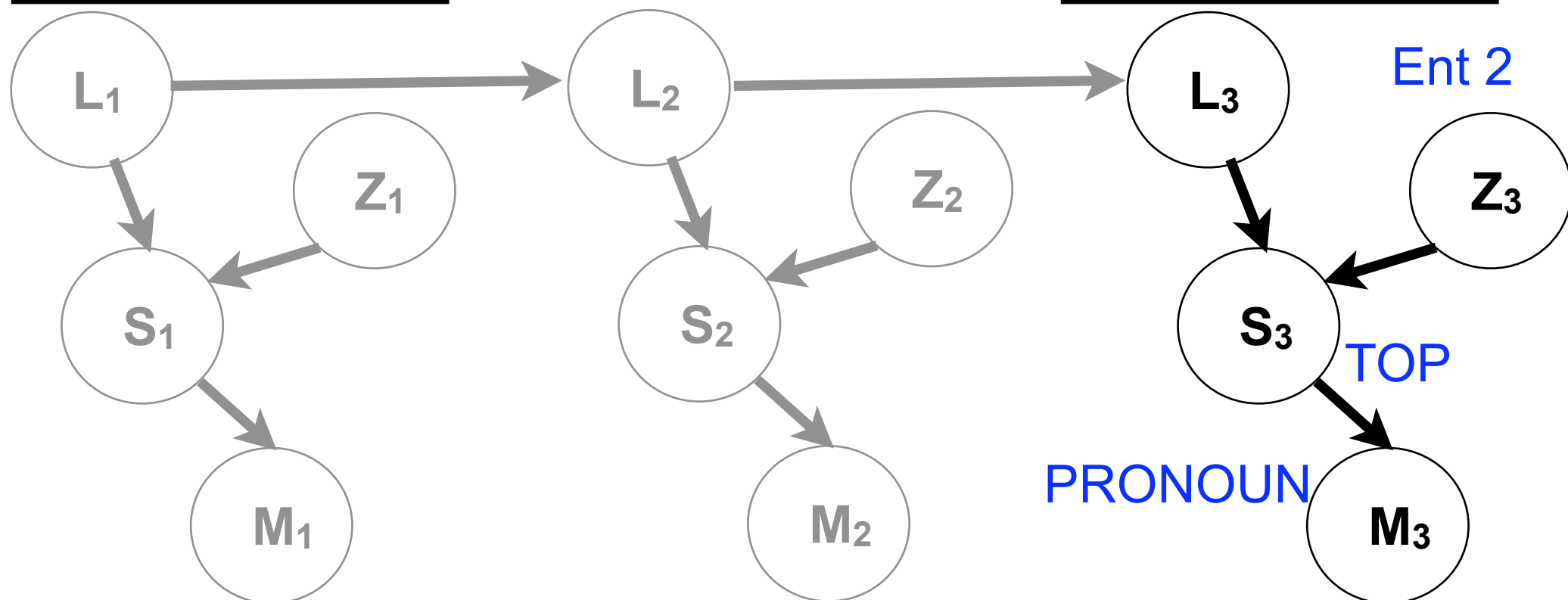


Saliency Model

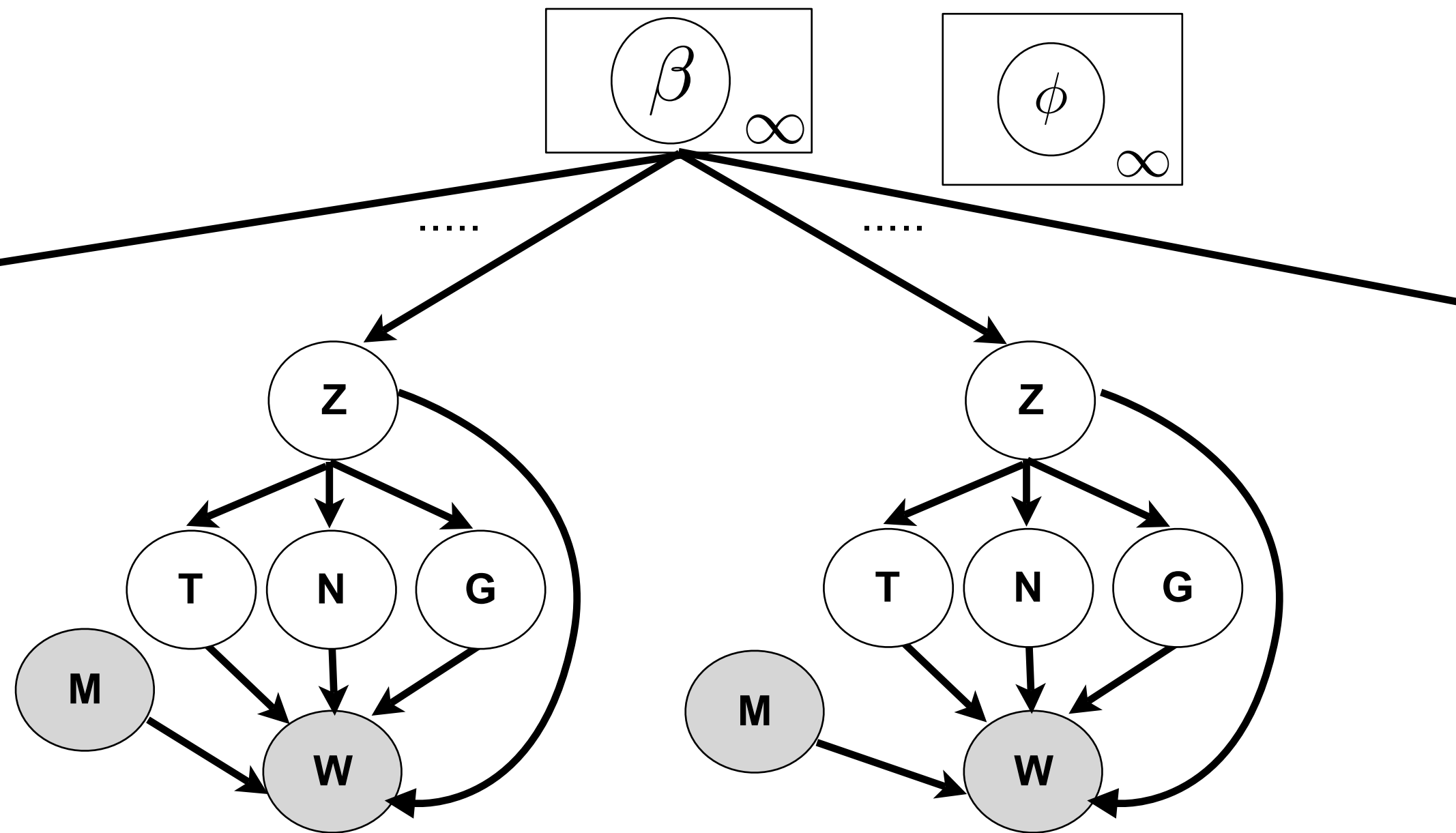
Entity	Activation
1	0.0
2	0.0

Entity	Activation
1	1.0
2	0.0

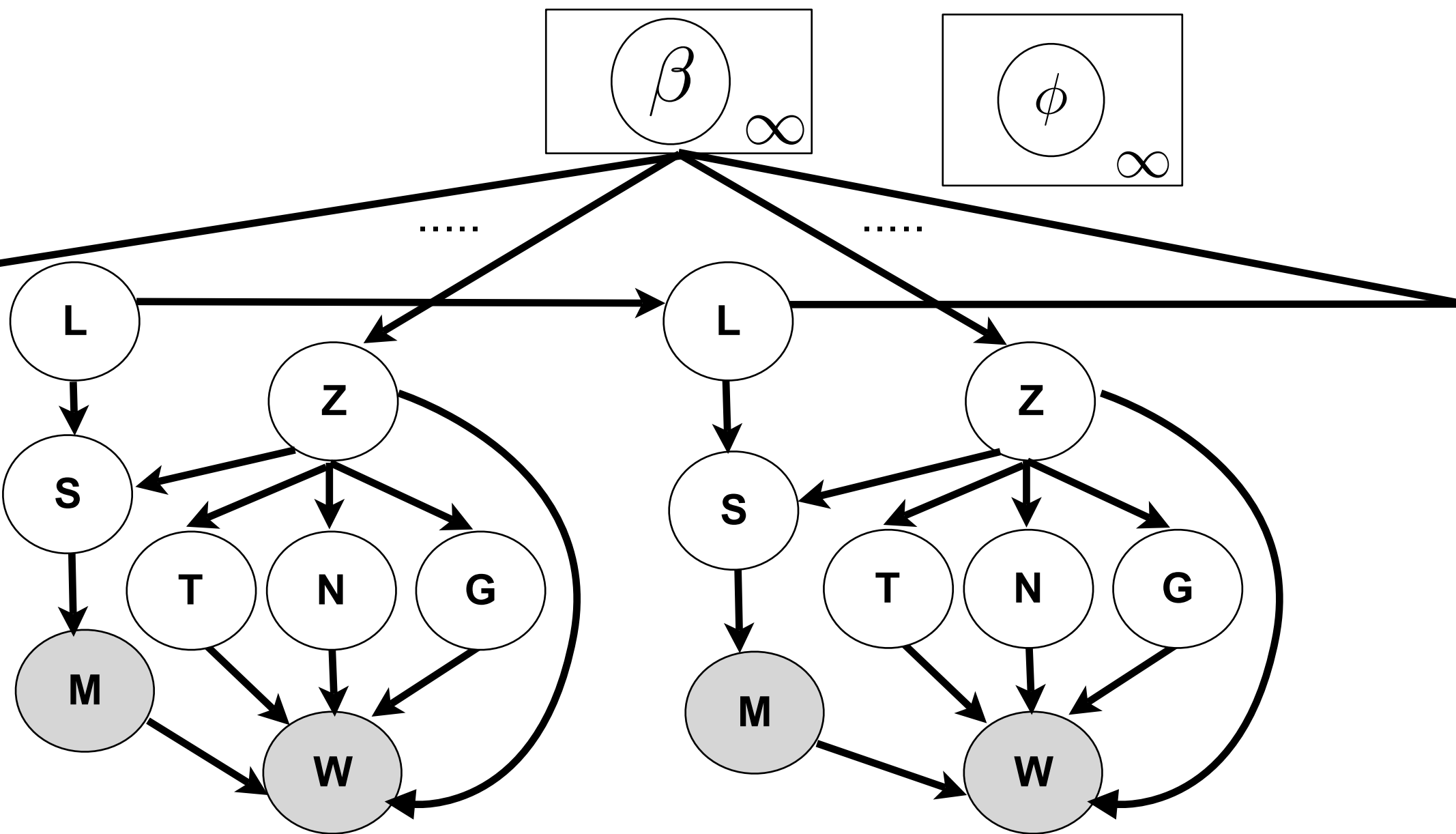
Entity	Activation
1	0.5
2	1.0



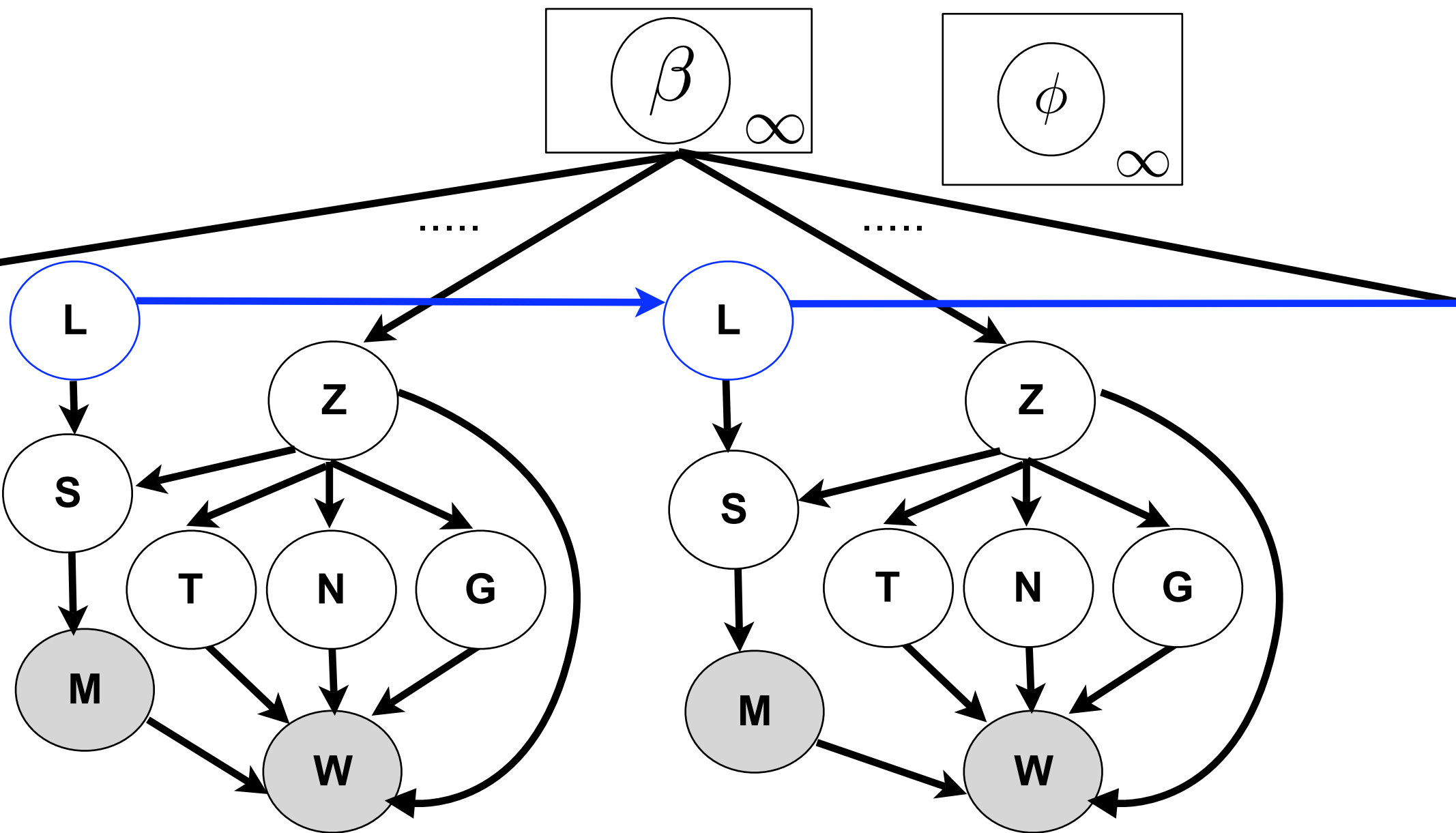
Enriching Mention Model



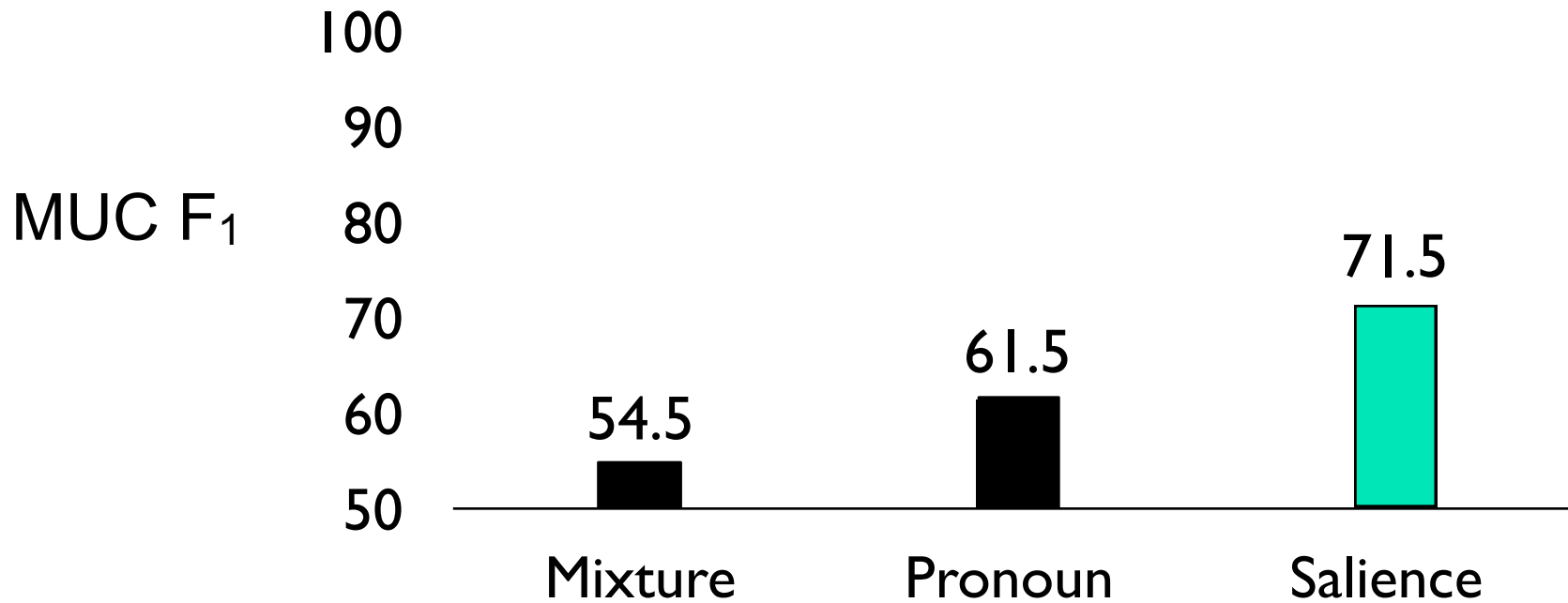
Enriching Mention Model



