Natural Language Inference in the Real World

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Natural Language Inference

Natural Language Inference

A man is pointing at a silver sedan.

Natural Language Inference

A man is pointing at a silver sedan.

There is no man pointing at a car.

Natural Language Inference

A man is pointing at a silver **sedan**.

There is no man pointing at a **car**.

Natural Language Inference

A man is pointing at a **silver** **sedan**.

There is no man pointing at a **car**.

Natural Language Inference

A man is pointing at a **silver** **sedan**.

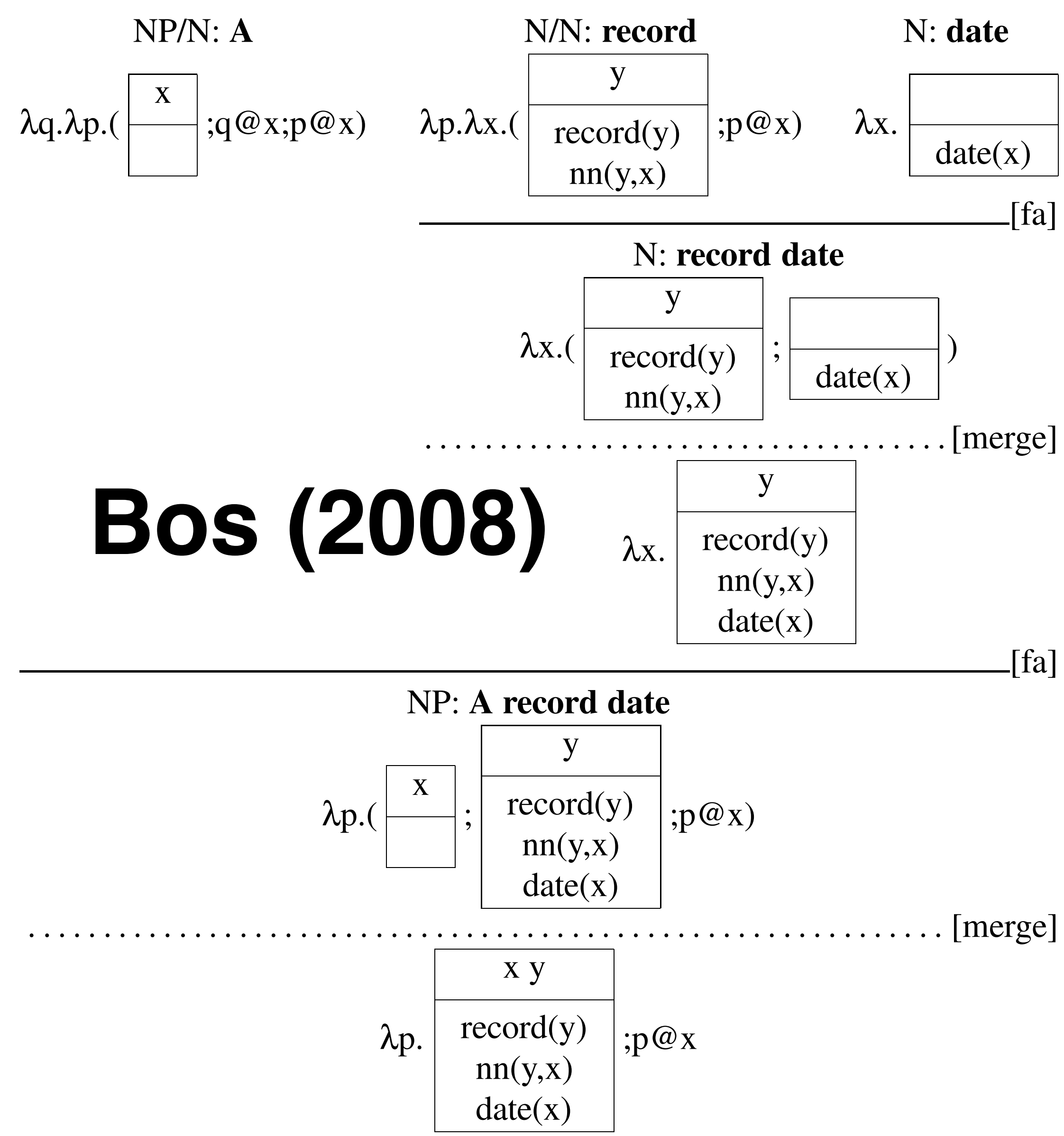
There is **no** man pointing at a **car**.

Natural Language Inference

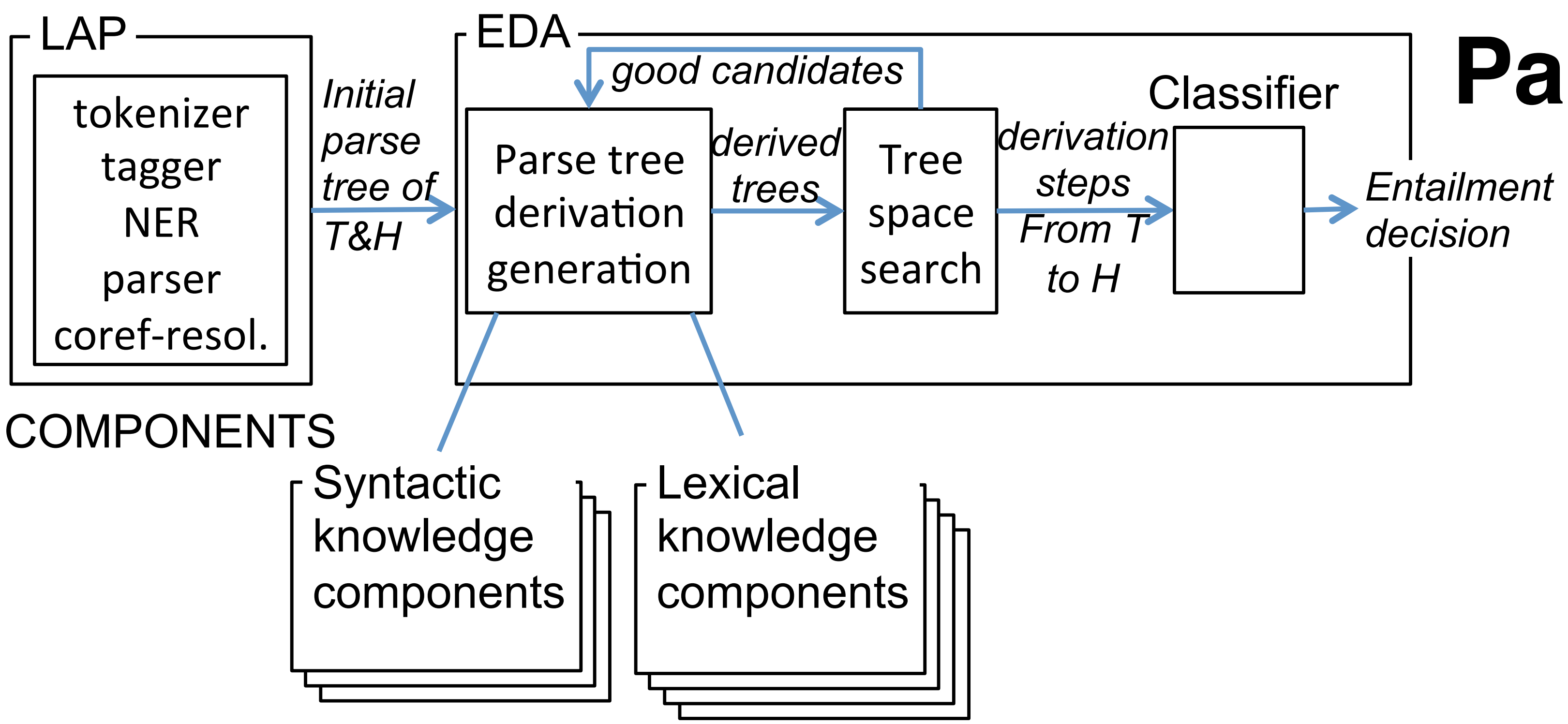
A man is pointing at a

There is **no** man poir

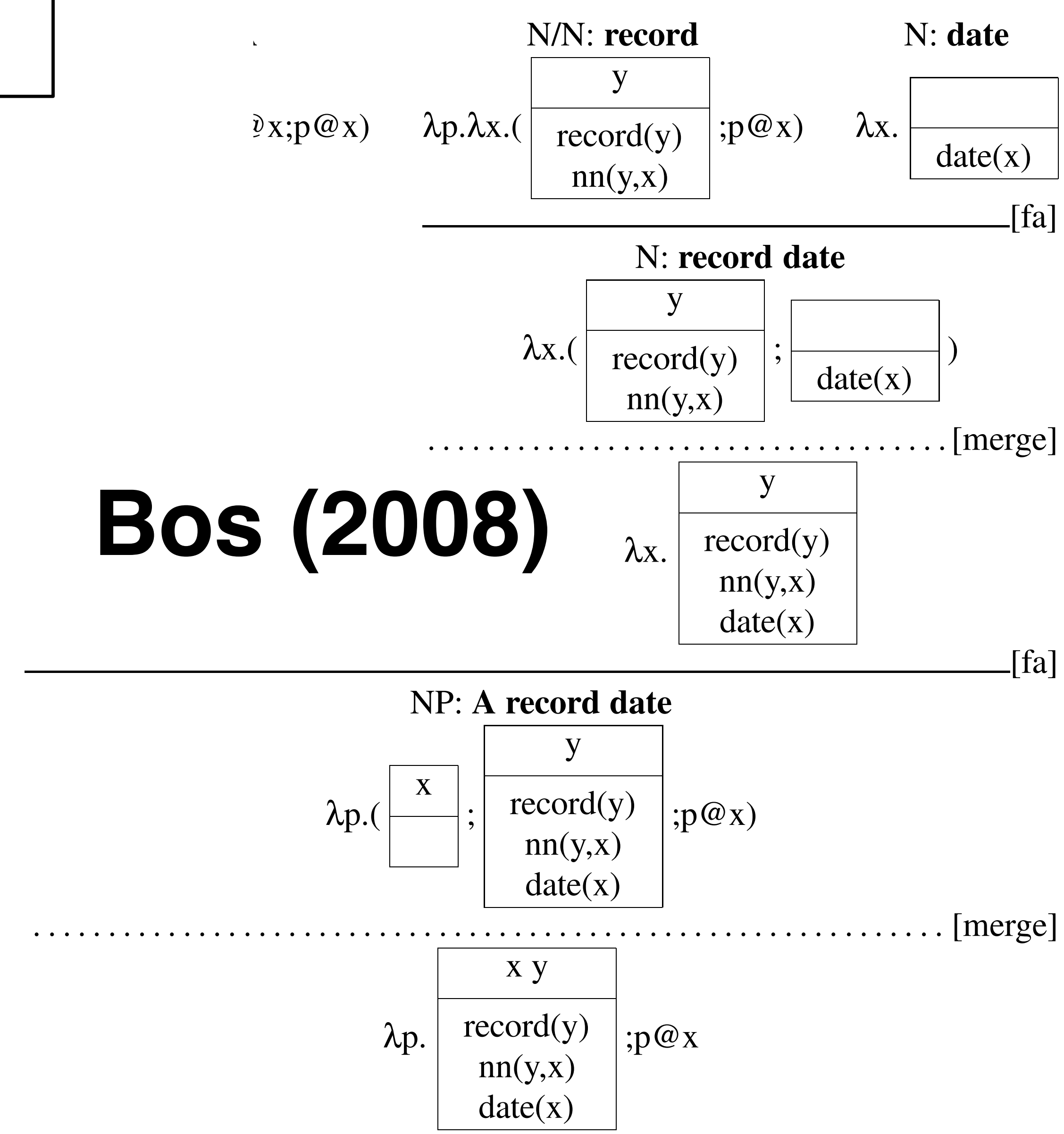
Bos (2008)



Natural Language Inference



Padó et al. (2015)



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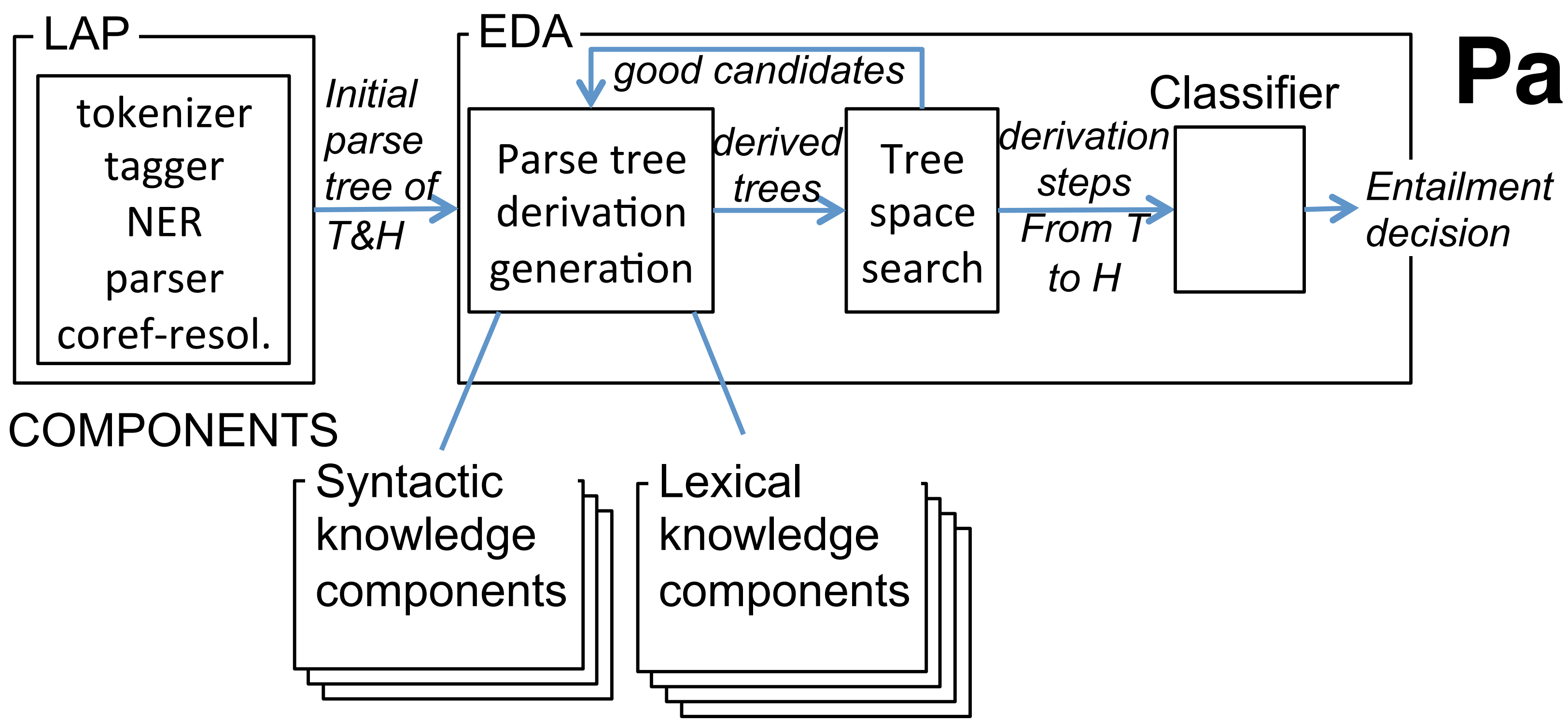

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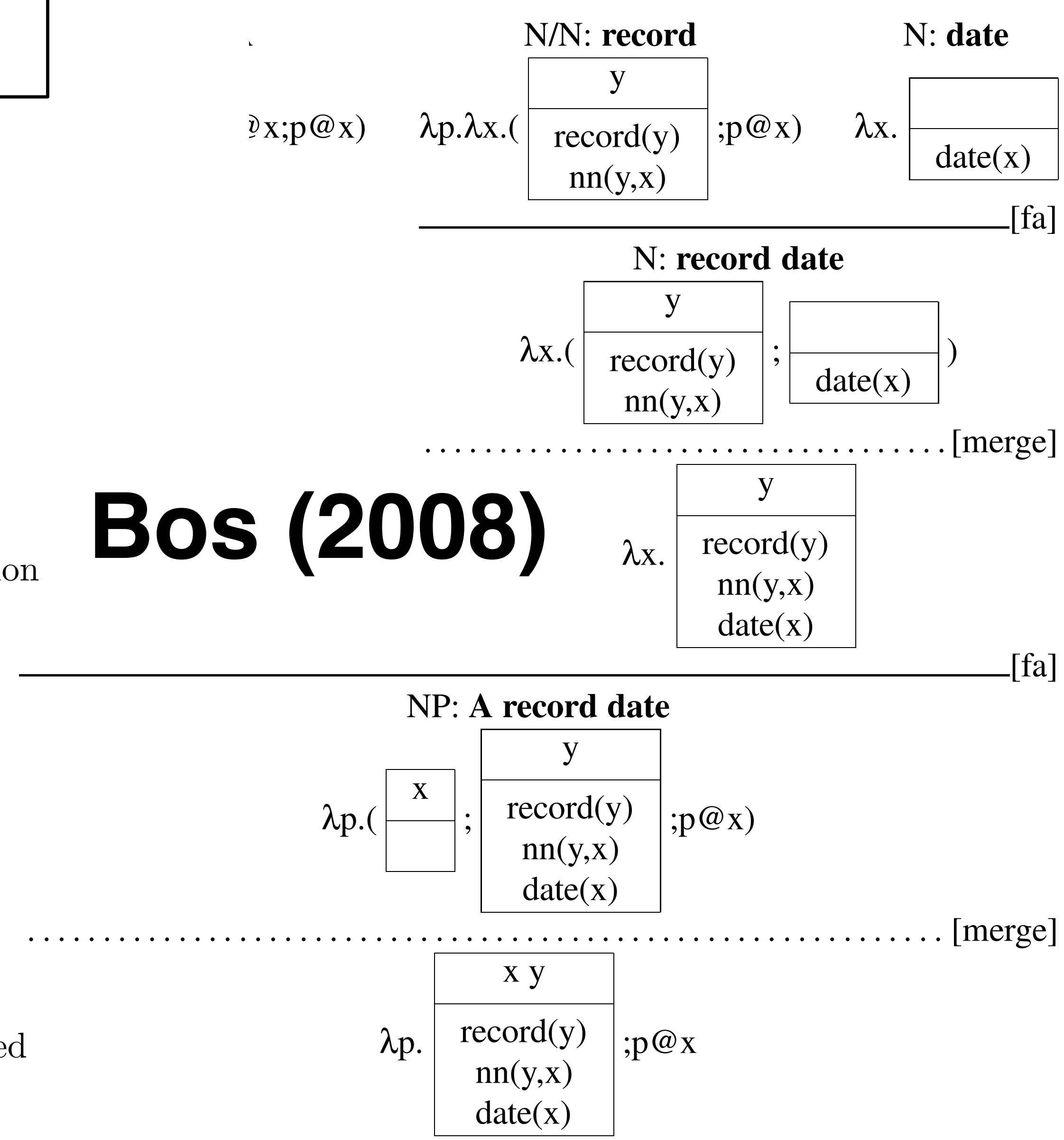
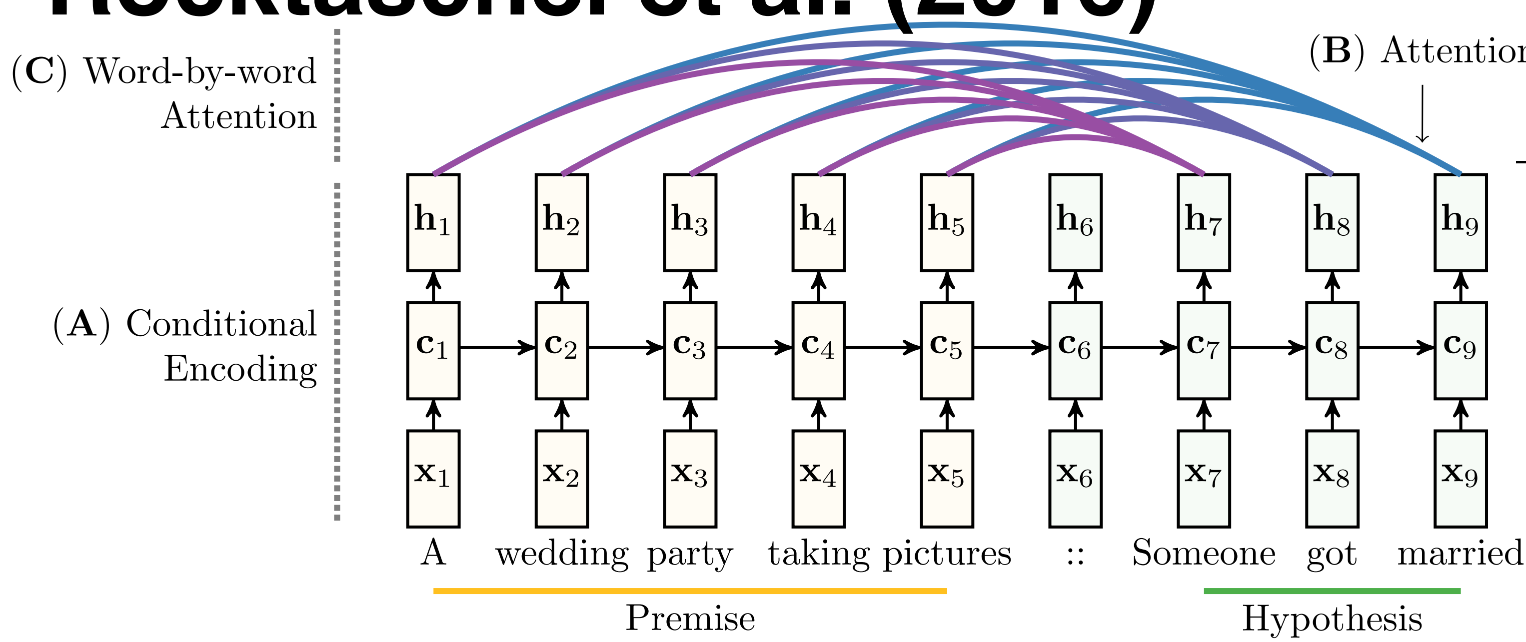


Bos (2008)

Rocktäschel et al. (2016)



Natural Language Inference

A man is pointing at a silver sedan.

No man is pointing at a car.

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

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Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

A man is pointing at a silver **sedan**.

A man is pointing at a silver **car**. SUB(**sedan**, **car**) $\sqsubset$ yes

No man is pointing at a car.

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

A man is pointing at a silver sedan.

A man is pointing at a **silver** car. SUB(sedan, car) $\sqsubset$ yes

A man is pointing at a car. DEL(**silver**) $\sqsubset$ yes

No man is pointing at a car.

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

A man is pointing at a silver sedan.			
A man is pointing at a silver car.	SUB(sedan, car)	$\sqsubset$	yes
A man is pointing at a car.	DEL(silver)	$\sqsubset$	yes
No man is pointing at a car.	INS(**no**)	$\wedge$	no

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

A man is pointing at a silver sedan.

Natural Language Inference

A man is pointing at a silver sedan.

Jimmy Dean refused to dance without pants.

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

A man is pointing at a silver sedan.

Last December they had argued that the council had failed to consider possible environmental effects of contaminated land at the site.

Natural Language Inference

A man is **pointing** at a **silver** **sedan**.

Last December they had argued that the council had failed to consider possible environmental effects of contaminated land at the site.

Natural Language Inference

A man is **pointing** at a **silver** **sedan**.

Last December they had **argued that** the council had **failed to consider** **possible environmental** **effects** of contaminated land at the site.