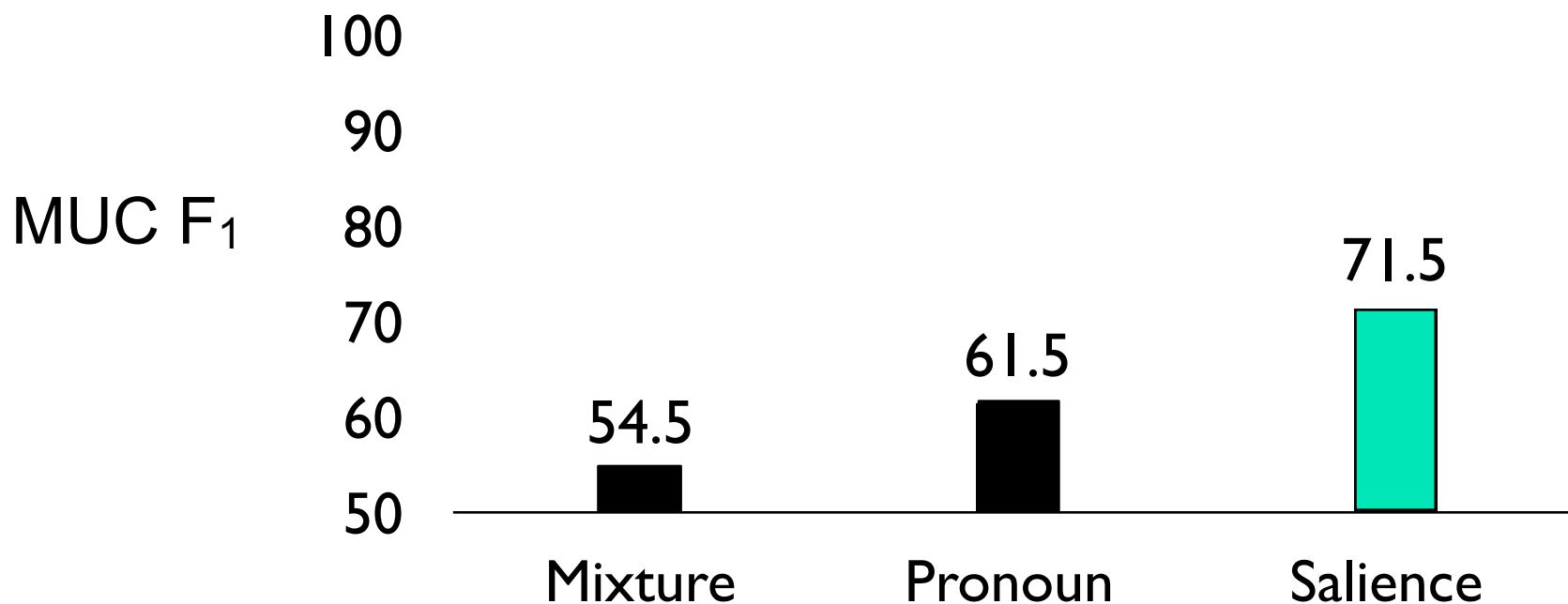
Enriching Mention Model



Saliency Model

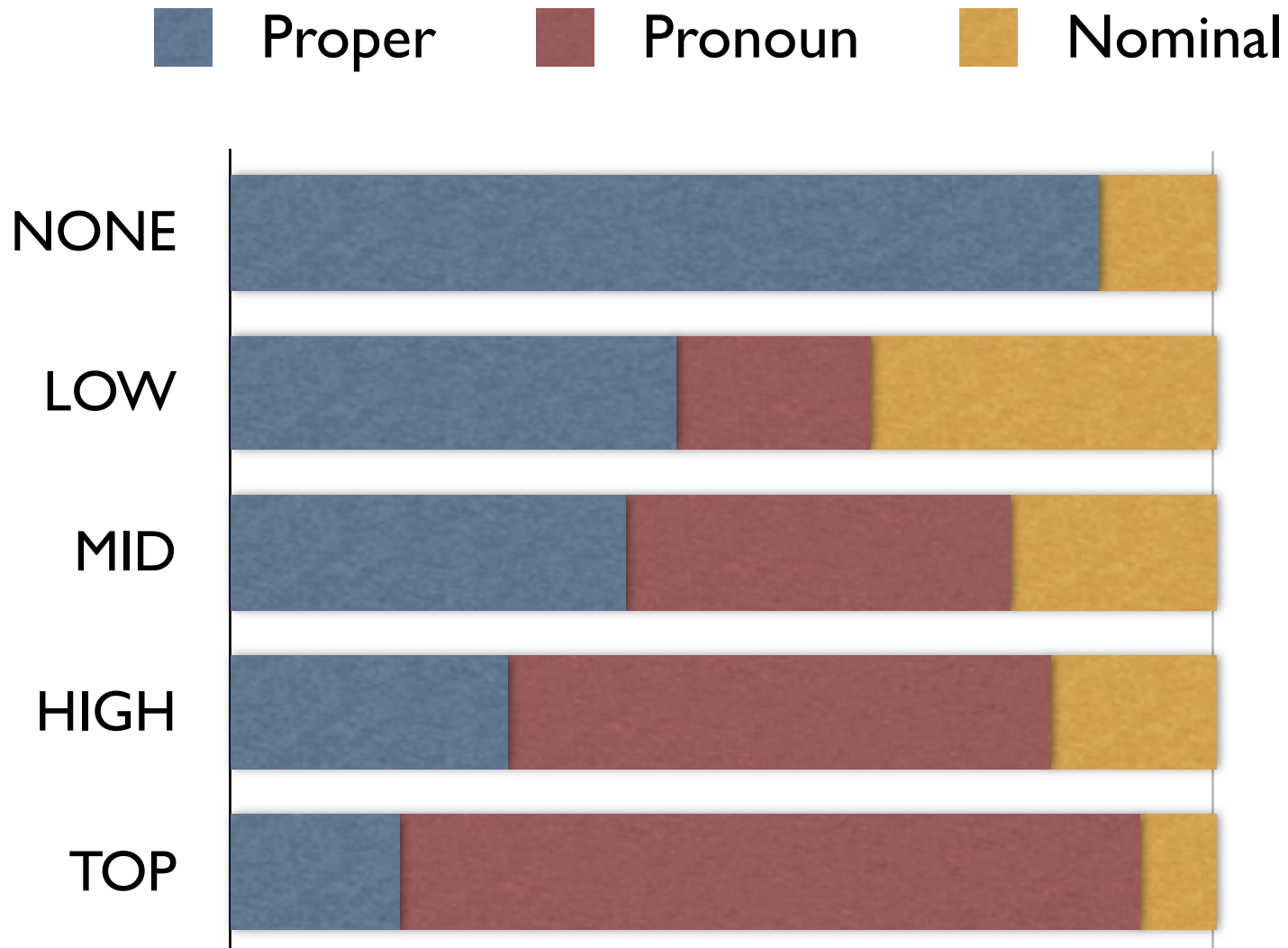


Salience Model

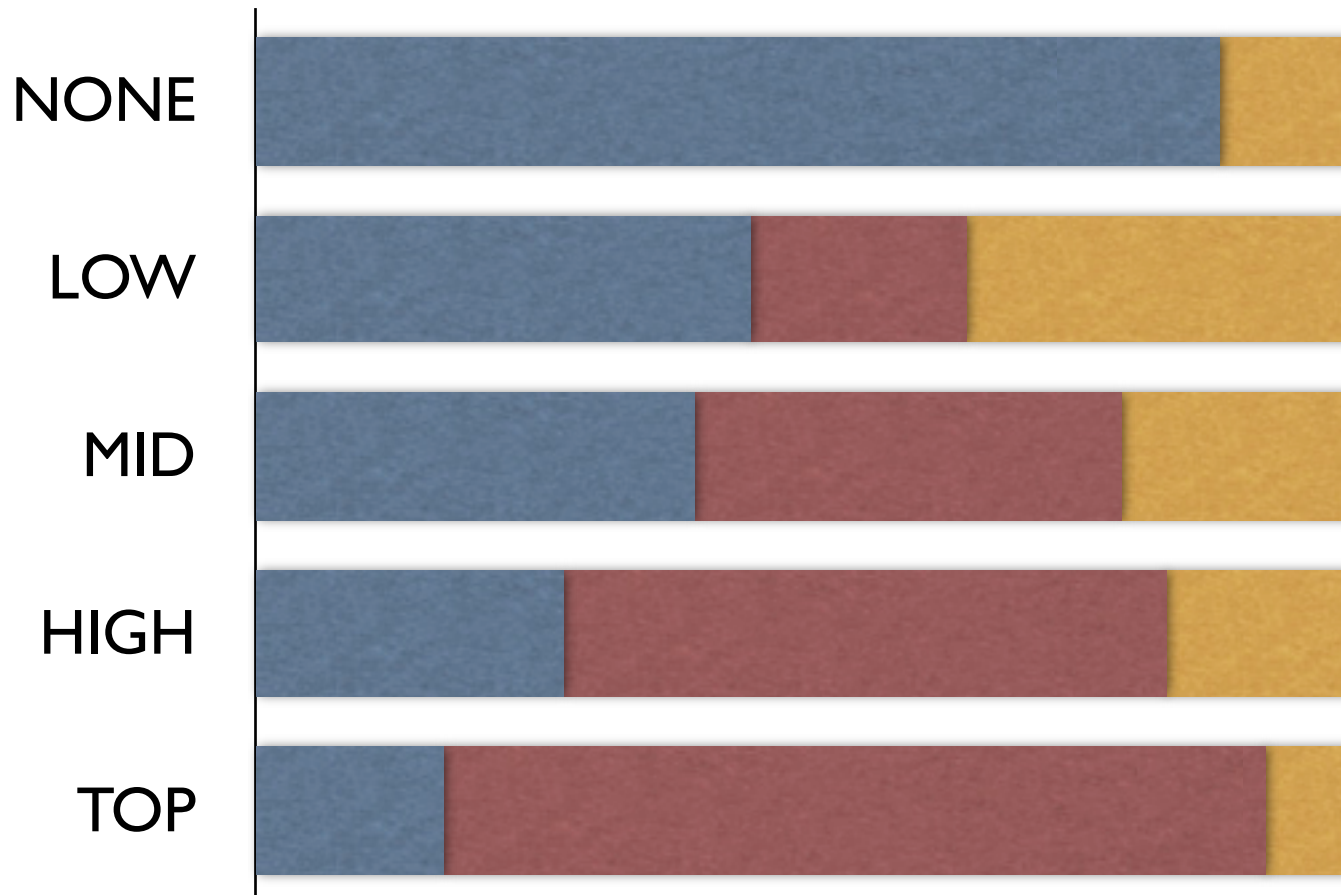


The **Weir Group**, whose headquarters is in the **U.S** is a large specialized corporation. This power plant, which, will be situated in **Jiangsu**, has a large generation capacity.