Natural Language Inference

Question Answering

Last December they had argued that **the council had failed to consider possible environmental effects** of contaminated land at the site.

Did the council **consider** the **environmental effects**?

Yes/No

Natural Language Inference

Summarization

Last December they had argued that **the council had failed to consider possible environmental effects** of contaminated land at the site.

They argued that the council **didn't consider environmental effects**.

Natural Language Inference

Dialogue

I decided I don't want to go to that **party** on Saturday.

Remove from calendar?

Wish List

Wish List

- We want to **get out of the "lab"** and model language that people actually use

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- We want to **get out of the “lab”** and model language that people actually use
- We want rules for logical composition that are **descriptive rather than prescriptive** based on judgements by **real people**

Wish List

- We want to **get out of the "lab"** and model language that people actually use

- We want rules for logical composition that are **descriptive rather than prescriptive** based on judgements by **real people**

- We want methods that are **derived from data**, rather than reliant on lexicons or ontologies

Last December they had argued that the council had failed to consider possible effects of contaminated land at the site.

The council considered environmental consequences.

Last December they had argued that the council had failed to consider possible effects of contaminated land at the site.

The council considered environmental consequences.

SUB(**effects**, **consequences**)

Last December they had argued that the council had failed to consider possible **effects** of contaminated land at the site.

The council considered environmental **consequences**.

lexical semantics

INS(**environmental**)

Last December they had argued that the council had failed to consider possible effects of contaminated land at the site.

The council considered **environmental** consequences.

modifiers

DEL(**possible**)

Last December they had argued that the council had failed to consider **possible** effects of contaminated land at the site.

The council considered **environmental** consequences.

(non-subsective) modifiers

SUB(**consider**, **consider**)

Last December they had argued that the council had failed to **consider** possible effects of contaminated land at the site.

The council **considered** environmental consequences.

predicates

DEL(**fail to**)

Last December they had argued that the council had **failed to** consider possible effects of contaminated land at the site.

The council considered environmental consequences.

“higher order” predicates

SUB(**effects**, **consequences**)

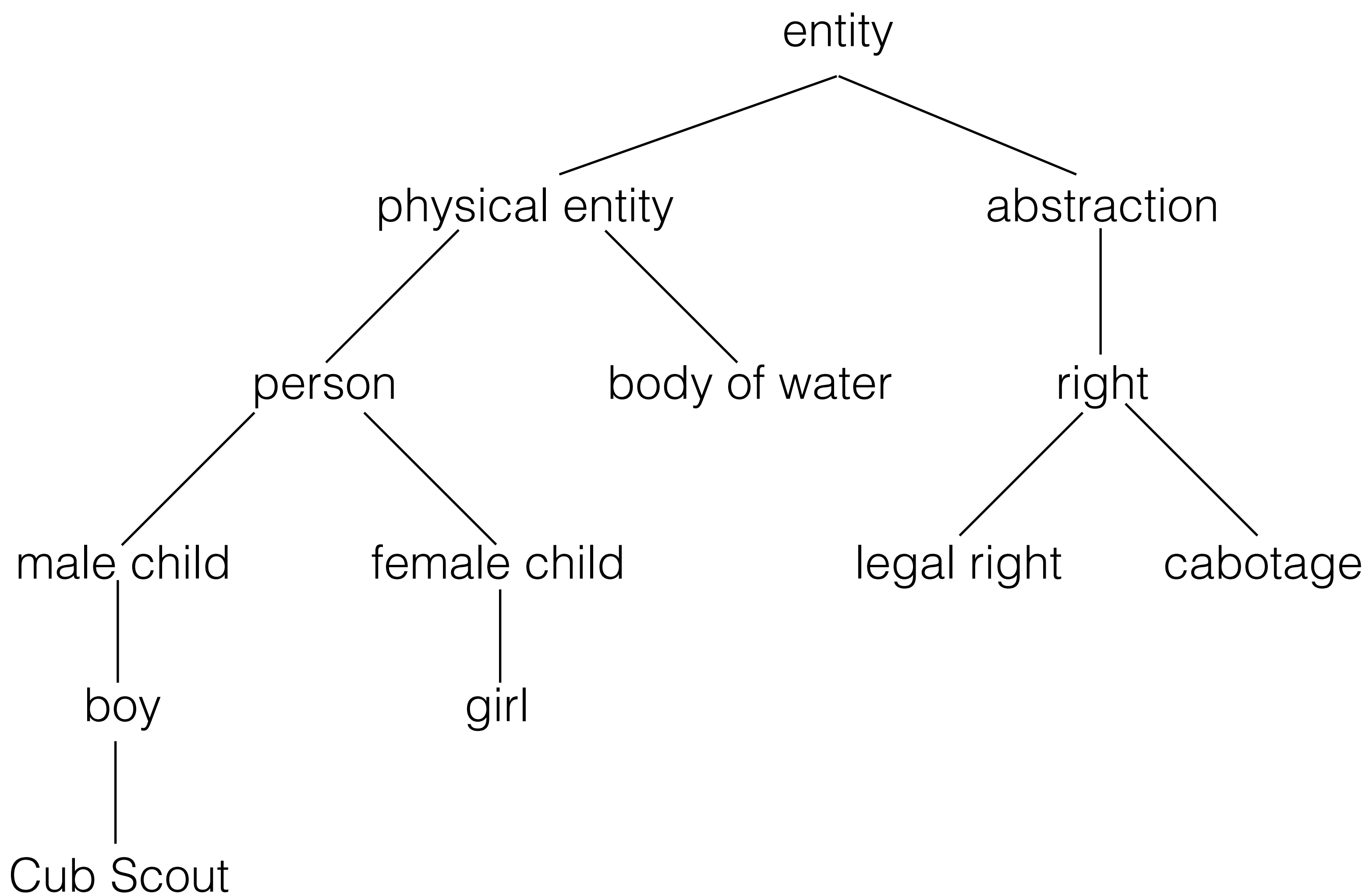
Last December they had argued that the council had failed to consider possible **effects** of contaminated land at the site.

The council considered environmental **consequences**.

lexical semantics

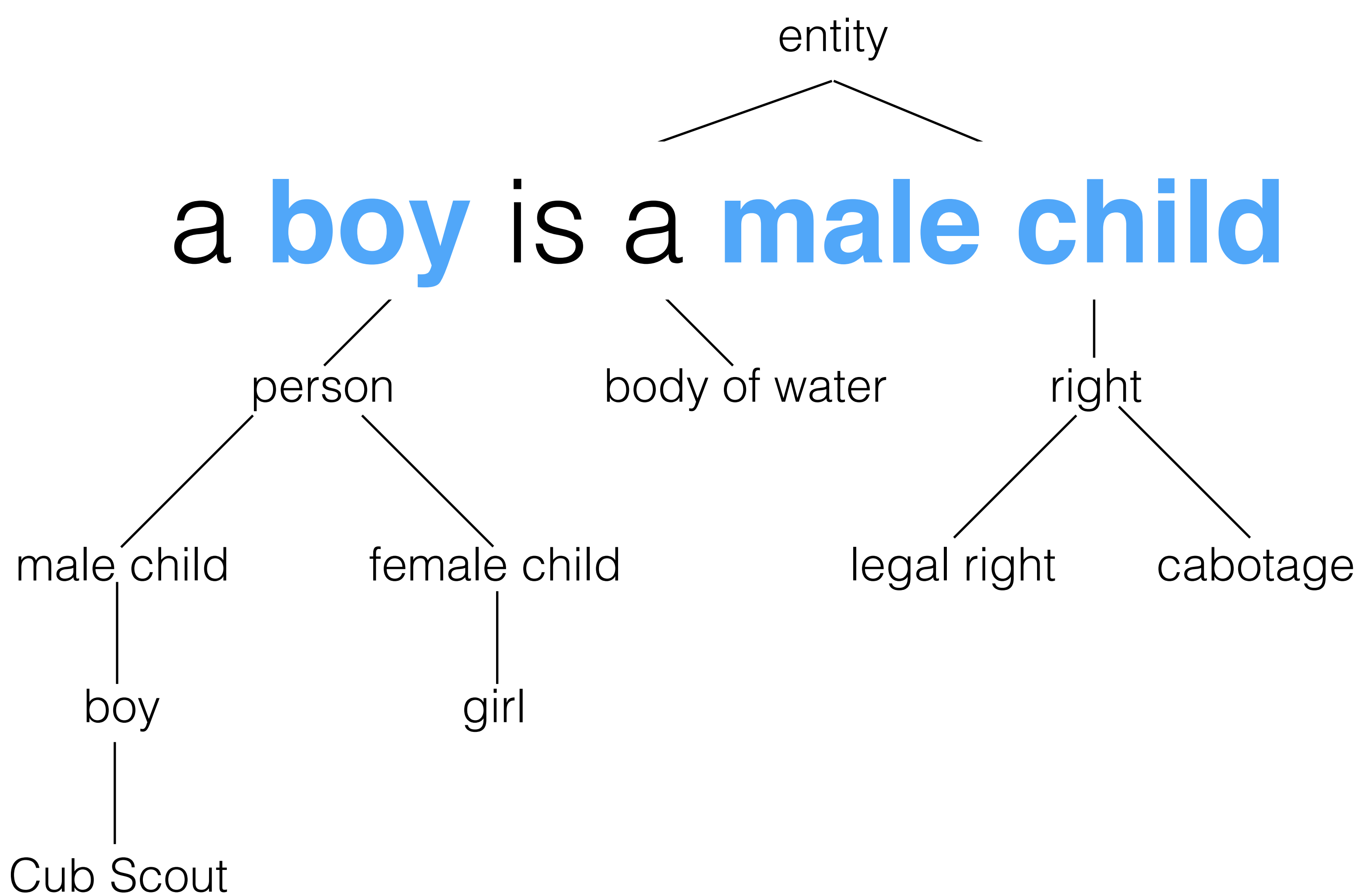
Lexical Semantics

Lexical Semantics



WordNet

Lexical Semantics



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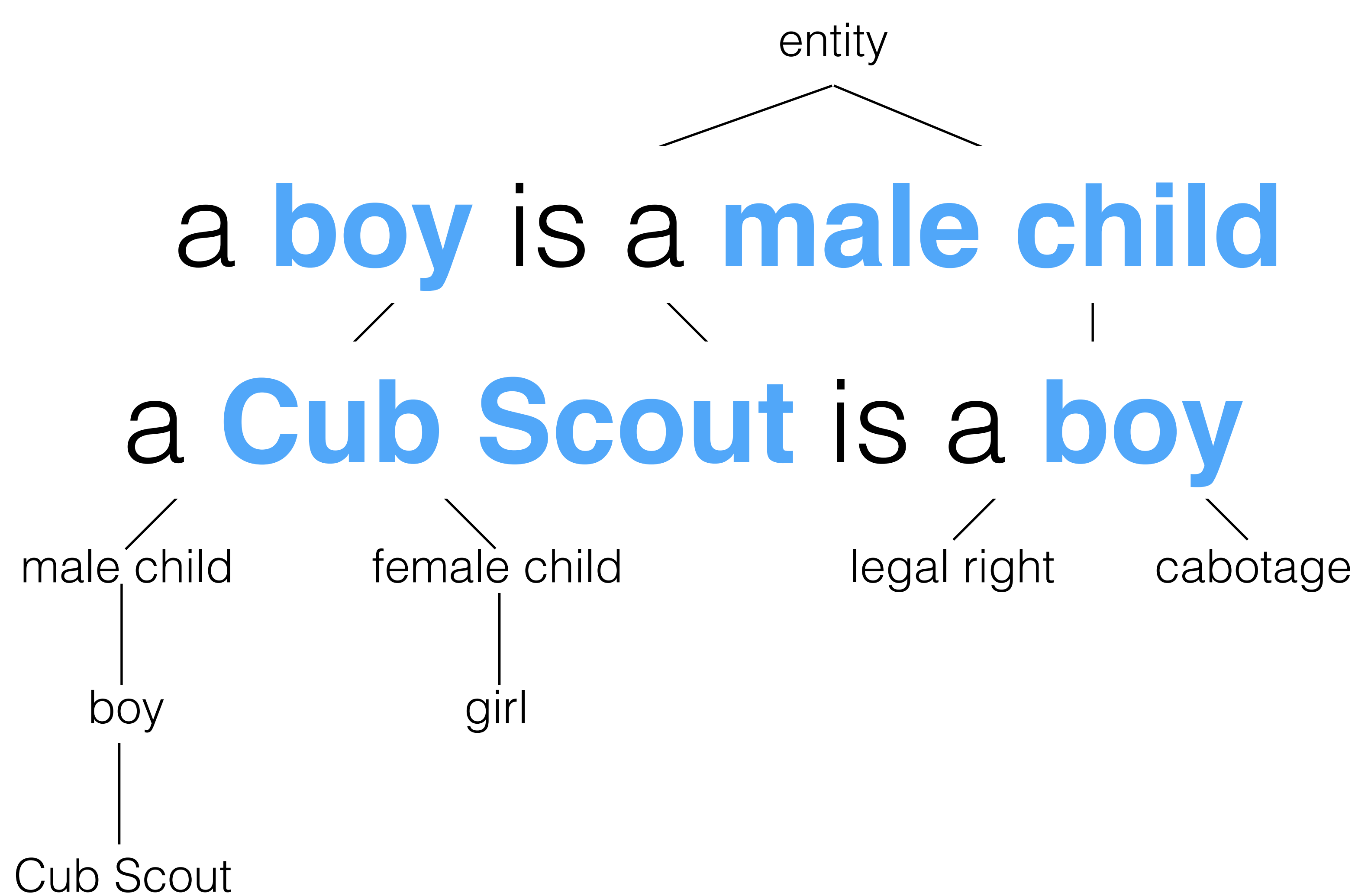