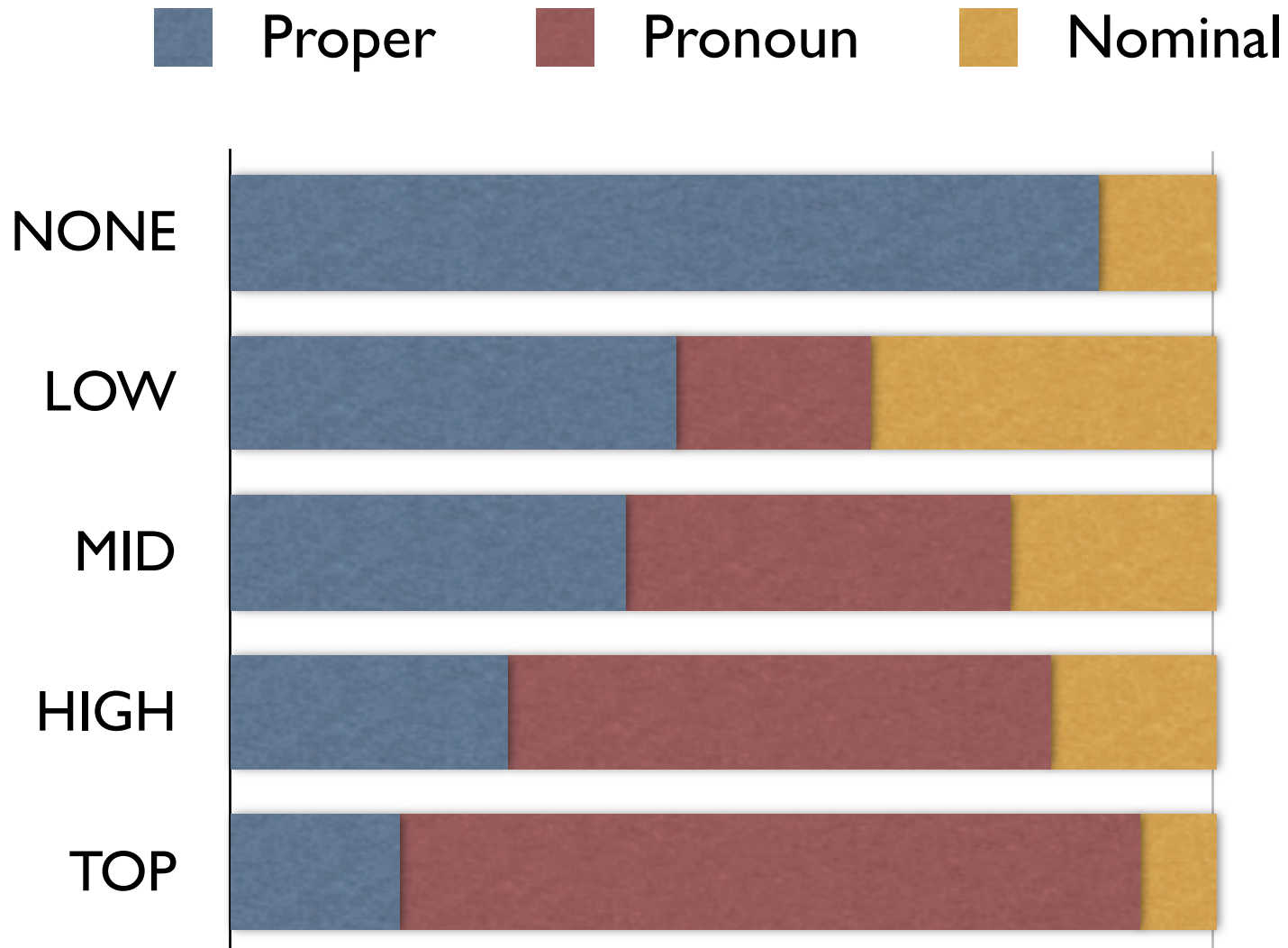
Saliency Model



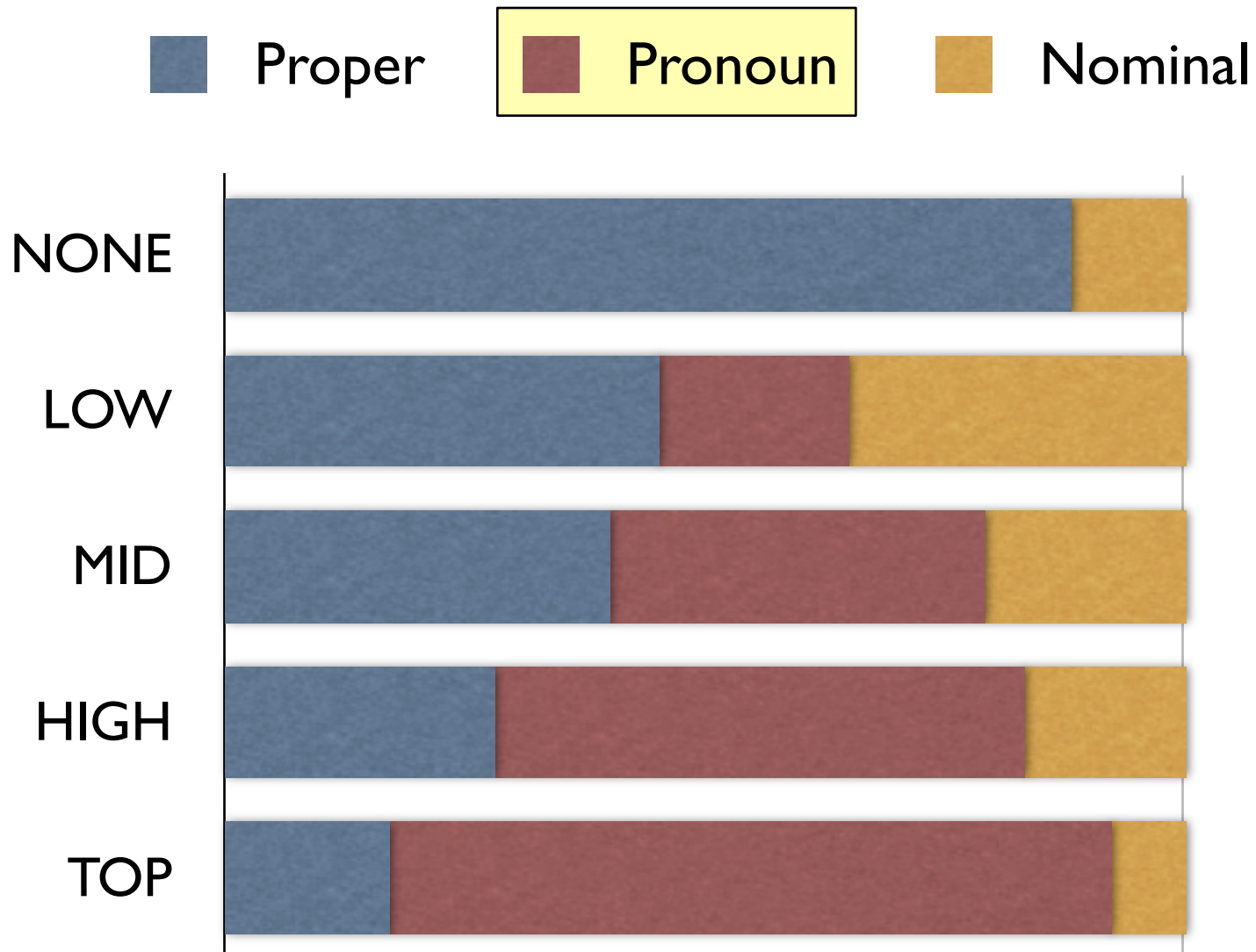
Saliency Model



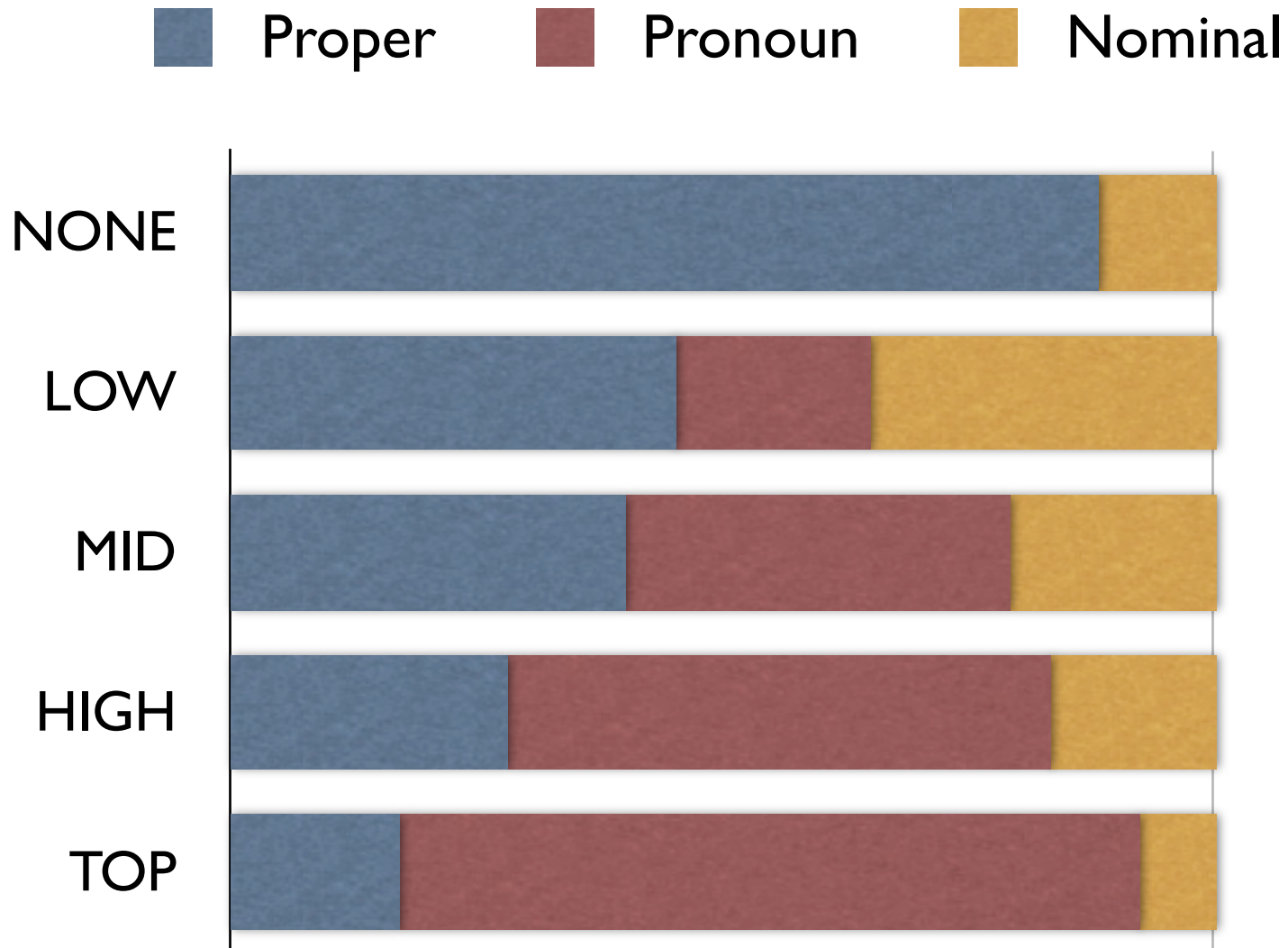
Saliency Model



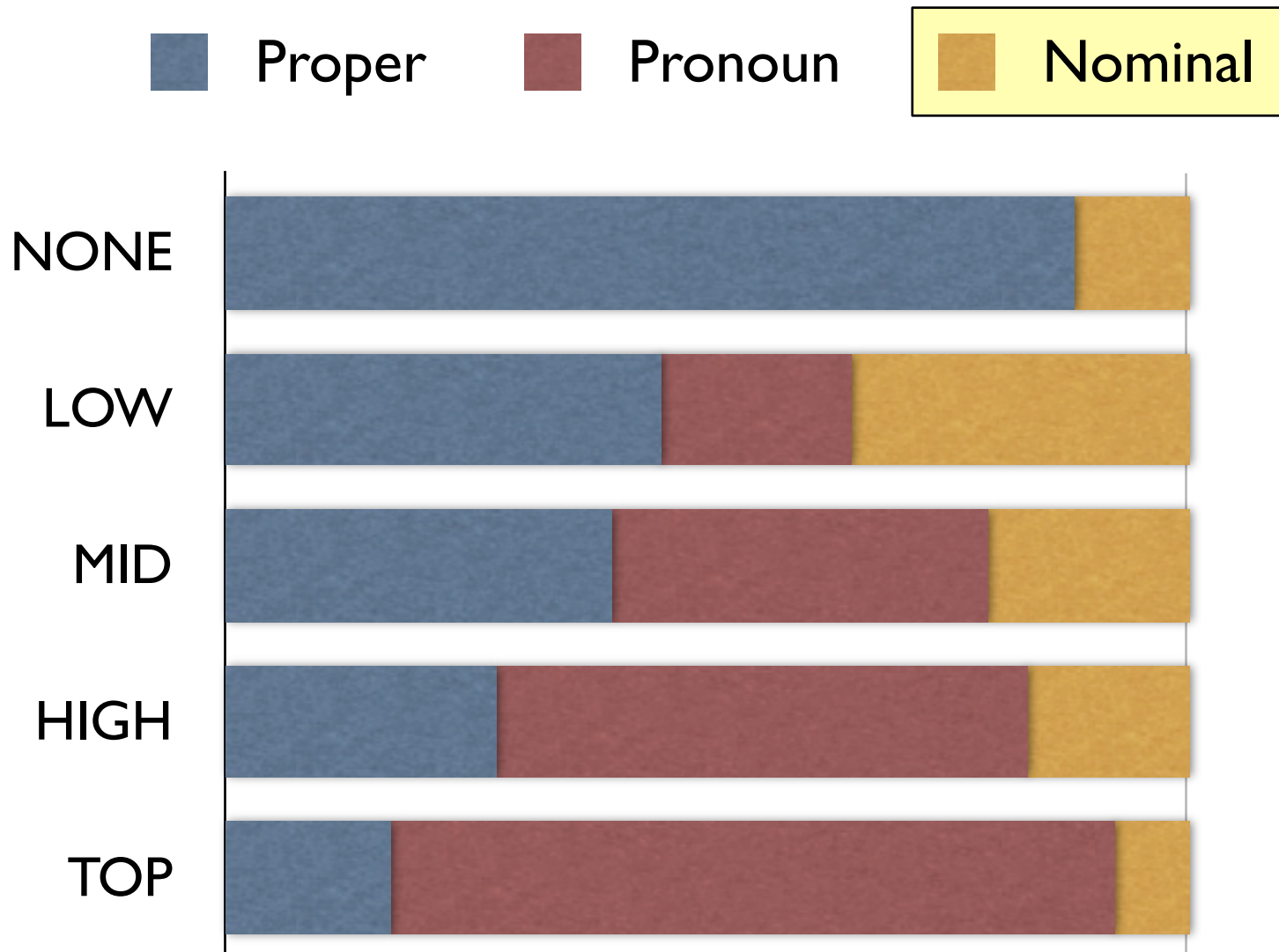
Saliency Model



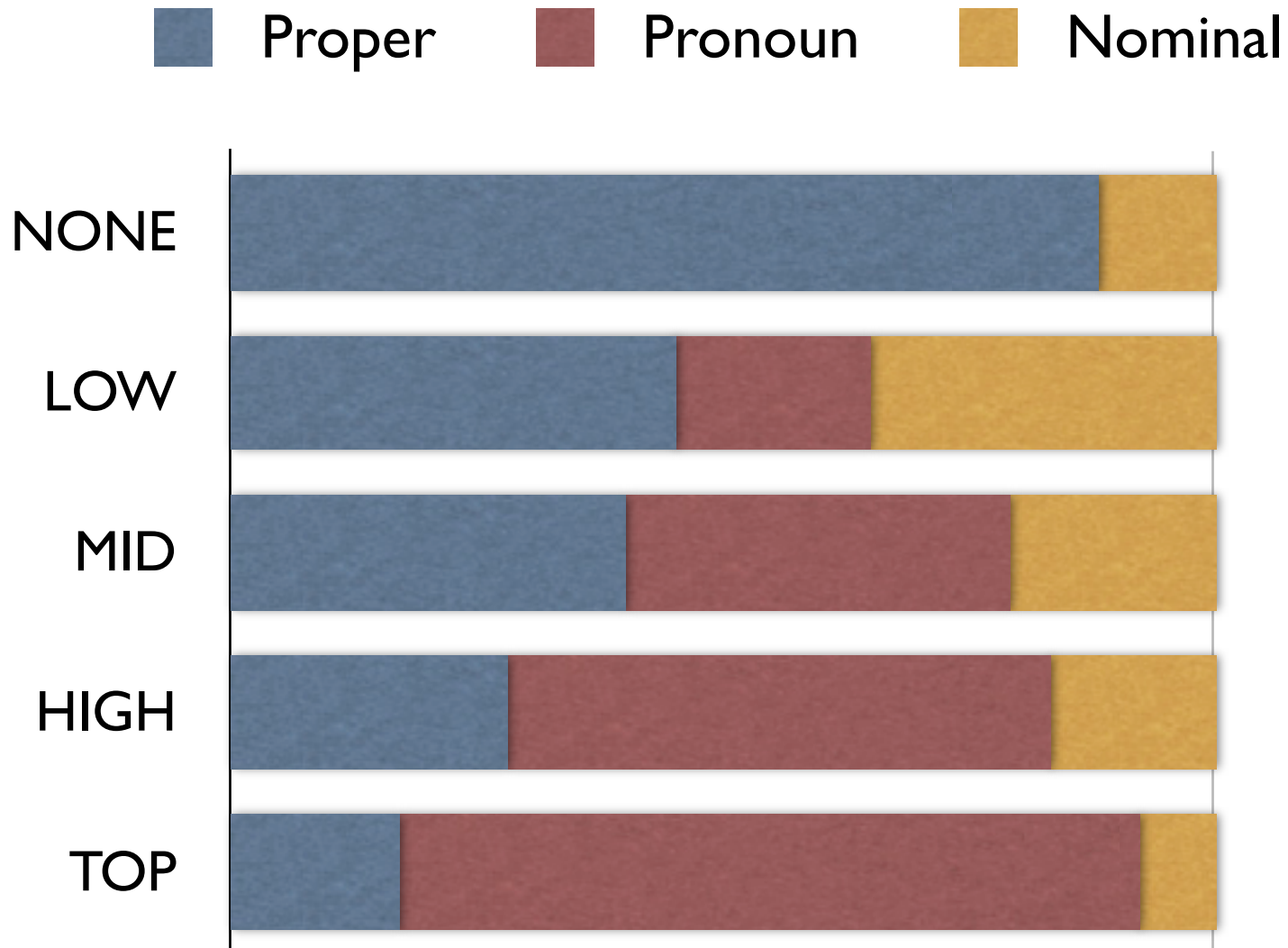
Saliency Model



Saliency Model



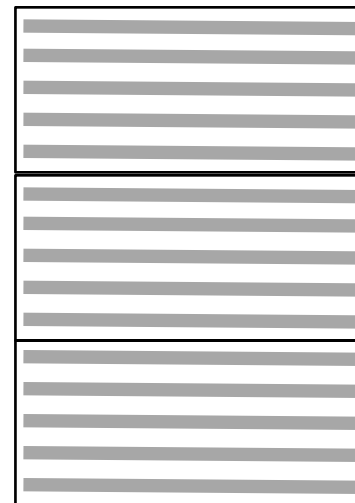
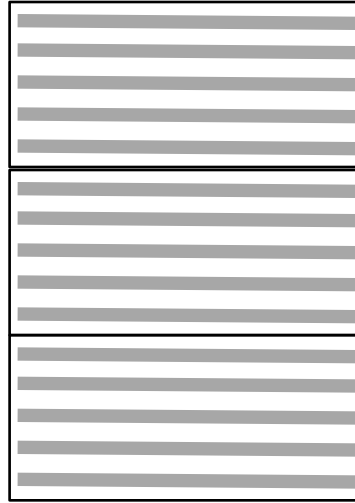
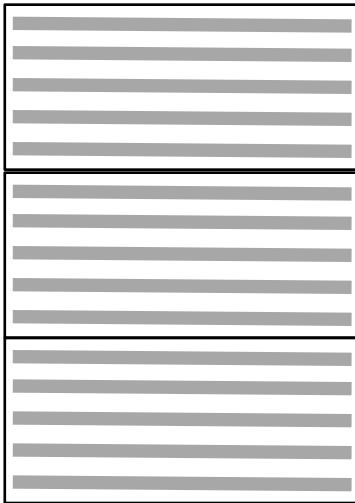
Saliency Model



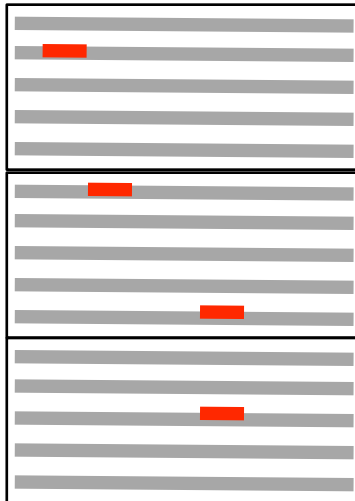


Global Coreference Resolution

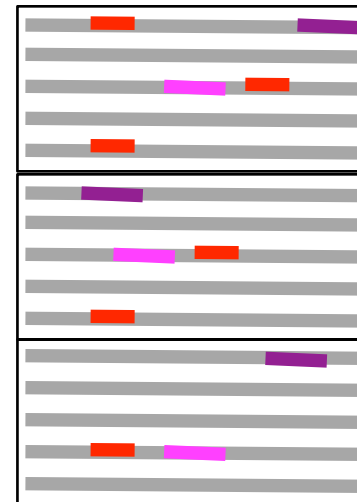
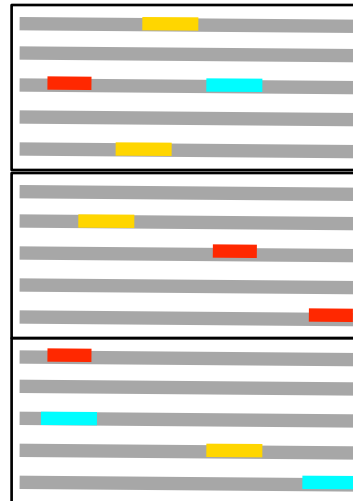
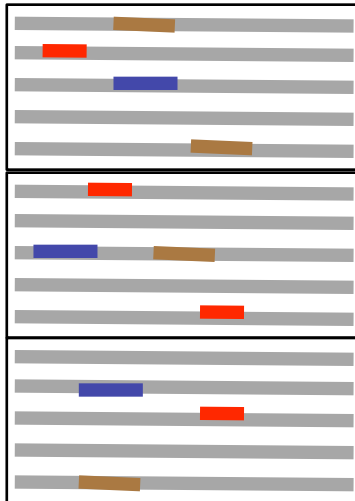
Global Coreference Resolution



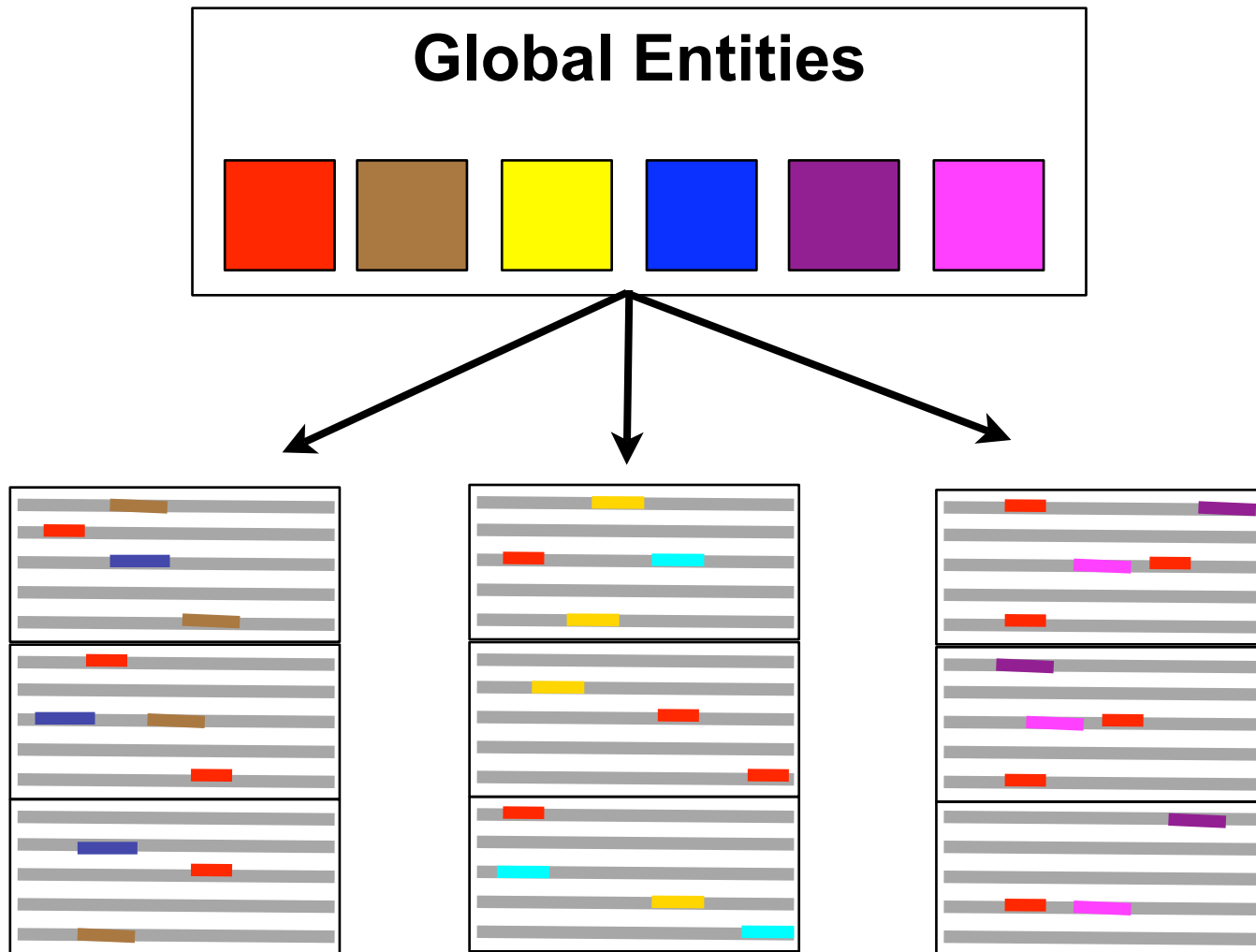
Global Coreference Resolution



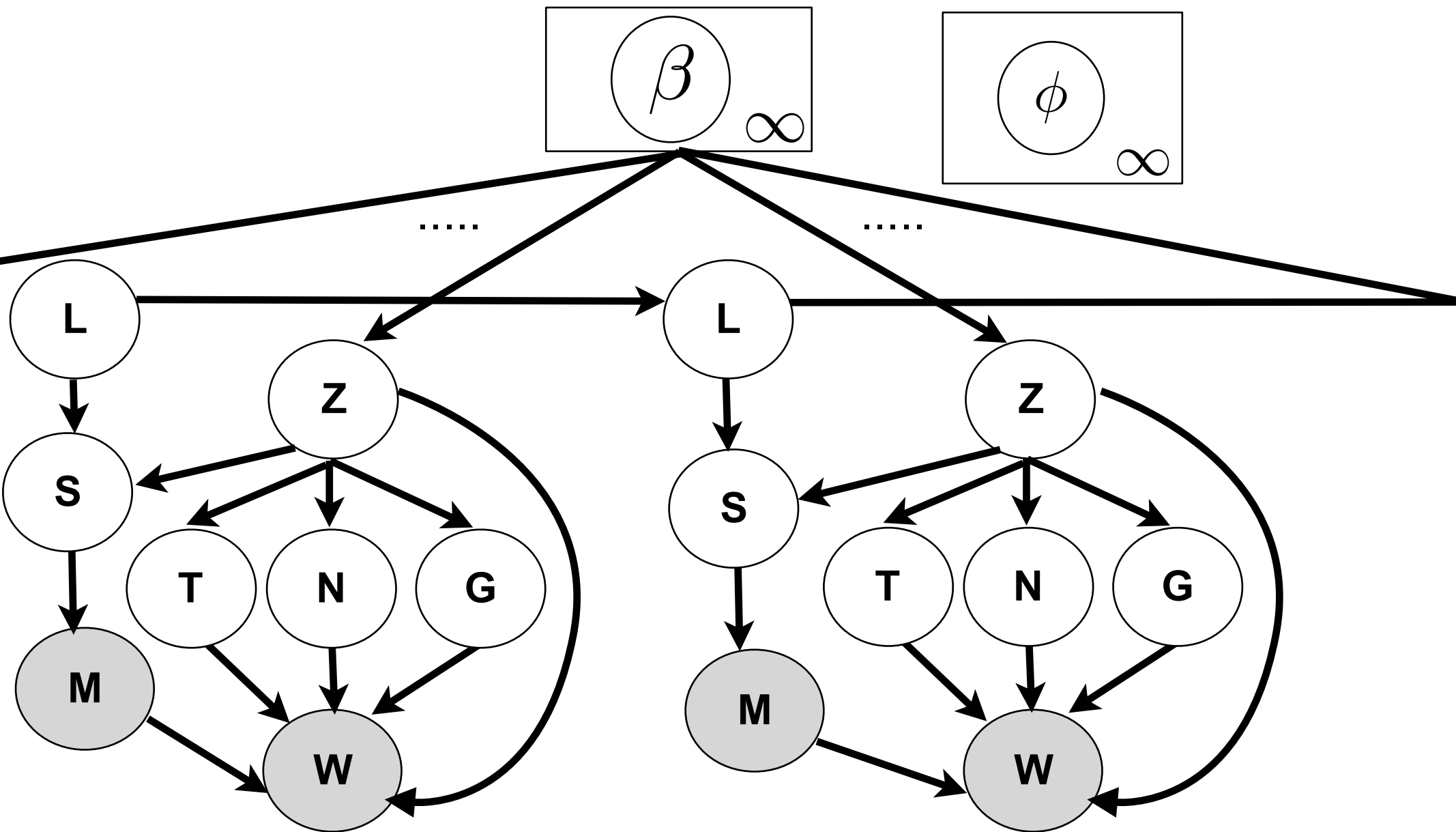
Global Coreference Resolution



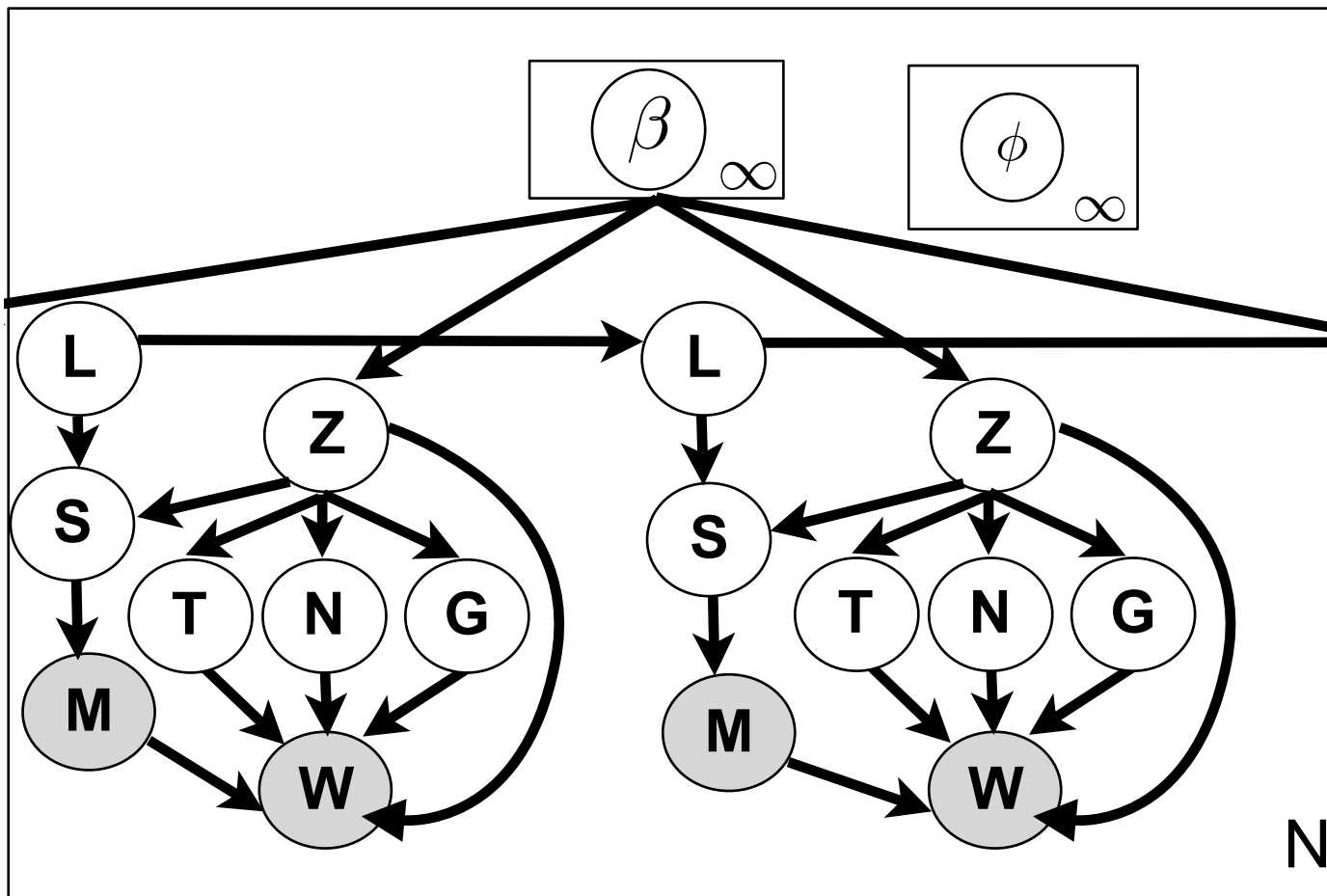
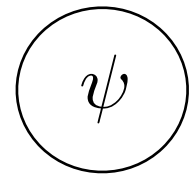
Global Coreference Resolution



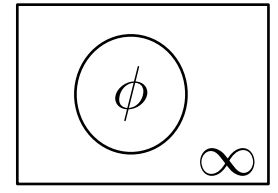
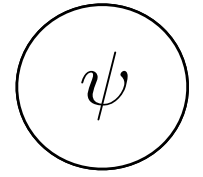
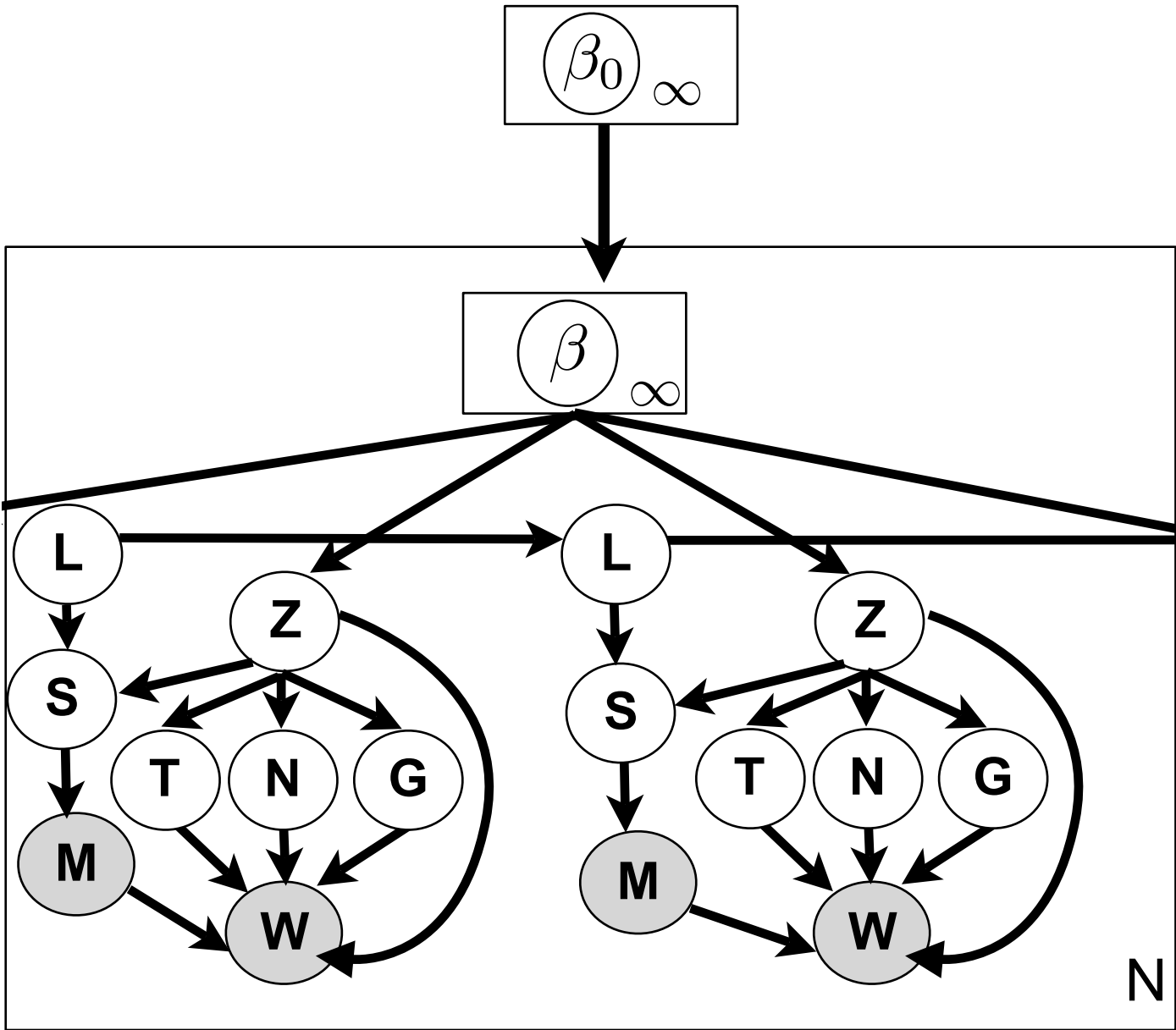
HDP Model