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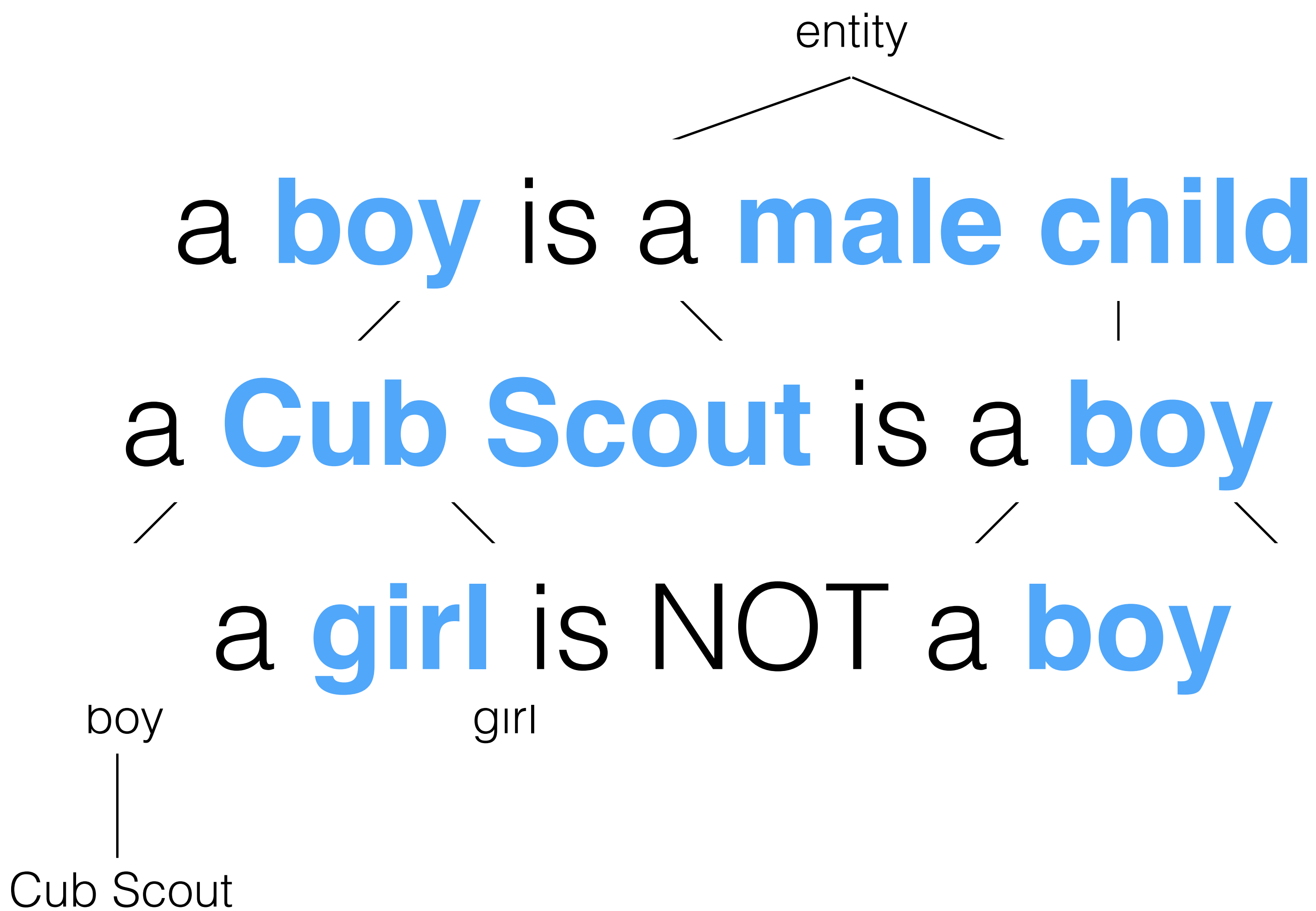

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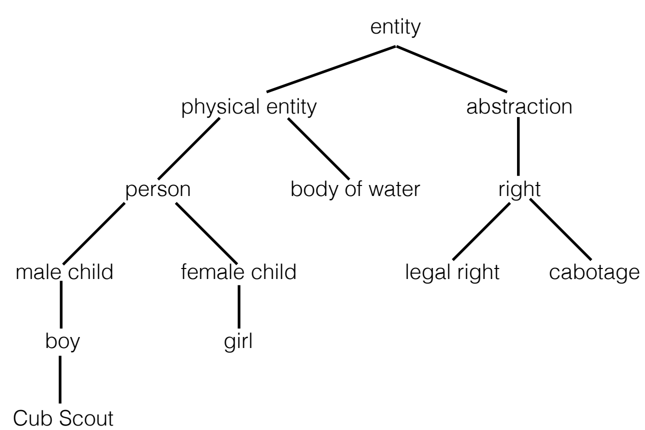
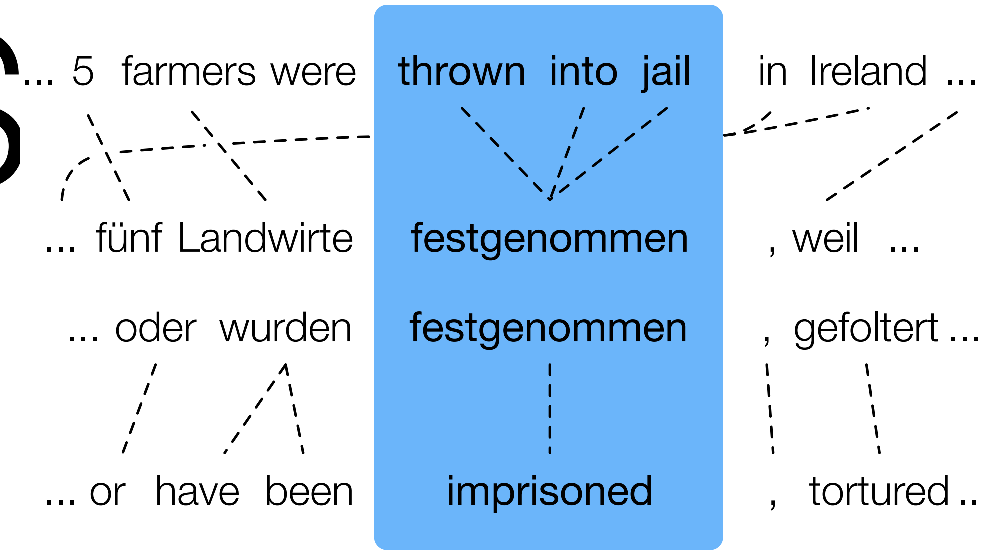
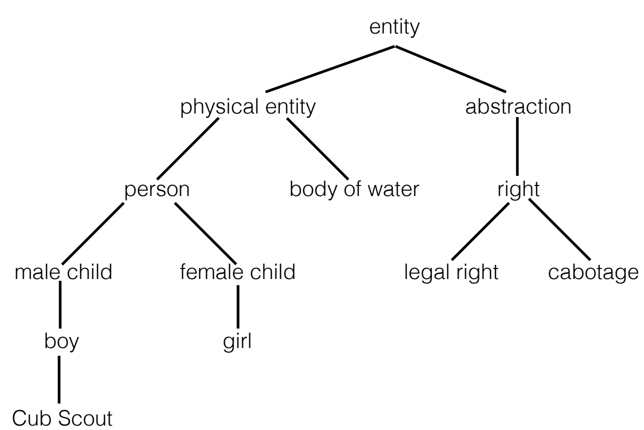


WordNet

Lexical S



Bilingual Pivoting (PPDB)



WordNet

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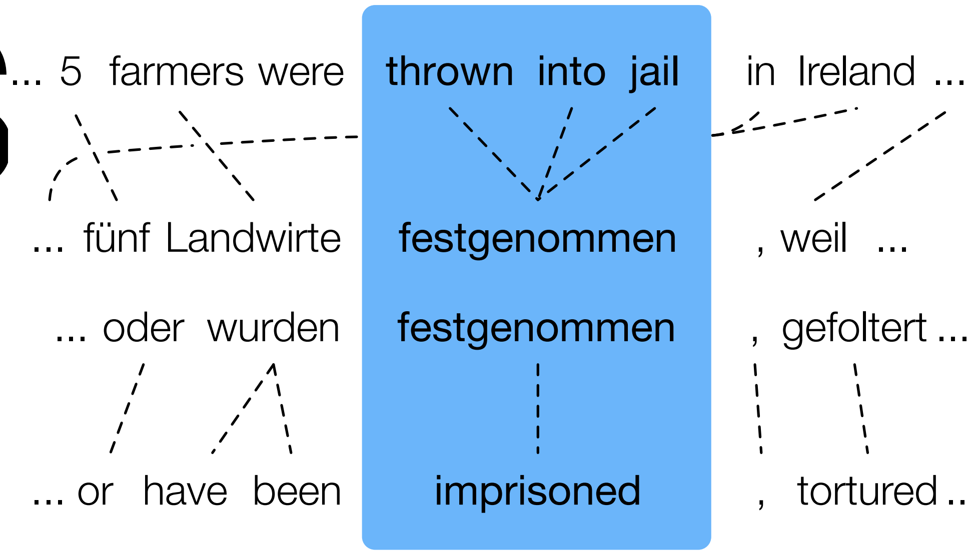

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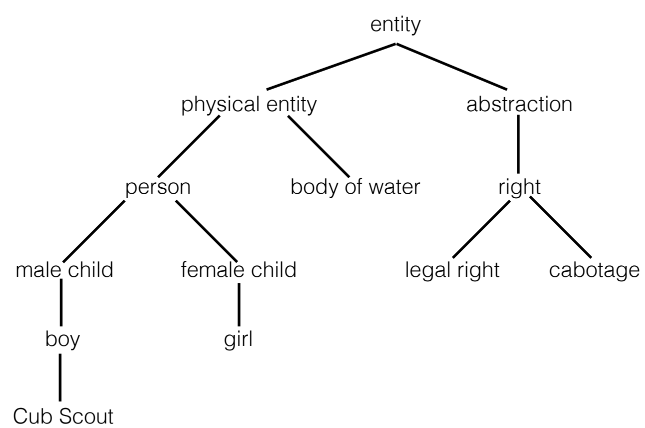
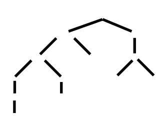


WordNet

Vector Space Models (word2vec)

Lexical Semantics



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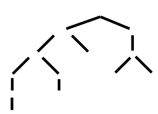
boy	pops	boy	bachelor	boy	foal	boy	cub
boy	youngster	boy	soldier	boy	chum	boy	wolf
boy	brother	boy	sweetheart	boy	blood	boy	honey

Lexical Semantics



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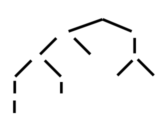
boy ⊏ kid

boy ⊏ person

Lexical Semantics



boy | girl

boy | puppy

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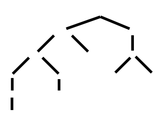

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boy # toddler

boy # idiot

The Paraphrase Database

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The Paraphrase Database

~100M word and phrase pairs

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boy	sons	boy	dude	[illegible]	[illegible]	[illegible]	[illegible]
boy	guys	boy	fella	[illegible]	[illegible]	[illegible]	[illegible]
boy	males	boy	laddie	boy	[illegible]	[illegible]	[illegible]
boy	son	boy	gentleman	boy	[illegible]	[illegible]	[illegible]
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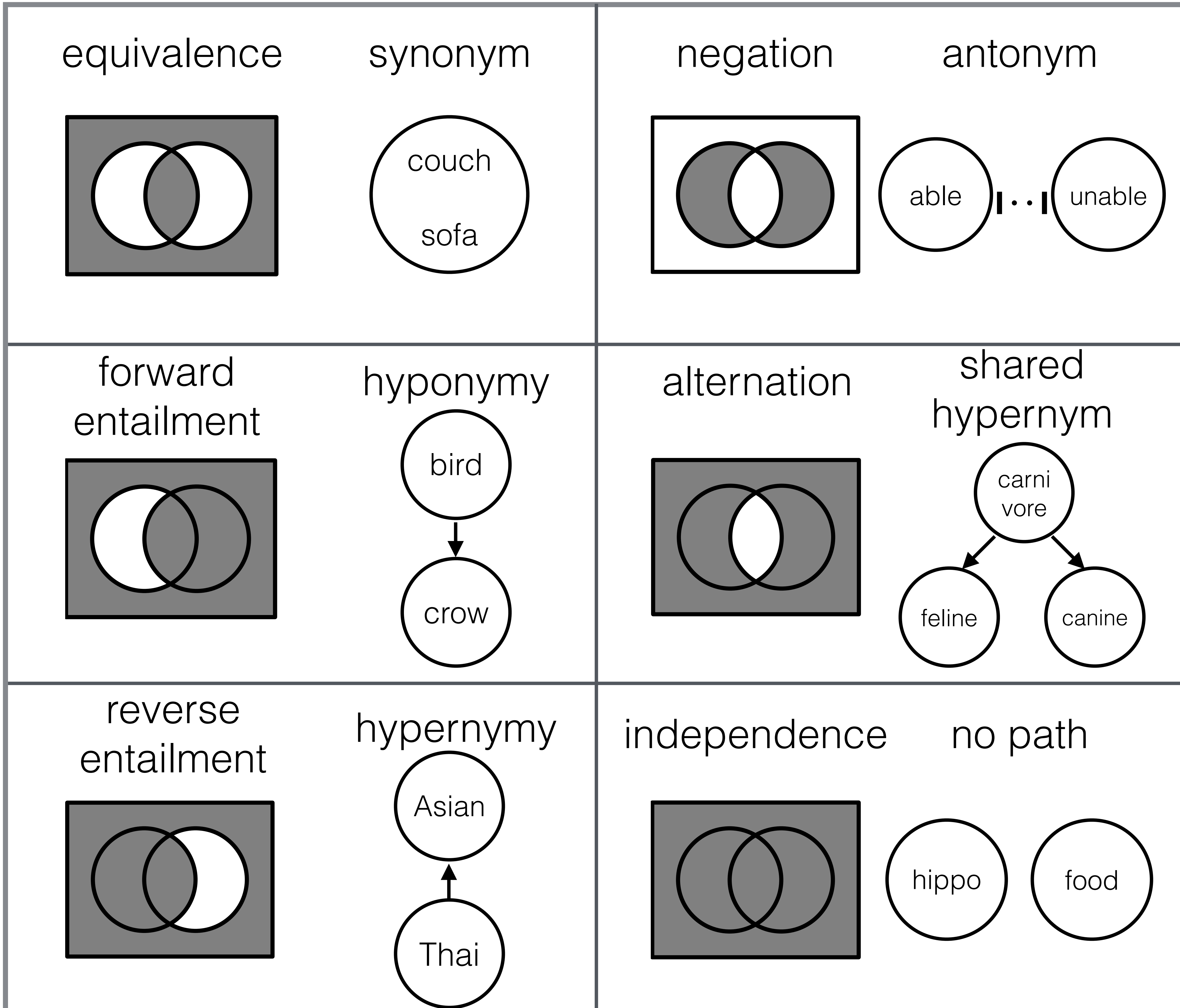
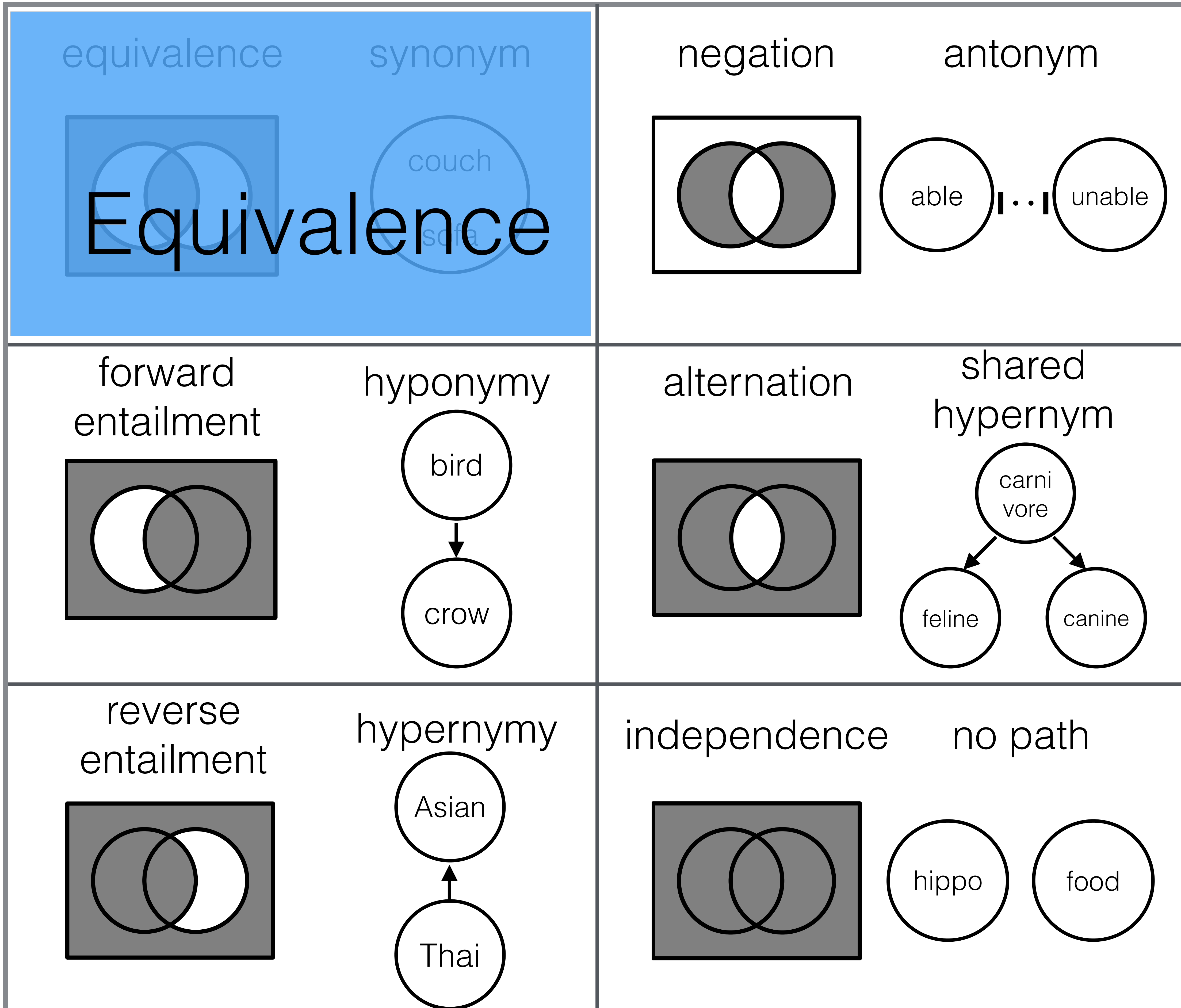


Adding Semantics to Data-Driven Paraphrasing. (Pavlick et al. ACL 2015)



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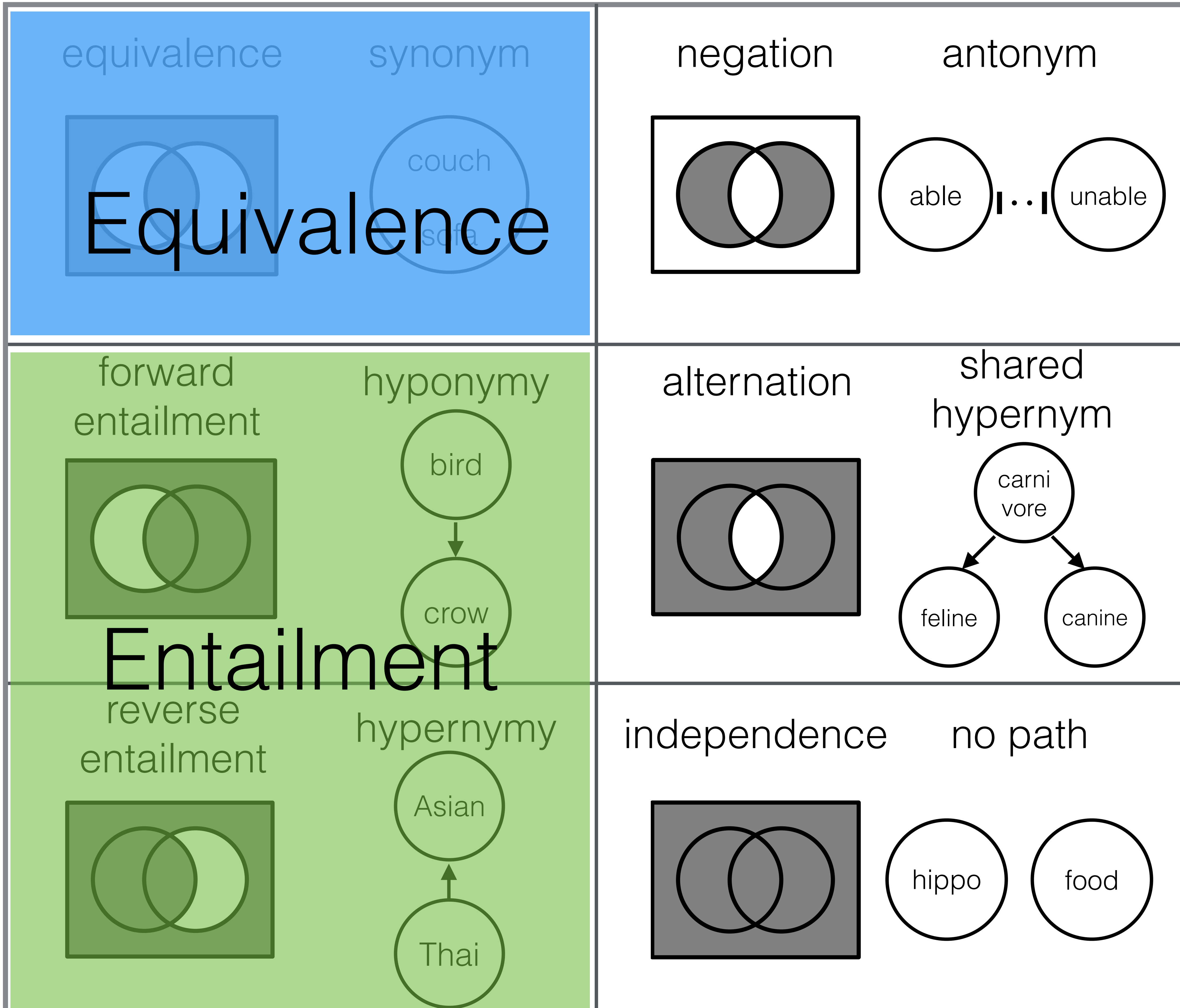