HDP Model

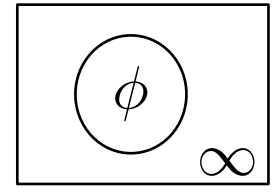
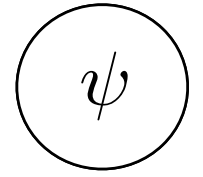
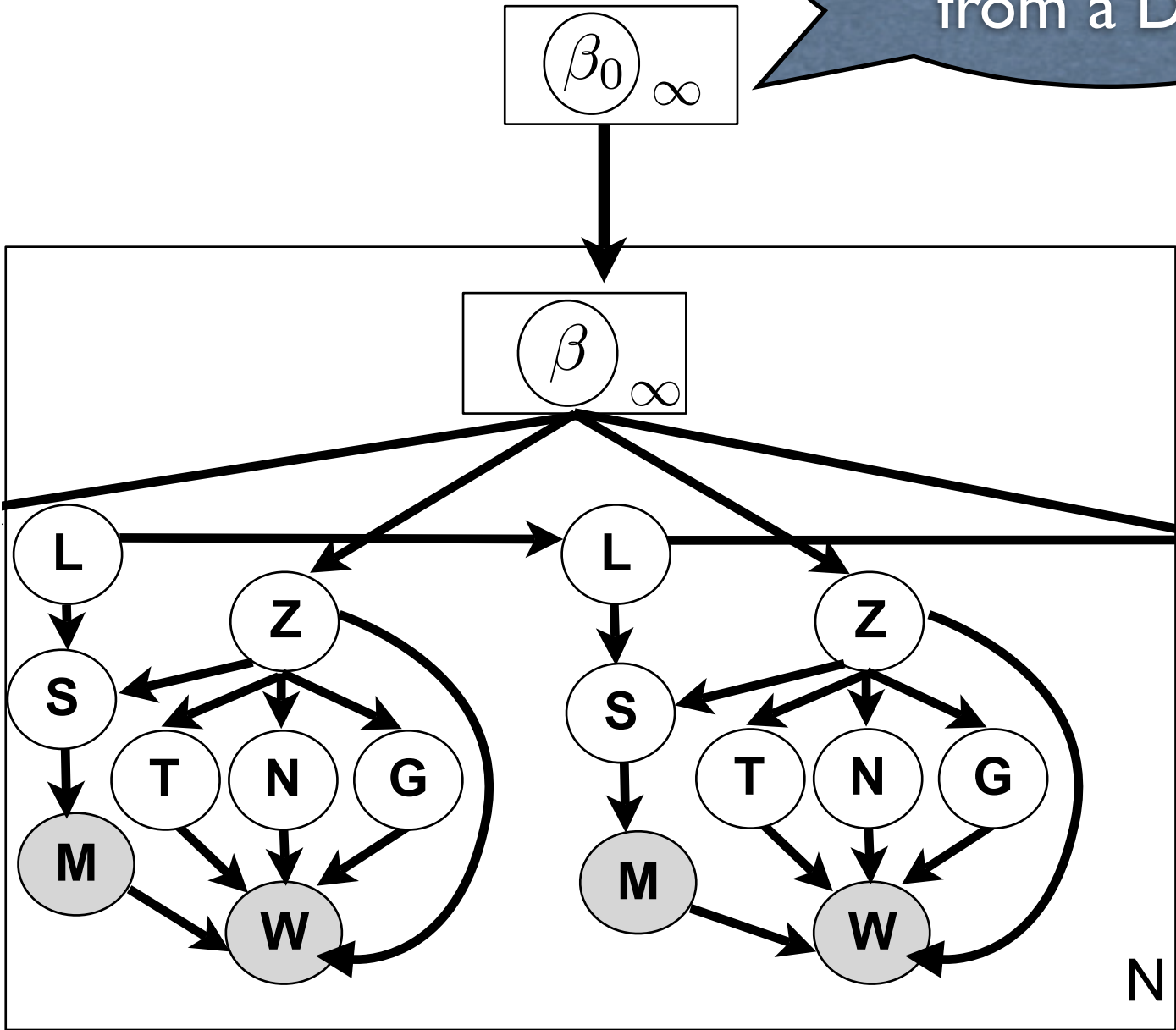


HDP Model

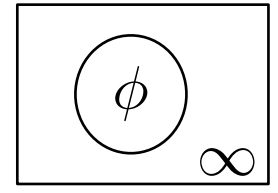
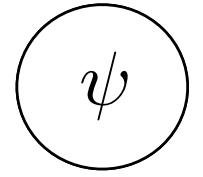
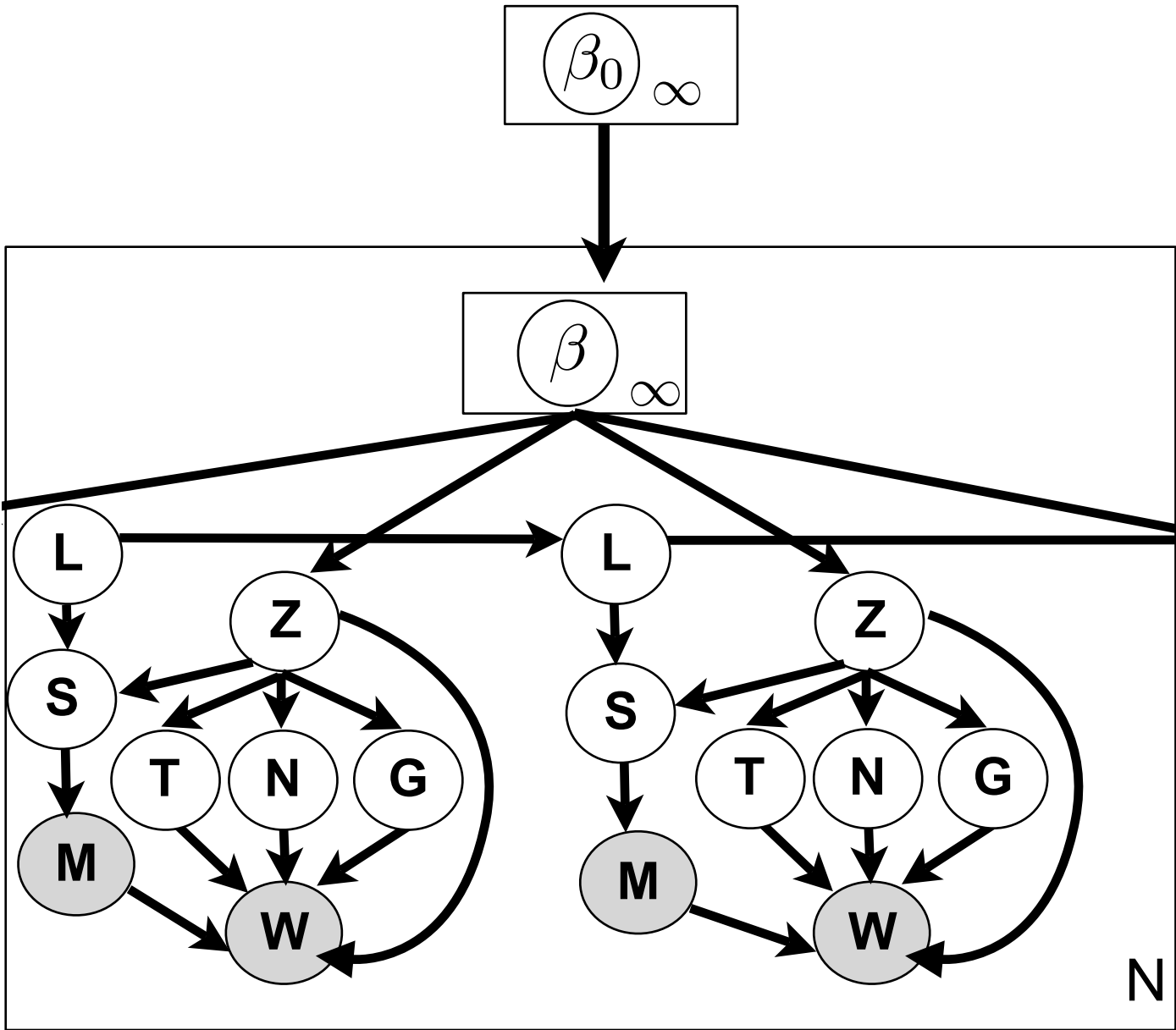


HDP Model

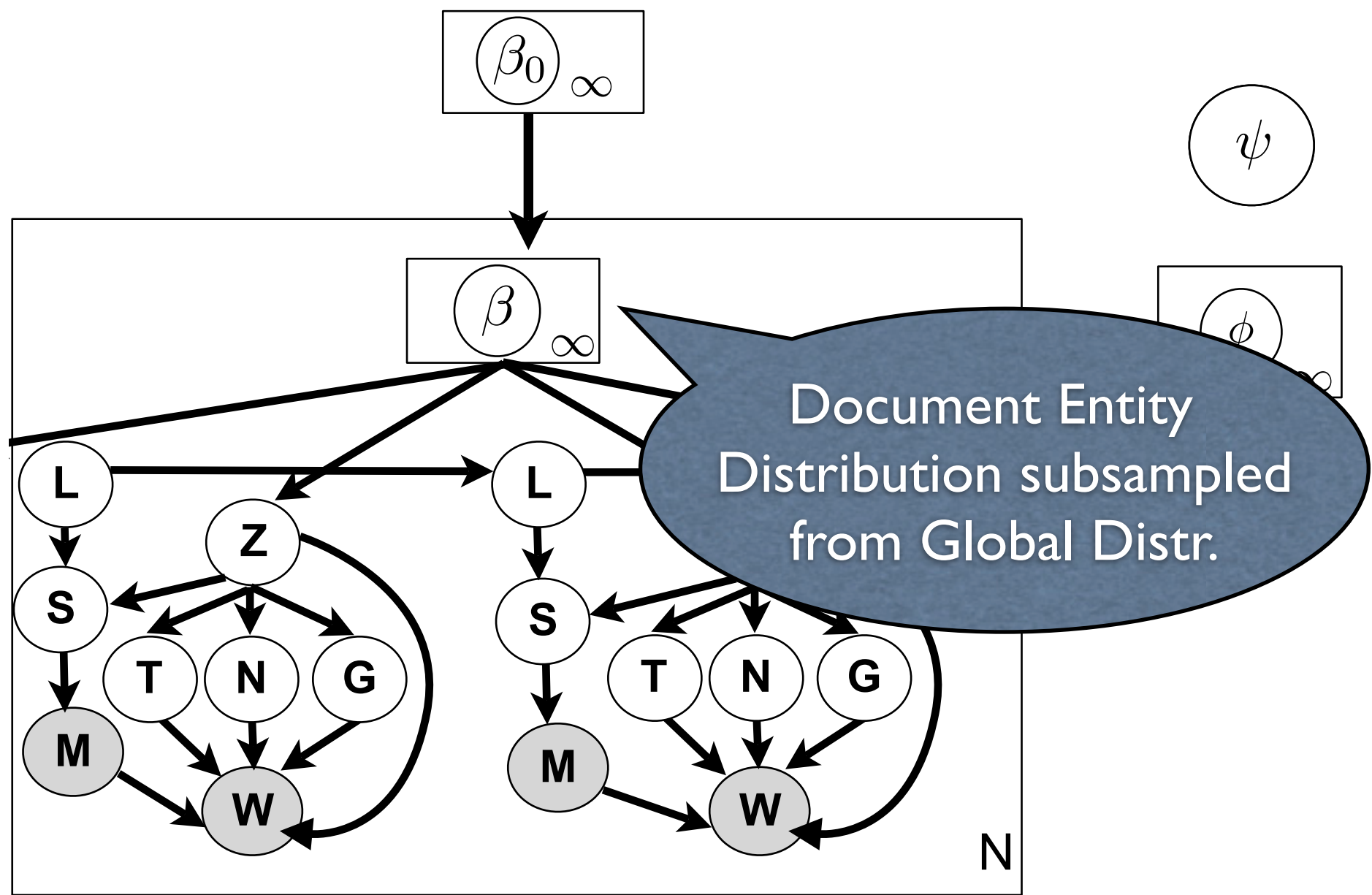
Global Entity Distribution drawn from a DP



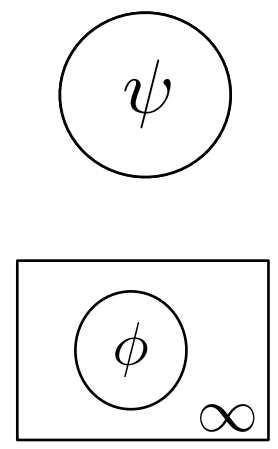
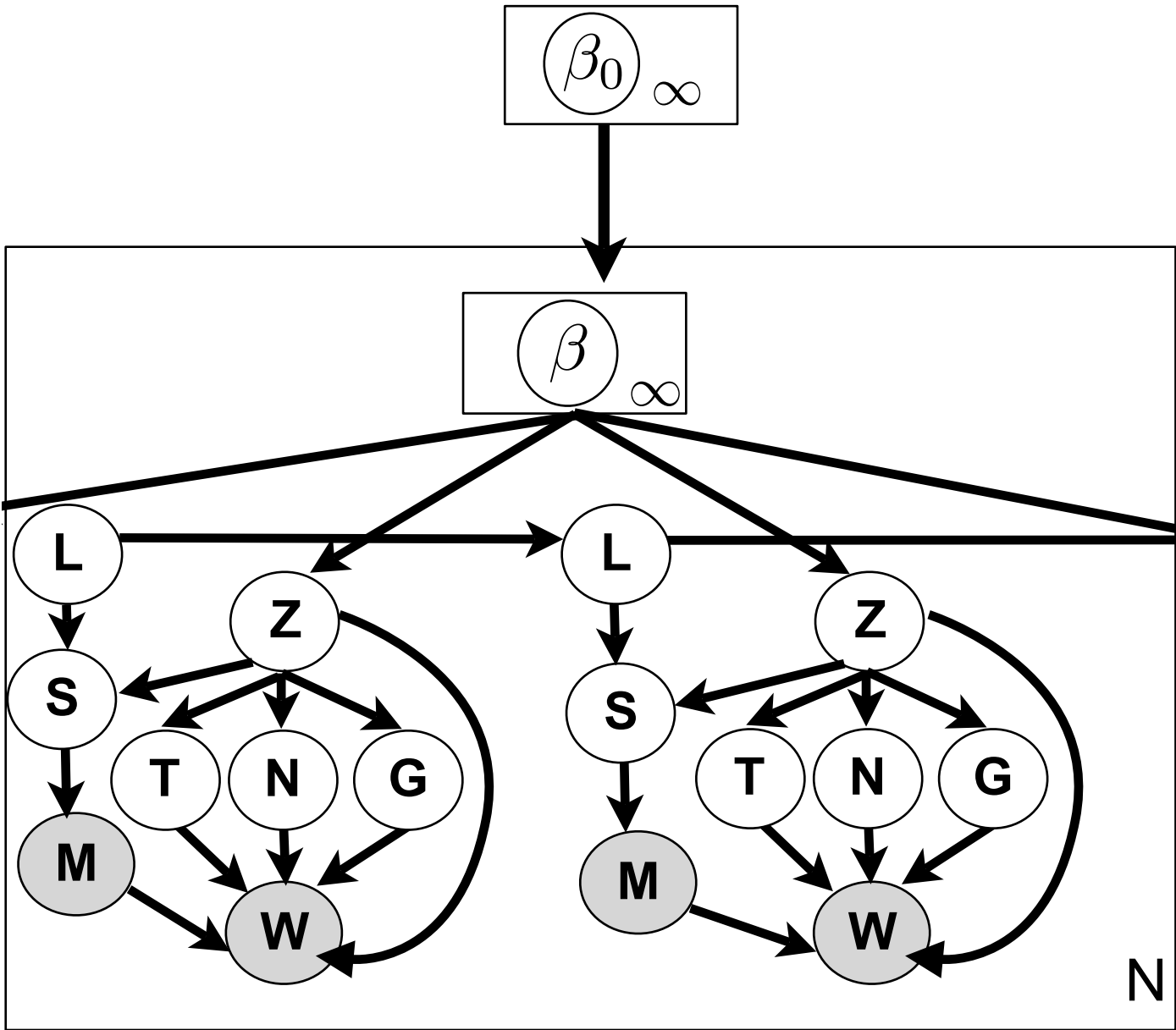
HDP Model



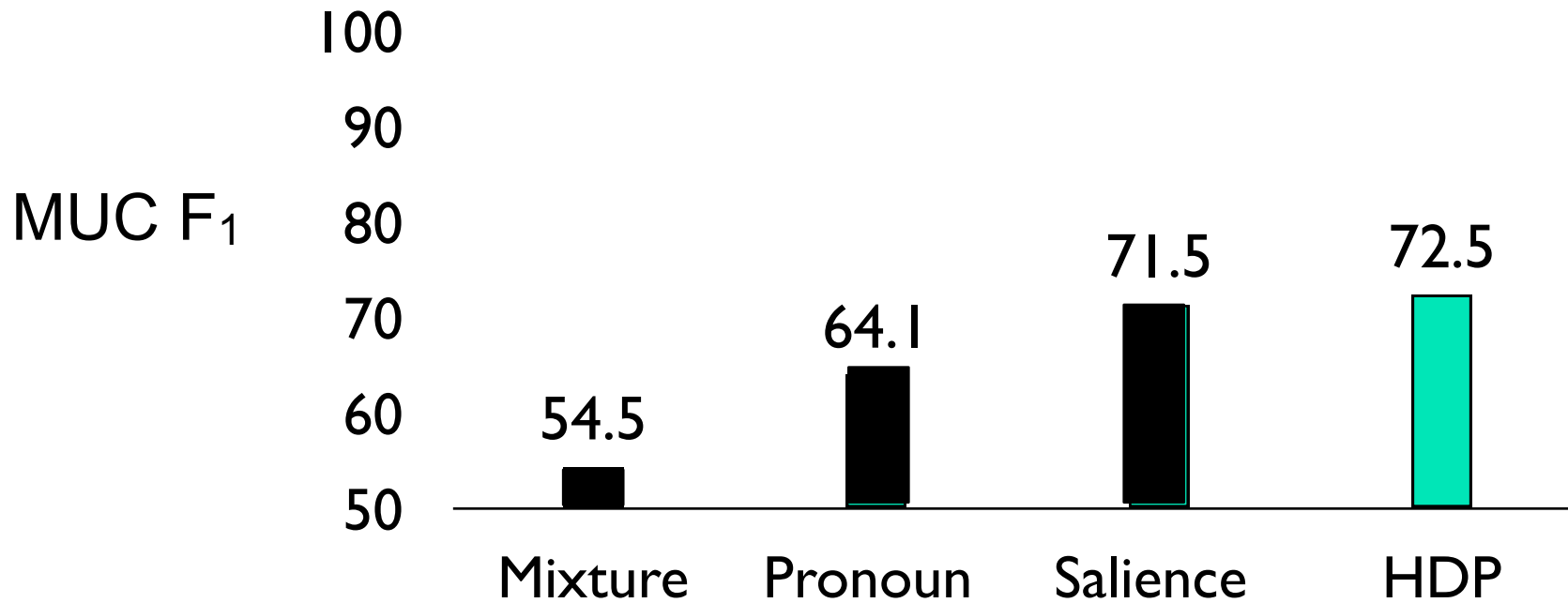
HDP Model



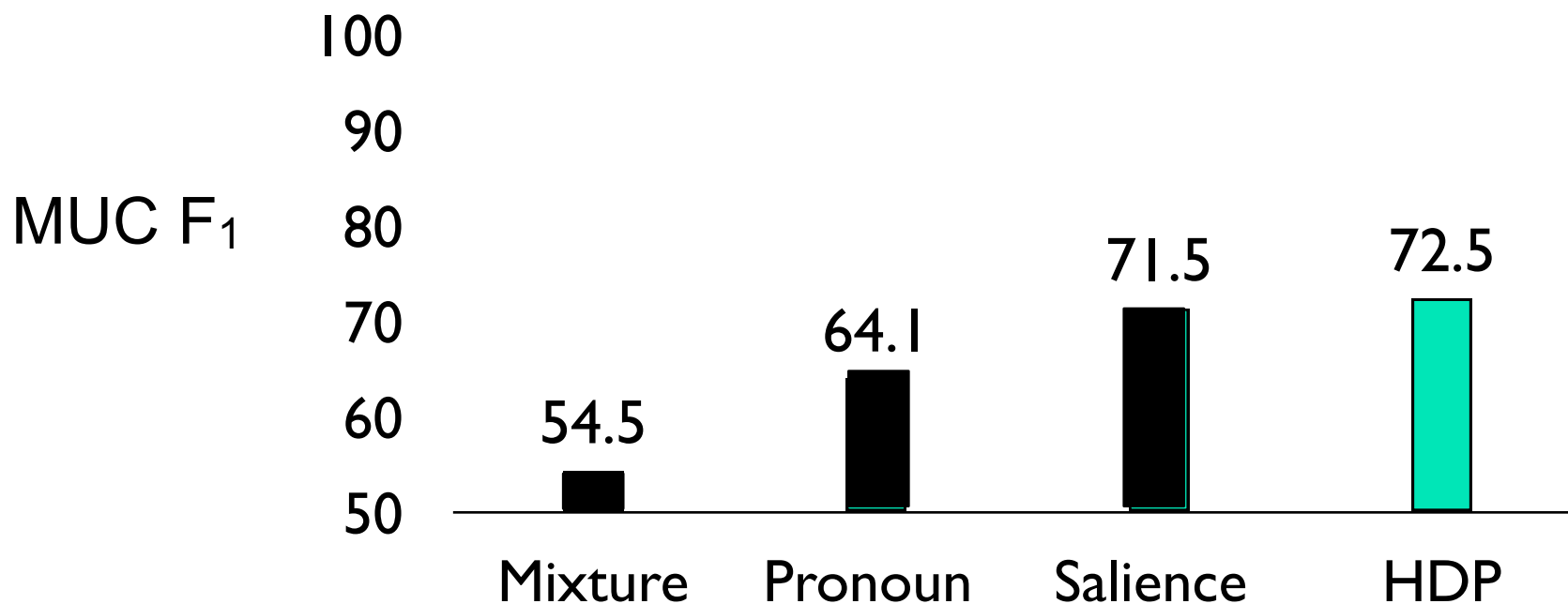
HDP Model



HDP Model

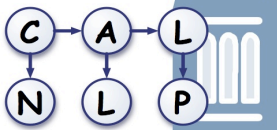


HDP Model



The **Weir Group** , whose headquarters is in the **U.S** is a large specialized **corporation**.
This **power plant** , which , will be situated in **Jiangsu** , has a large generation capacity.

University of
California



Berkeley

HDP Model



HDP Model

Bush

he

Rice

HDP Model

Bush

he

Rice

Rice

Bush

she

MUC6 Formal Experiments

- MUC6: 30 train / test documents
- Our Unsupervised Result

Dataset	# Docs.	P	R	F
MUC6	60	80.8	52.8	63.9
+DRYRUN	251	79.1	59.7	68.0
+NWIRE	381	80.4	62.4	70.3

- Recent Supervised Result
 - 73.4 F_1 [McCallum and Wellner, 2004]

ACE Formal Experiments

- ACE 2004 English NWIRE
 - 64.2 F_1 [This paper] **Unsupervised**
 - 67.5 F_1 [Denis et al., 2007] **Supervised**

Summary

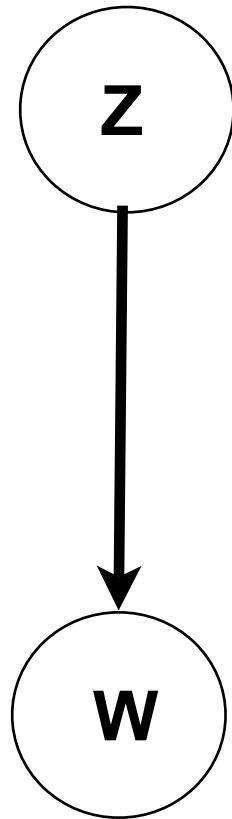
- Fully generative unsupervised Bayesian nonparametric coref model
- Sequential model of local attentional state at the document level
- HDP global coreference model
- Broadly competitive with many supervised results

Thanks!



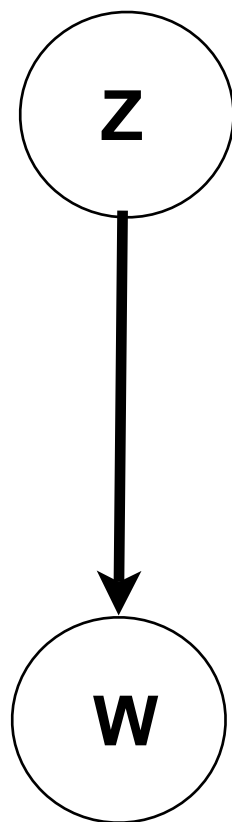
Questions?

Enriching Mention Model



Enriching Mention Model

Entity Parameters

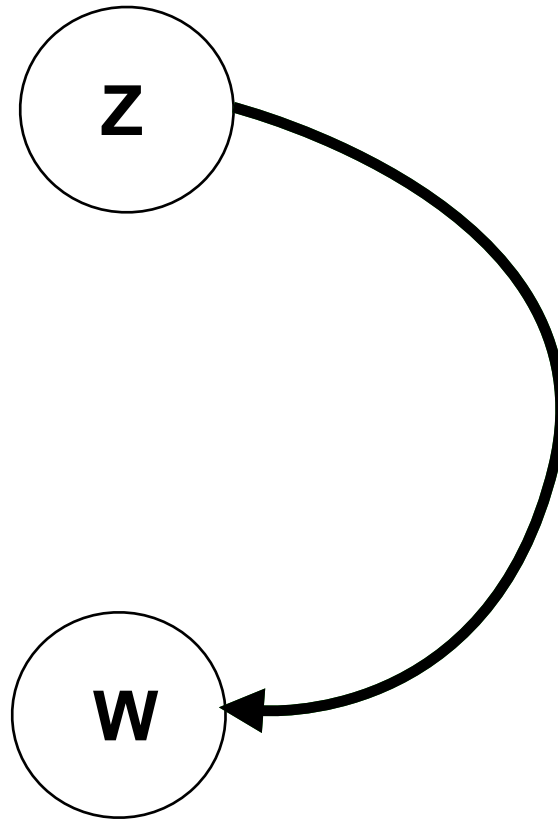


Word | Entity

“group”: 0.3, “its”: 0.2, ...

Enriching Mention Model

Entity Parameters

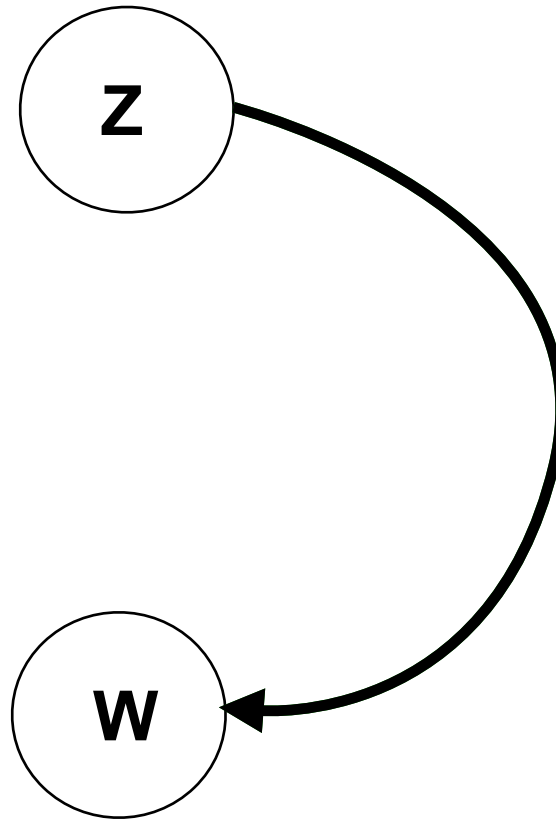


Word | Entity

“group”: 0.3, “its”: 0.2, ...

Enriching Mention Model

Entity Parameters



Word | Entity

“group”: 0.3, “its”: 0.2, ...



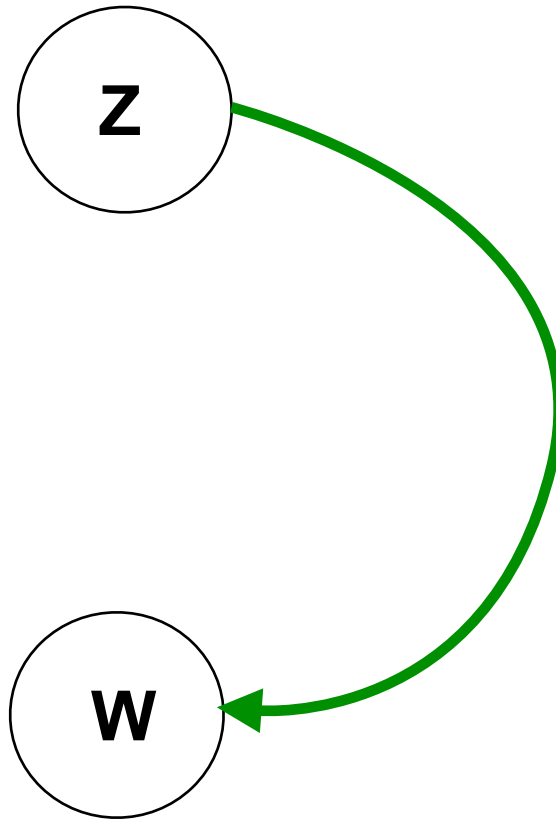
Non-pronoun



Pronoun

Enriching Mention Model

Entity Parameters



Word | Entity

“group”: 0.3, “its”: 0.2, ...

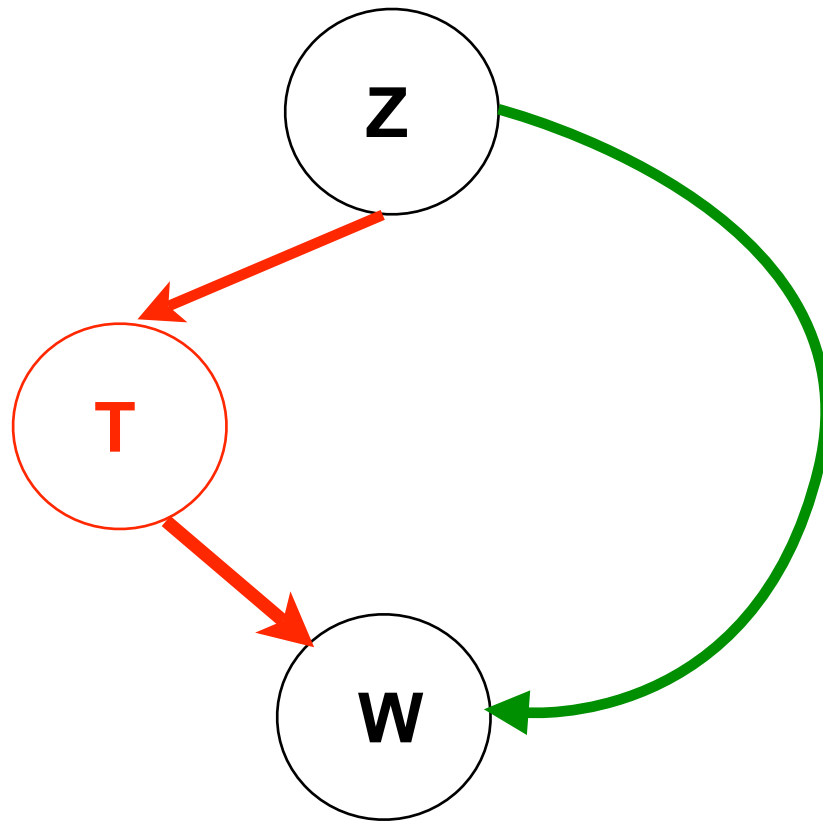


Non-pronoun



Pronoun

Enriching Mention Model



Entity Parameters

Word | Entity

“group”: 0.3, “its”: 0.2, ...

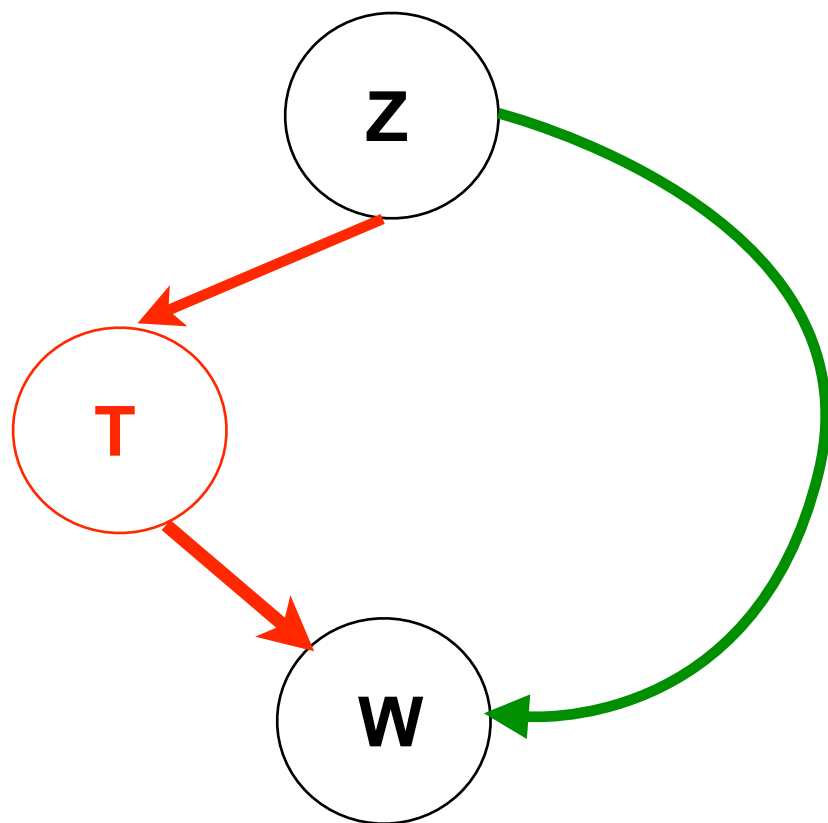


Non-pronoun



Pronoun

Enriching Mention Model



Entity Parameters

Word | Entity

“group”: 0.3, “its”: 0.2, ...

Entity Type | Entity

ORG: 0.5, LOC: 0.2, ...