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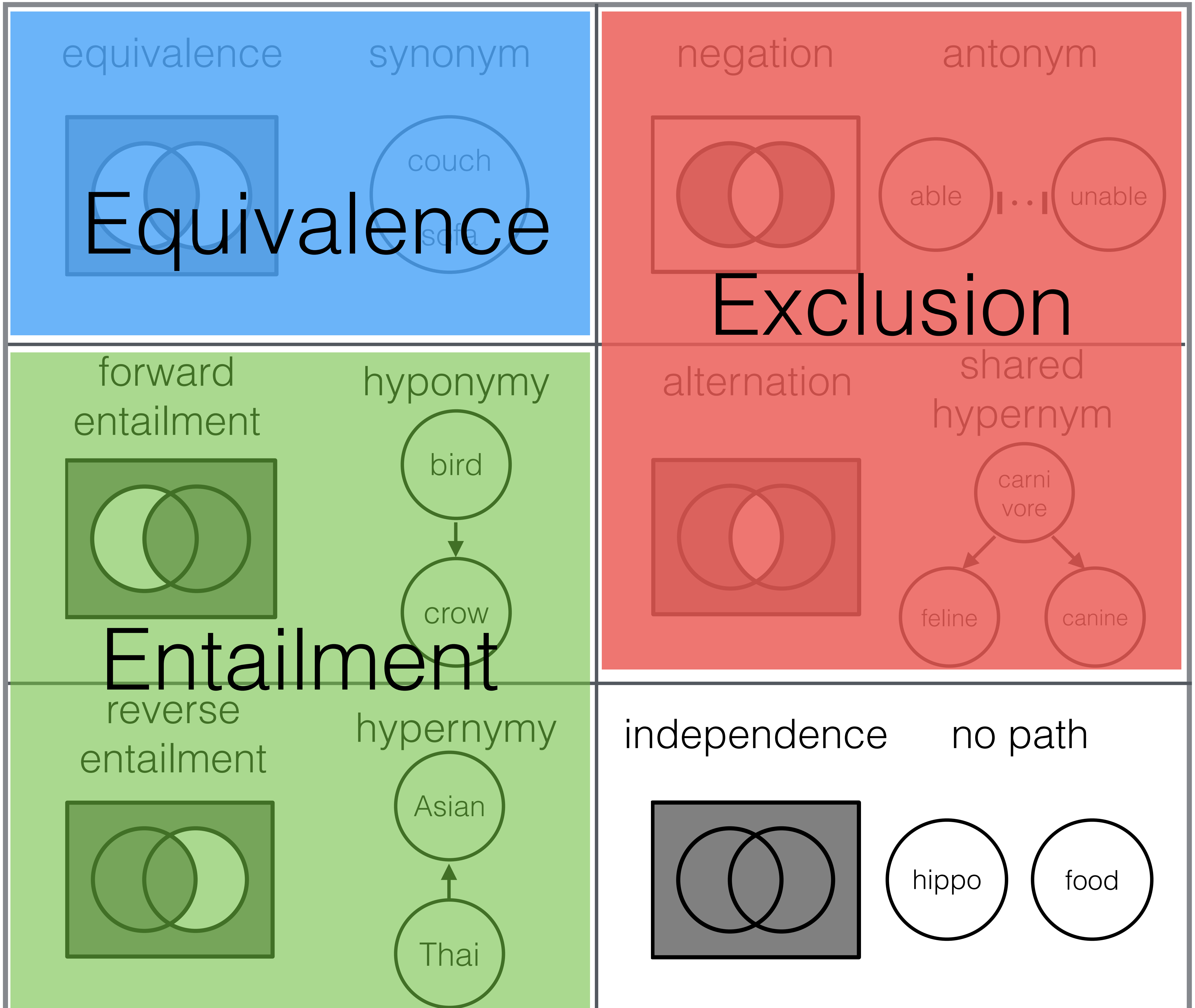

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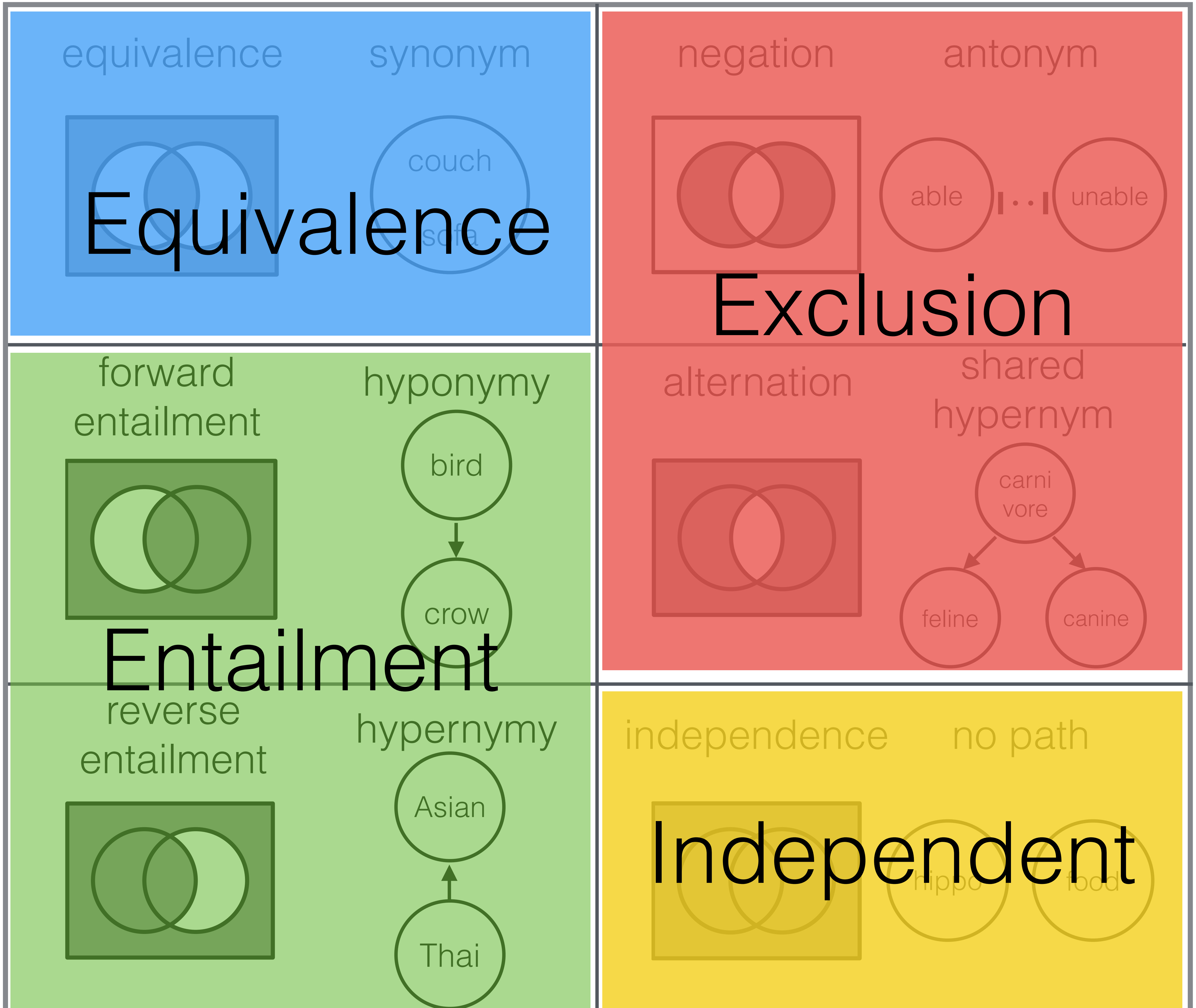

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Monolingual Features

symmetric and asymmetric similarities based on dependency context

	nsubj-draw	lost-dep	nsubj-vomit	poss-shoe	dep-brother	nsubjpass-buckled	nsubj-yell	rcmod-tired	…			
little girl	1	1	1	1	1	0	0	1	0	0	1	0
kid	1	0	1	0	1	1	1	1	1	1	1	1

`cosine:0.431 lin:0.544`

`balprec:0.396 weeds:0.289…`

Discovery of Inference Rules from Text. (Lin and Pantel SIGKDD 2001)

Monolingual Features

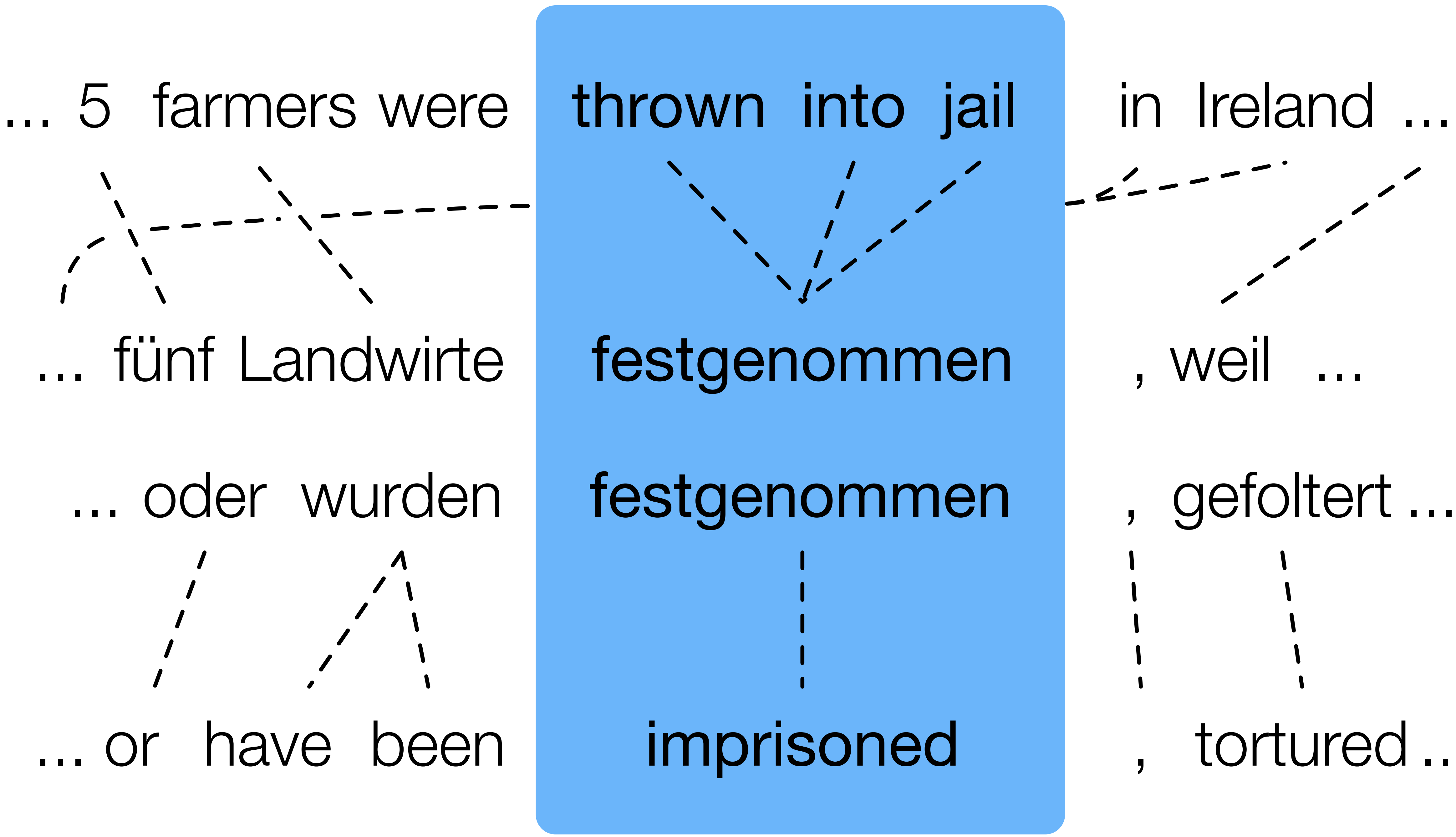
lexico-syntactic patterns

*…if this can happen to my **little girl** , it can happen to other **kids**…*


```
[X]<-nmod-[happen]-advcl->[happen]-nmod->[Y]:1
[X]<-conj-[Y]:1
[X]<-pobj-[as]<-prep-[know]<-rcmod-[Y]:1
```

Automatic acquisition of hyponyms from large text corpora. (Hearst COLING 1992)
Semantic taxonomy induction from heterogenous evidence. (Snow et al. ACL 2006)

Bilingual Features



Paraphrasing with bilingual parallel corpora. (Bannard and Callison-Burch ACL 2005)
PPDB: The paraphrase database. (Ganitkevitch et al. NAACL 2013)

Monolingual features only

	equiv.	entail.	excl.	other	indep.
equiv.	58%	20%	4%	15%	3%
entail.	20%	51%	3%	18%	7%
excl.	26%	14%	37%	17%	6%
other	8%	13%	2%	71%	6%
indep.	15%	21%	5%	36%	23%

Bilingual features only

	equiv.	entail.	excl.	other	indep.
equiv.	62%	21%	5%	4%	8%
entail.	27%	5%	7%	7%	54%
excl.	6%	14%	30%	36%	14%
other	1%	7%	6%	78%	8%
indep.	8%	19%	9%	30%	35%

Adding Semantics to Data-Driven Paraphrasing. (Pavlick et al. ACL 2015)

Monolingual features only

	equiv.	entail.	excl.	other	indep.
equiv.	58%	20%	4%	15%	3%
entail.	20%	51%	3%	18%	7%
excl.	26%	14%	37%	17%	6%
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indep.	8%	19%	9%	30%	35%

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Bilingual features only

Adding Semantics to Data-Driven Paraphrasing. (Pavlick et al. ACL 2015)

	equiv.	entail.	excl.	other	indep.
equiv.	83%	10%	0%	2%	4%
entail.	6%	76%	2%	7%	8%
excl.	2%	8%	73%	13%	3%
other	1%	4%	2%	88%	6%
indep.	5%	10%	3%	18%	64%

All features

Adding Semantics to Data-Driven Paraphrasing. (Pavlick et al. ACL 2015)

Equivalent	Entailment	Exclusion	Other	Independent
look at/ watch	little girl/girl	close/open	swim/water	girl/play
a person/ someone	kuwait/ country	minimal/ significant	husband/ marry	found/party
clean/ cleanse	tower/ building	boy/young girl	oil/oil price	man/talk
distant/ remote	sneaker/ footwear	nobody/ someone	country/ patriotic	profit/year
phone/ telephone	heroin/drug	blue/green	drive/ vehicle	holiday/ series
last autumn/ last fall	typhoon/ storm	france/ germany	playing/toy	city/south

Adding Semantics to Data-Driven Paraphrasing. (Pavlick et al. ACL 2015)

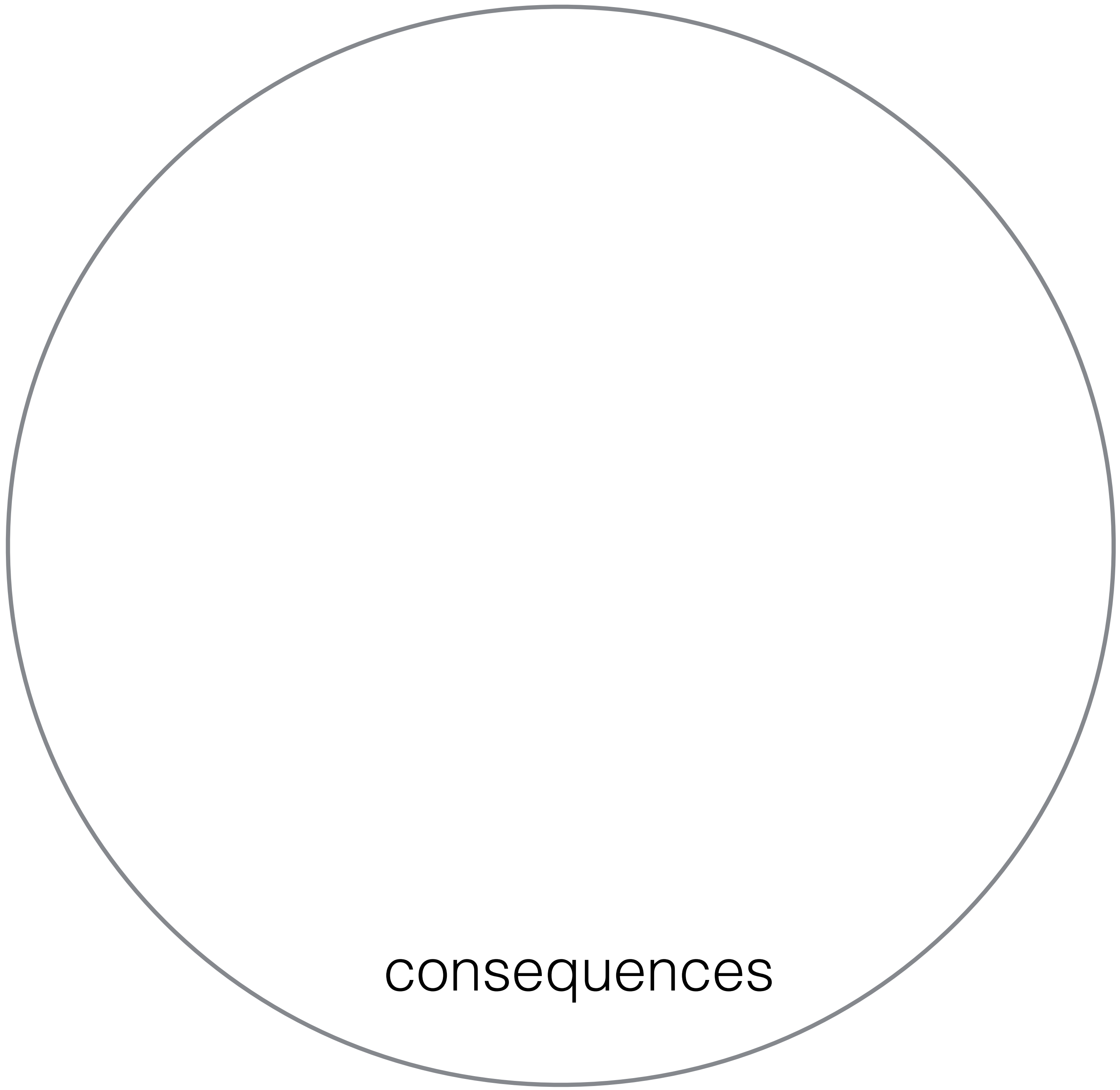
INS(**environmental**)

Last December they had argued that the council had failed to consider possible effects of contaminated land at the site.

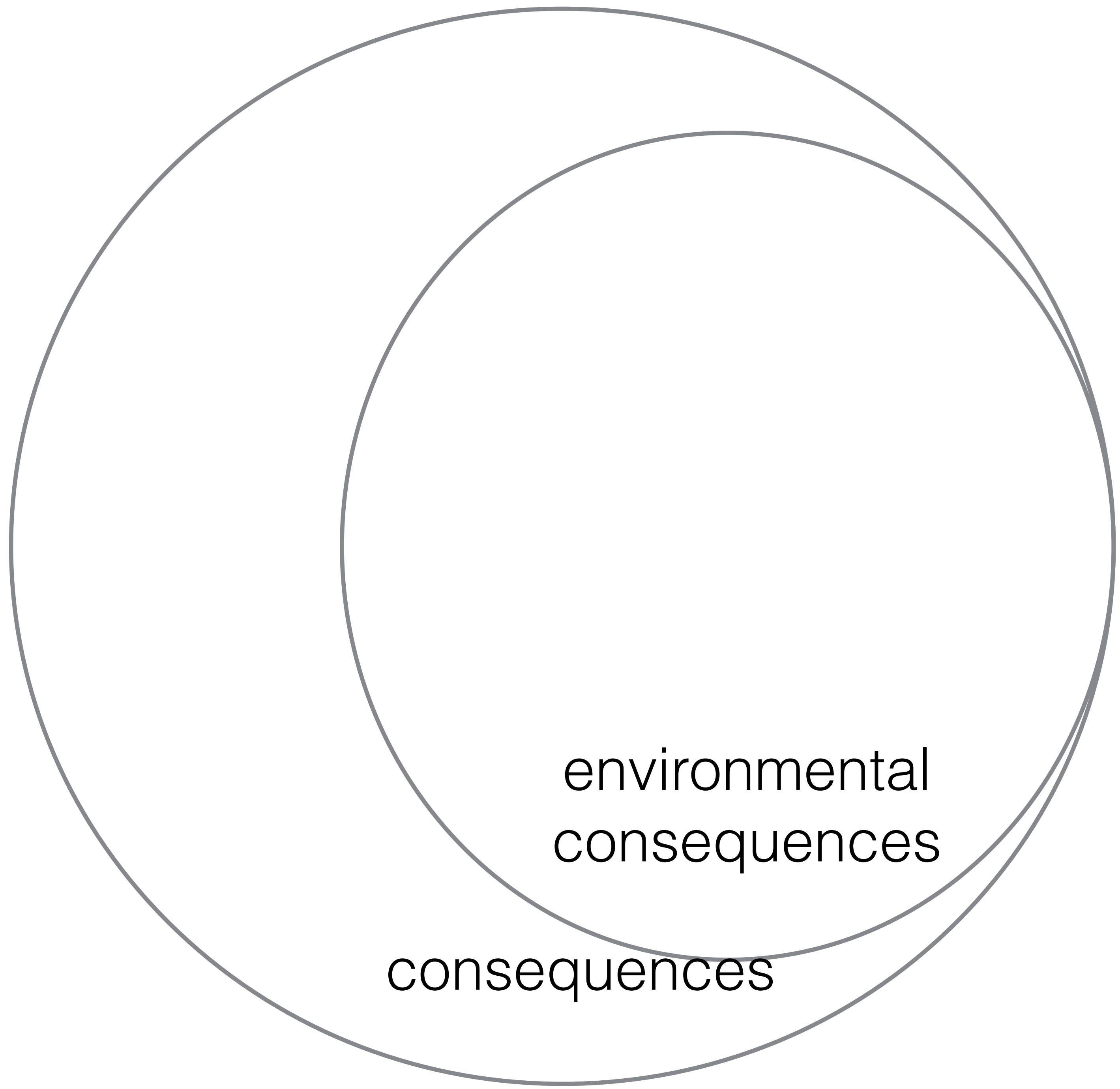
The council considered **environmental** consequences.