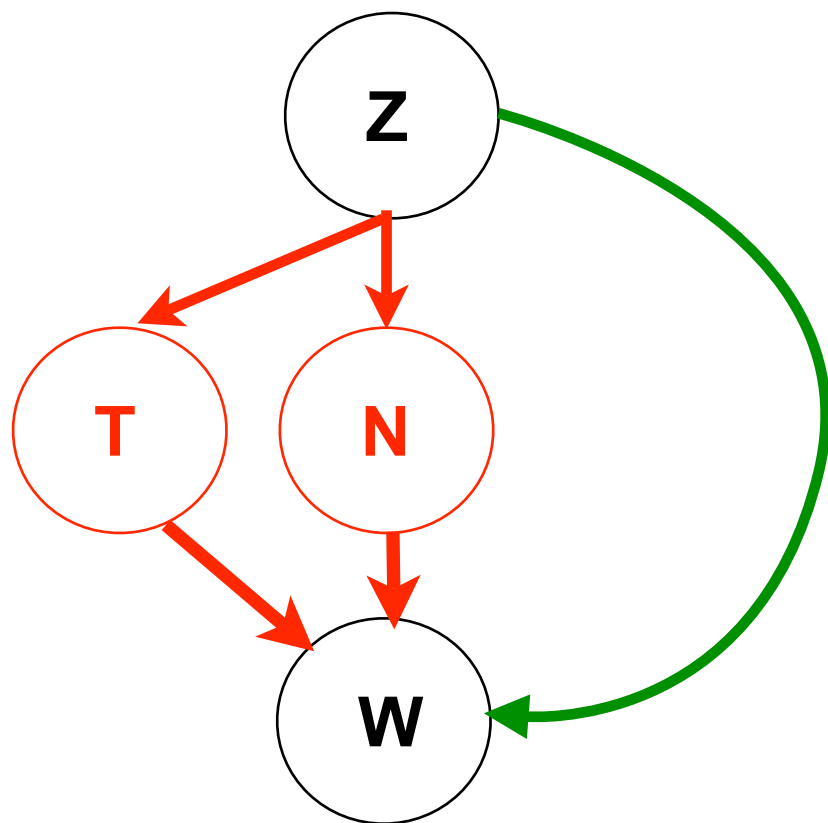


Non-pronoun



Pronoun

Enriching Mention Model



Non-pronoun



Pronoun

Entity Parameters

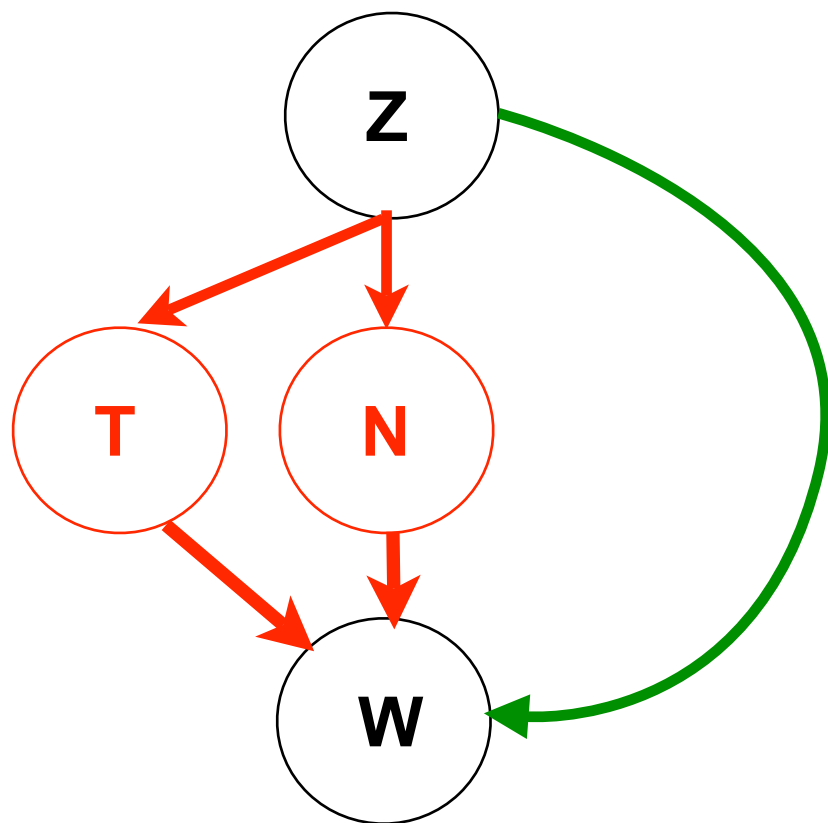
Word | Entity

“group”: 0.3, “its”: 0.2, ...

Entity Type | Entity

ORG: 0.5, LOC: 0.2, ...

Enriching Mention Model



Non-pronoun



Pronoun

Entity Parameters

Word | Entity

“group”: 0.3, “its”: 0.2, ...

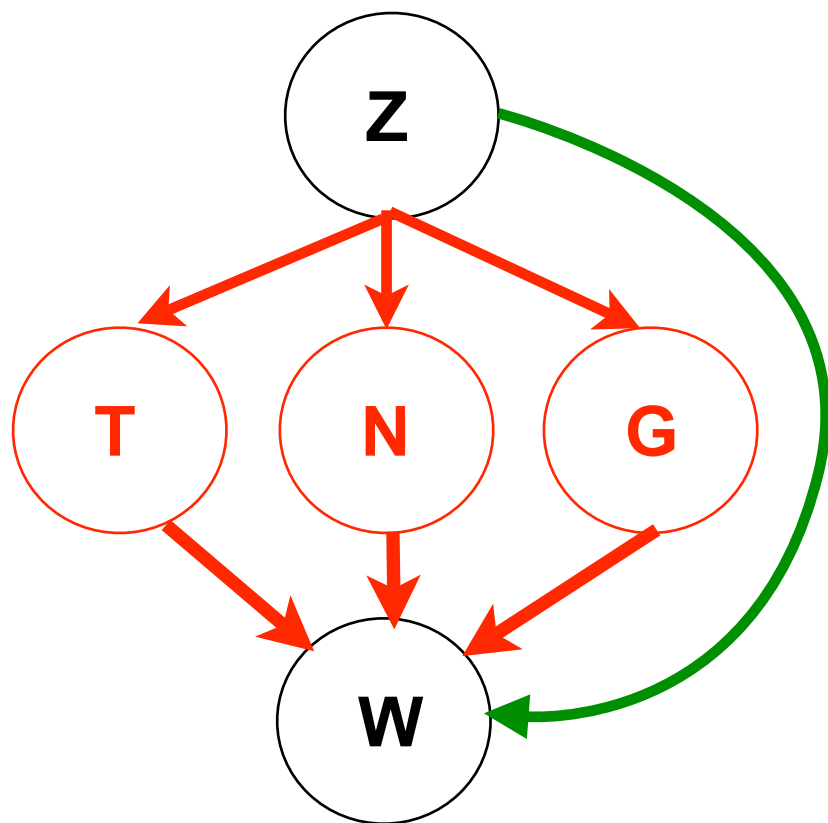
Entity Type | Entity

ORG: 0.5, LOC: 0.2, ...

Number | Entity

PL: 0.6, SING: 0.4

Enriching Mention Model



Non-pronoun



Pronoun

Entity Parameters

Word | Entity

“group”: 0.3, “its”: 0.2, ...

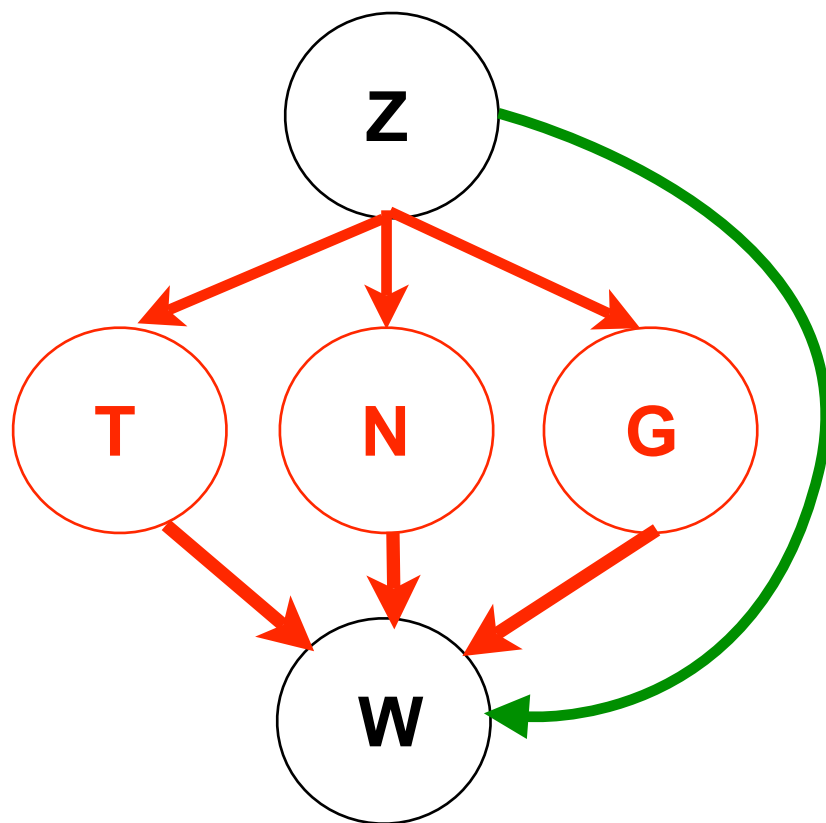
Entity Type | Entity

ORG: 0.5, LOC: 0.2, ...

Number | Entity

PL: 0.6, SING: 0.4

Enriching Mention Model



Non-pronoun



Pronoun

Entity Parameters

Word | Entity

“group”: 0.3, “its”: 0.2, ...

Entity Type | Entity

ORG: 0.5, LOC: 0.2, ...

Number | Entity

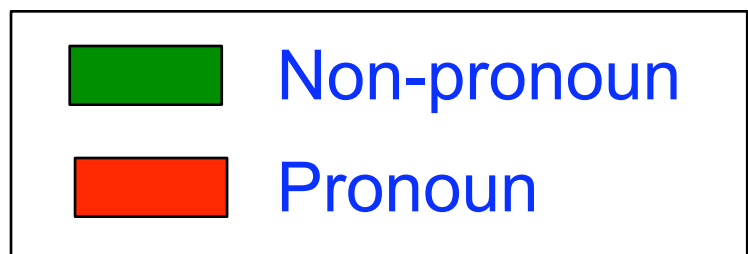
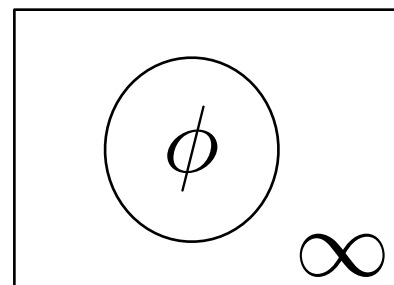
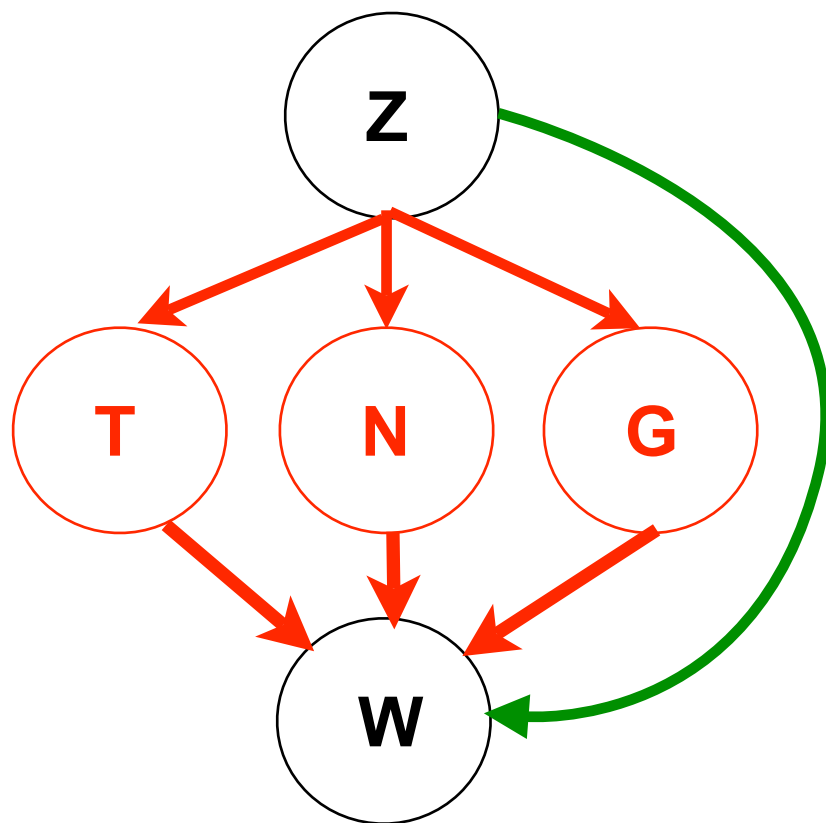
PL: 0.6, SING: 0.4

Gender | Entity

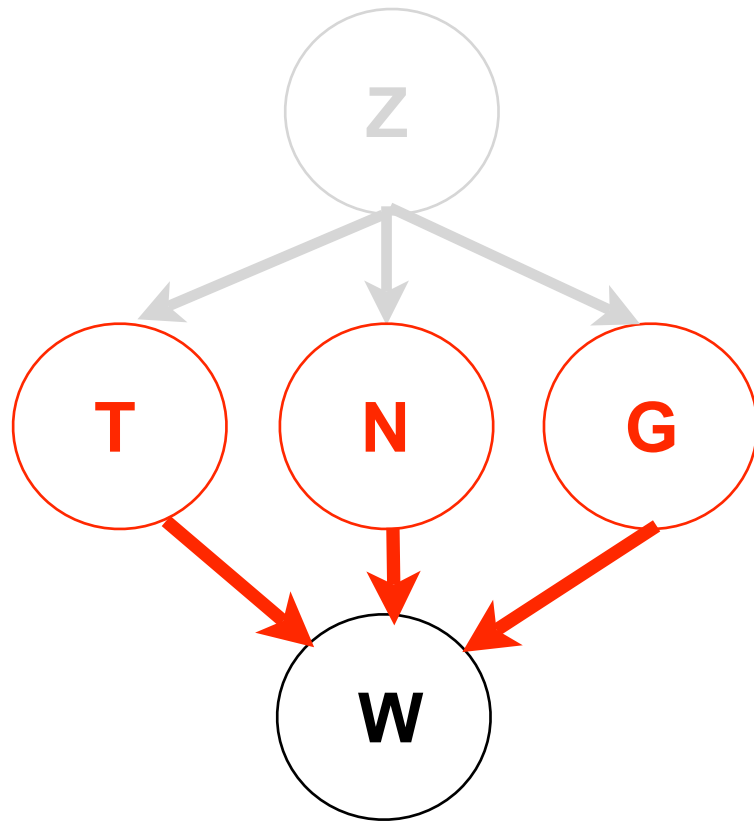
NEUT: 0.7, M: 0.2, F: 0.1

Enriching Mention Model

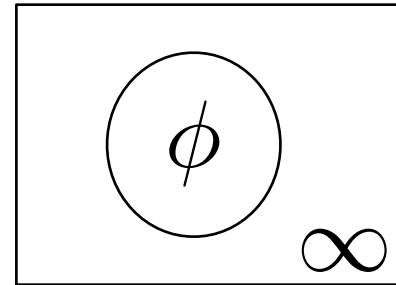
Entity Parameters



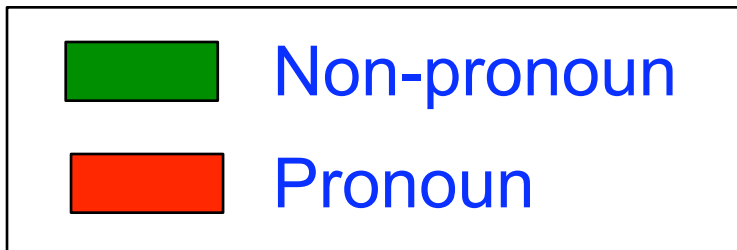
Enriching Mention Model



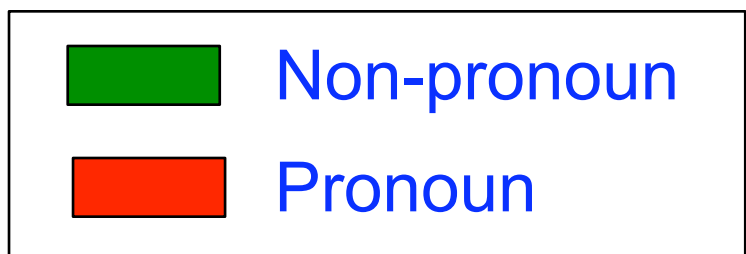
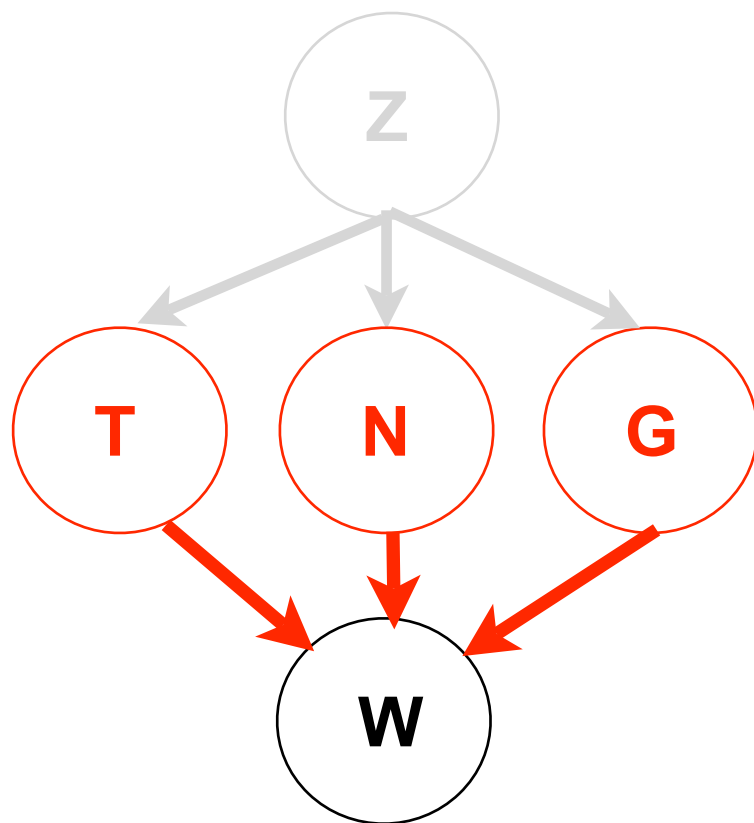
Entity Parameters



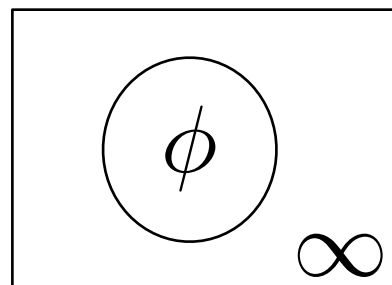
Pronoun Parameters



Enriching Mention Model



Entity Parameters



Pronoun Parameters

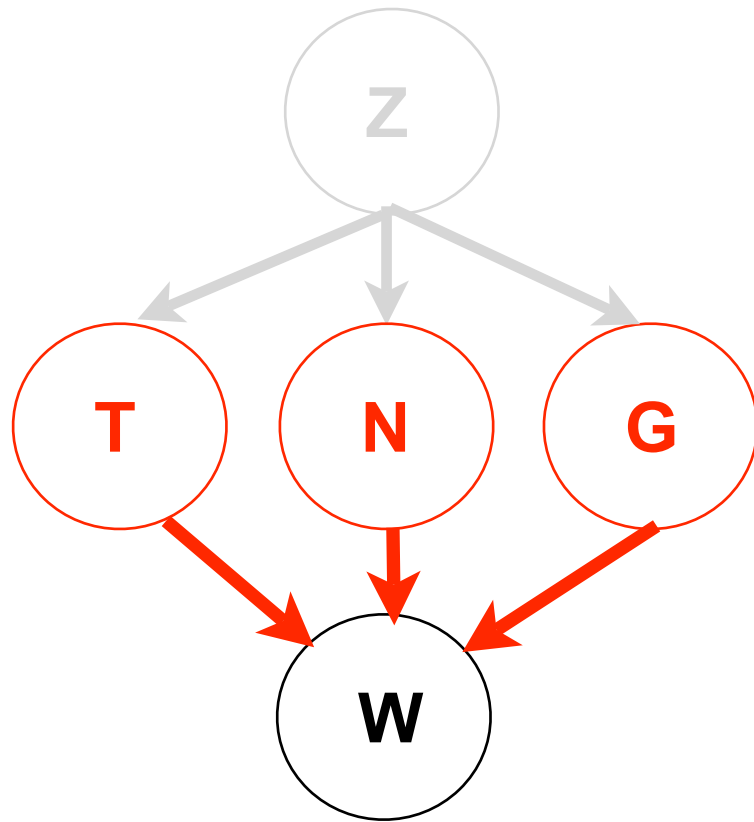
W | PERS, SING, MALE

“he”:0.5, “him”: 0.5

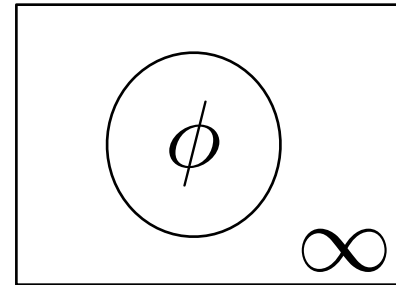
W | ORG, PL, NEUT

“they”:0.3, “it”: 0.2,...

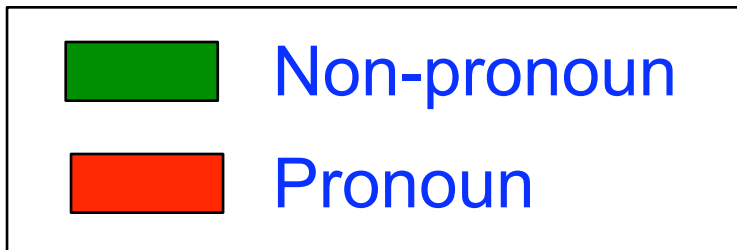
Enriching Mention Model



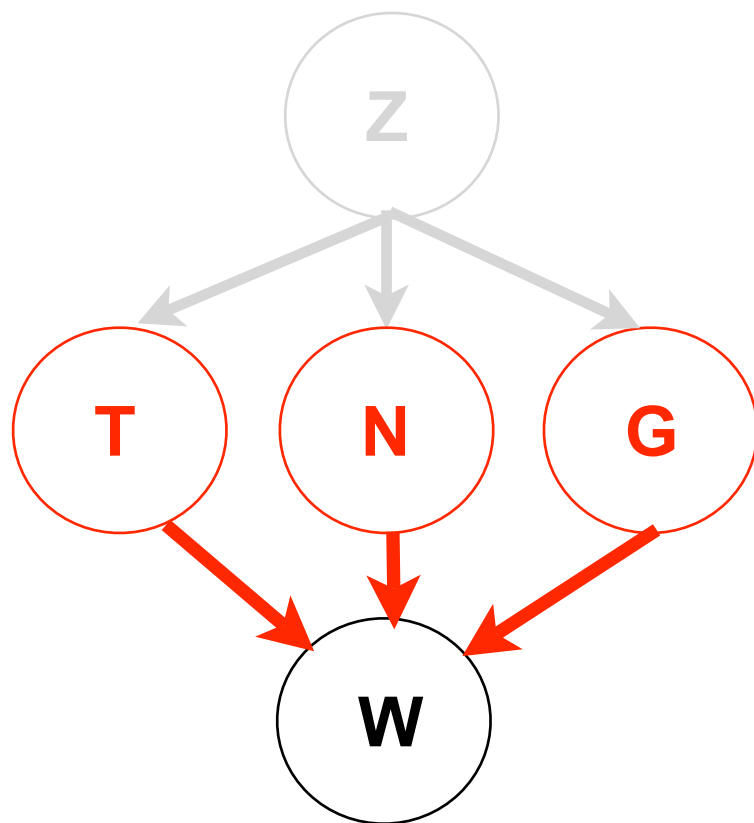
Entity Parameters



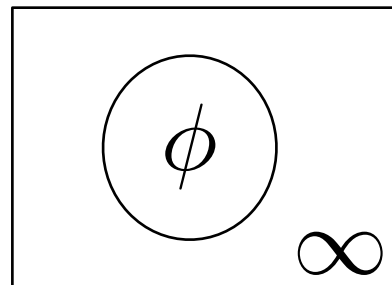
Pronoun Parameters



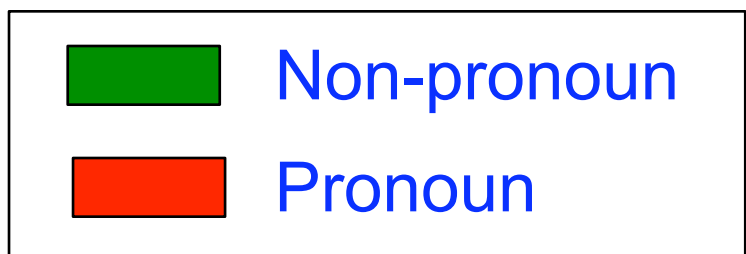
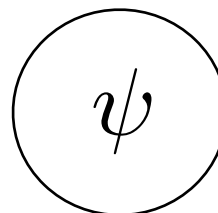
Enriching Mention Model



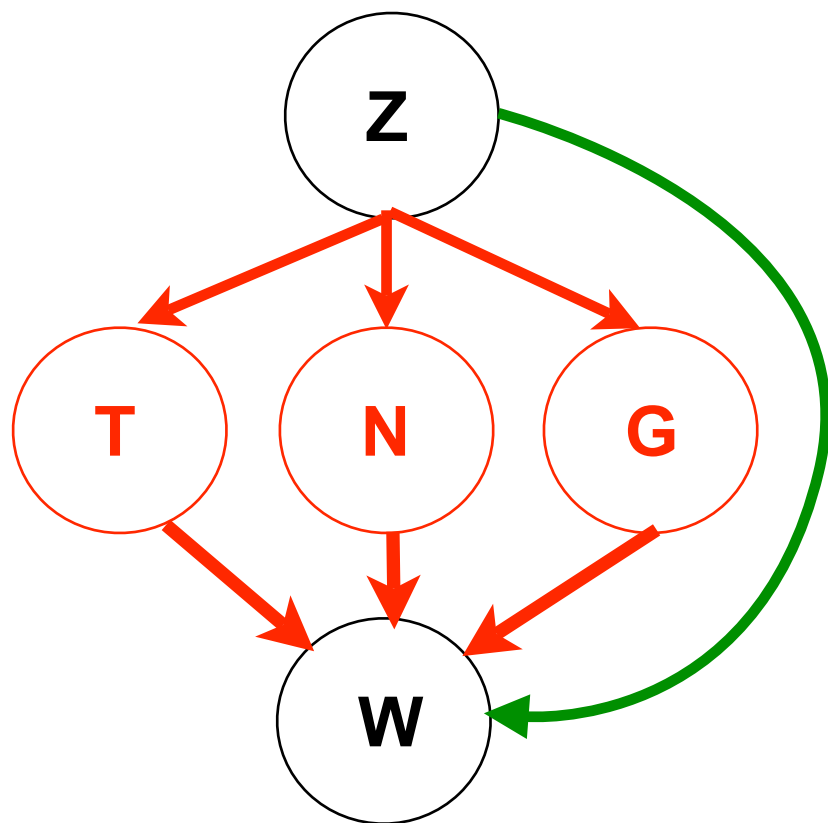
Entity Parameters



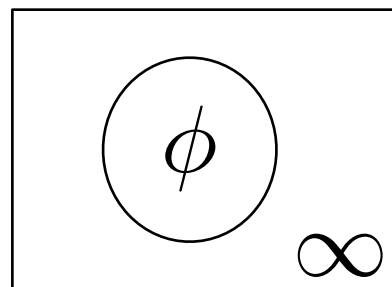
Pronoun Parameters



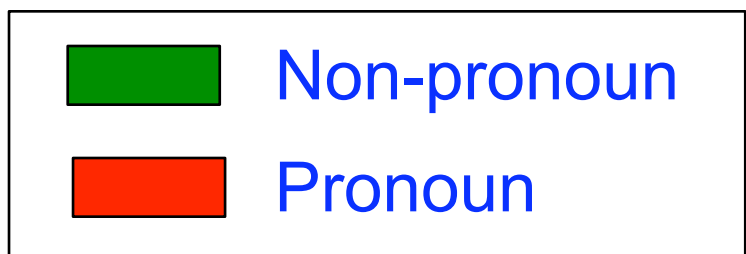
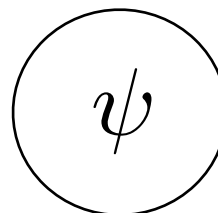
Enriching Mention Model



Entity Parameters

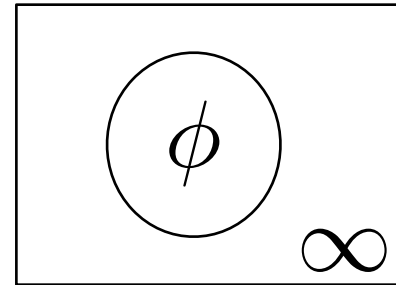


Pronoun Parameters

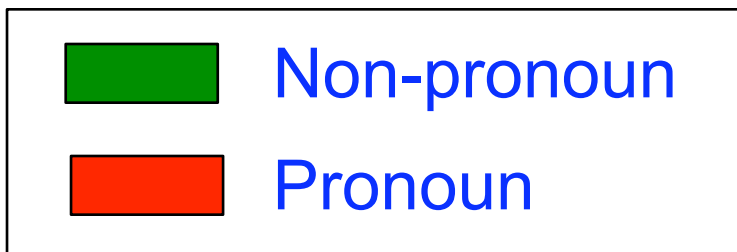
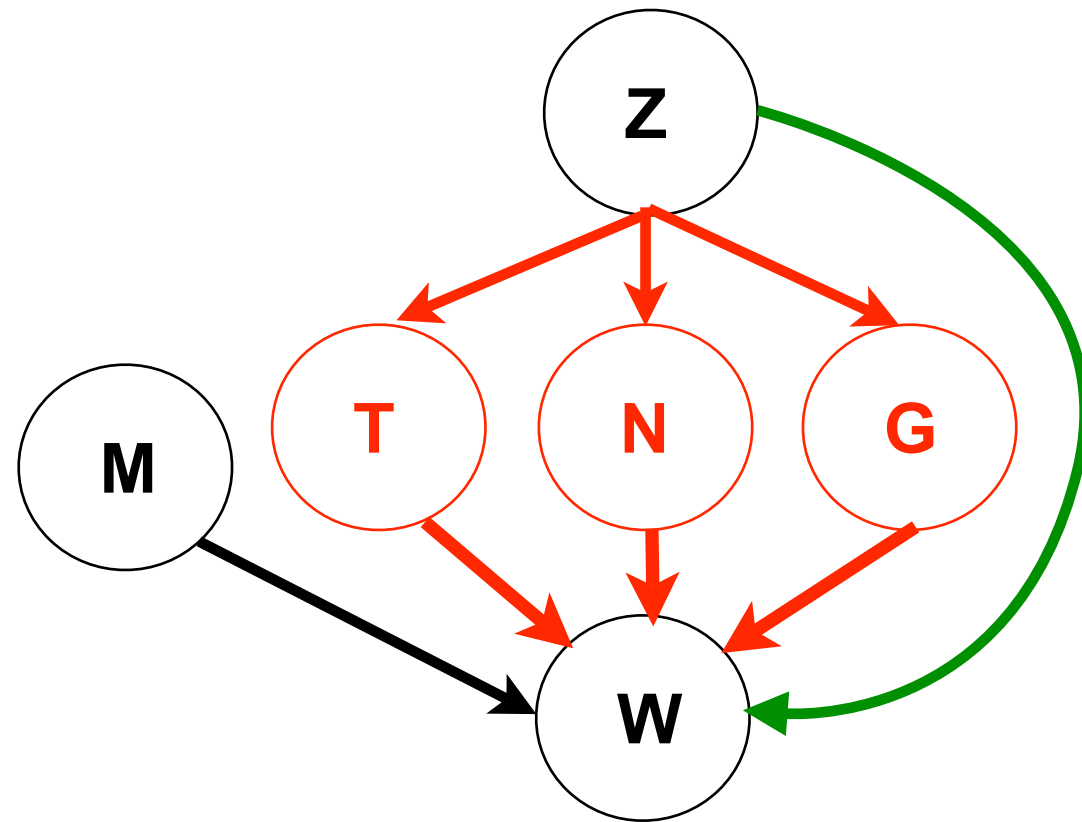
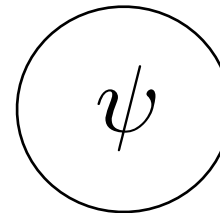


Enriching Mention Model

Entity Parameters

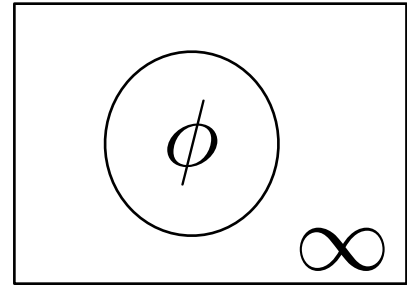


Pronoun Parameters

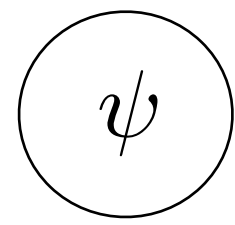


Enriching Mention Model

Entity Parameters



Pronoun Parameters



Mention Type

- Proper: 1/3
- Nominal: 1/3
- Pronoun: 1/3