modifiers

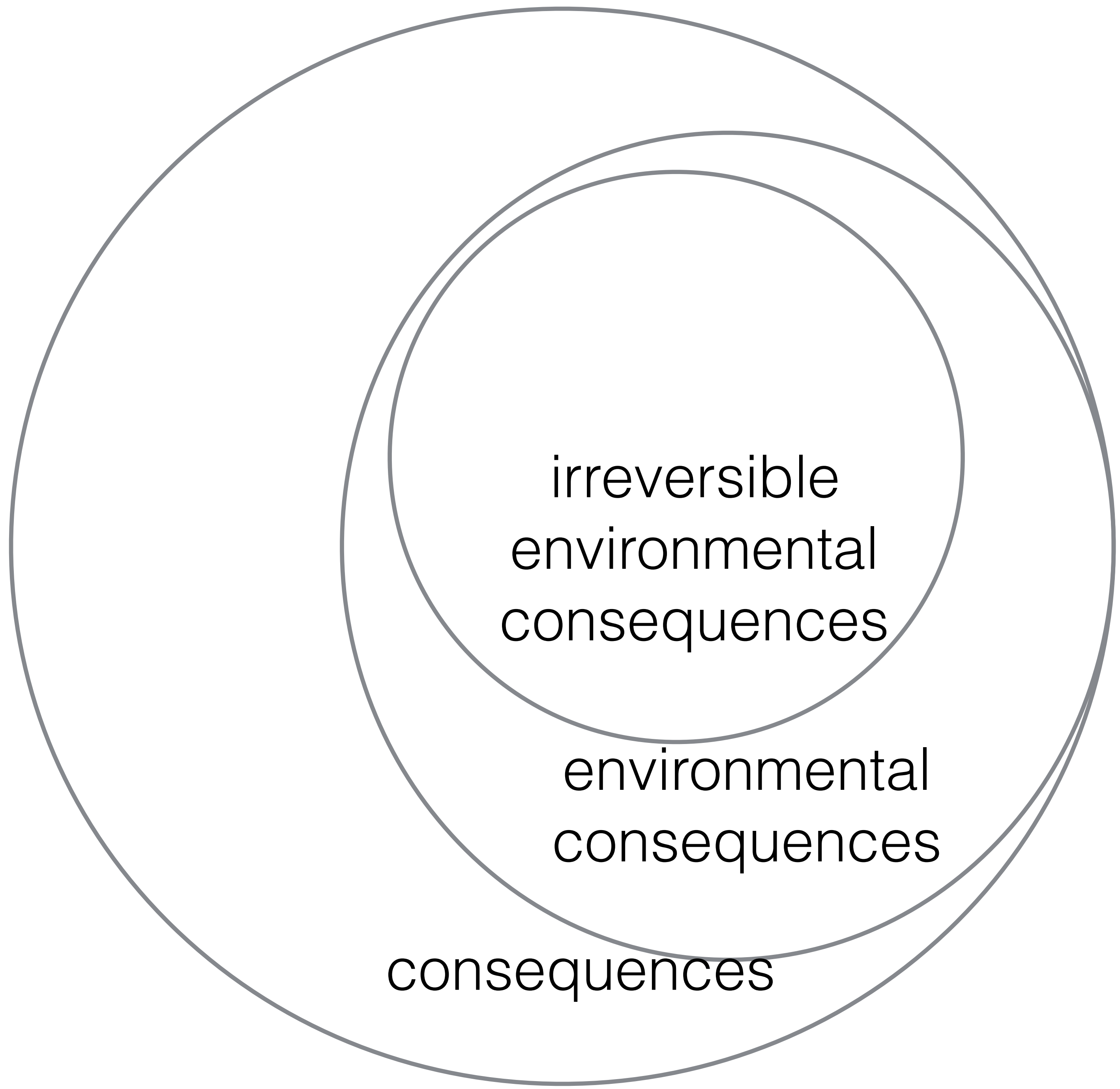
Denotational Semantics



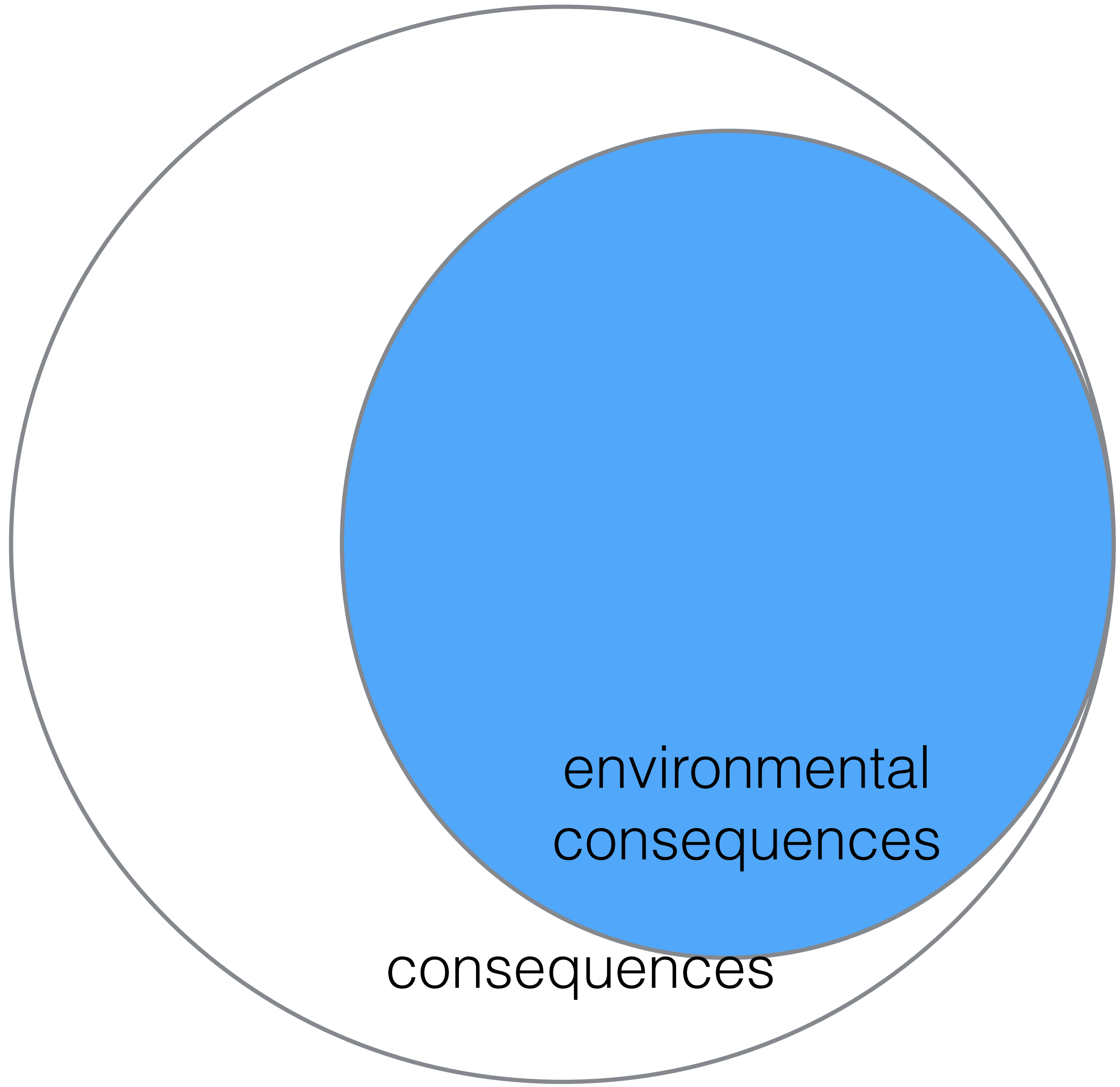
Denotational Semantics



Denotational Semantics

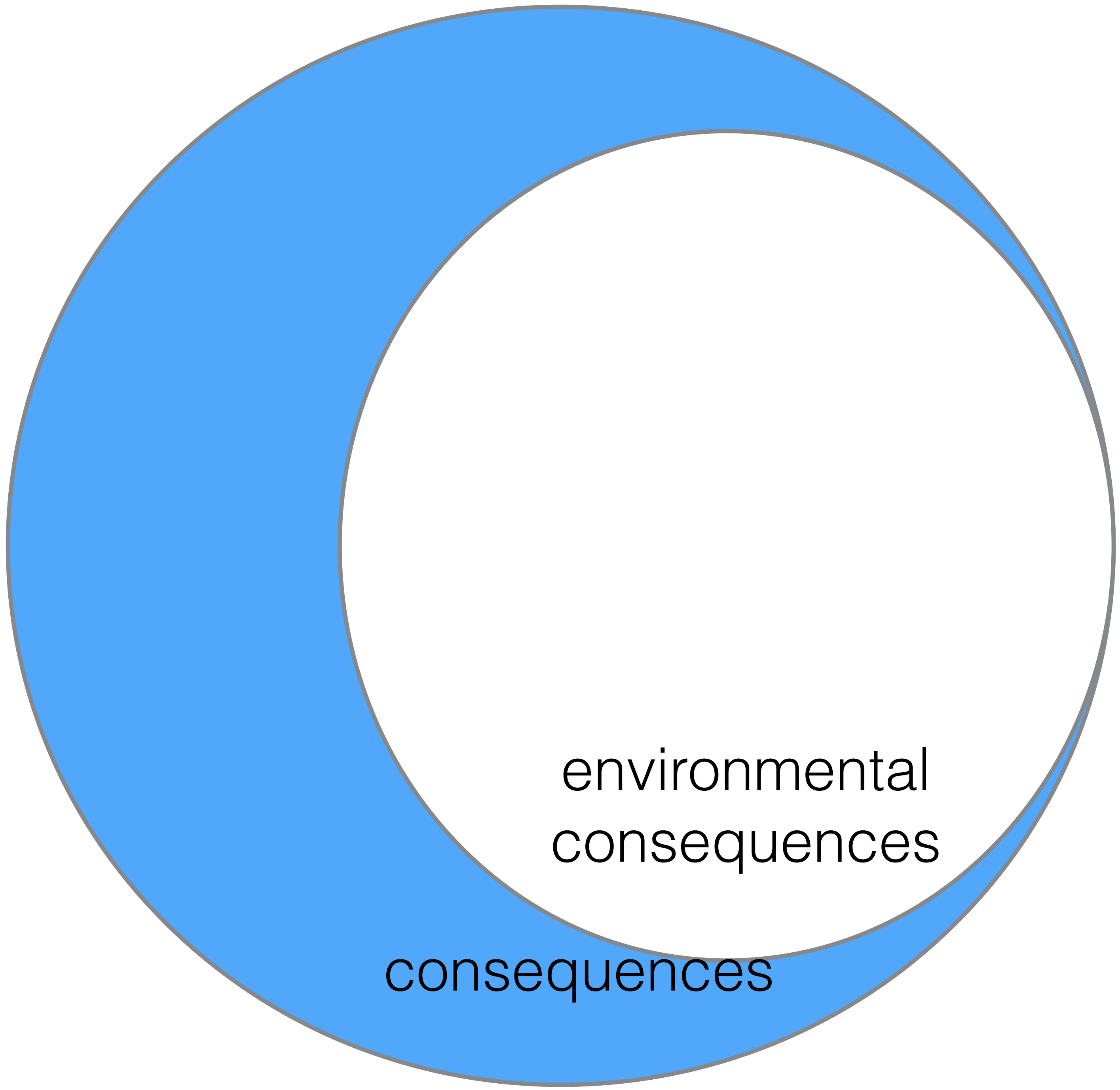


Denotational Semantics



Does **environmental consequence** entail **consequence**?

Denotational Semantics



Does **consequence**
entail **environmental consequence**?

Natural Language Inference

A man is pointing at a silver sedan.

A man is pointing at a **silver** car. SUB(sedan, car) $\sqsubset$ yes

A man is pointing at a car. DEL(**silver**) $\sqsubset$ yes

No man is pointing at a car.

Natural Language Inference. (MacCartney PhD Thesis 2009)

Natural Language Inference

From image descriptions to visual denotations. (Young et al. TACL 2014)

A man is pointing at a silver sedan.

Entailment above the word level in distributional semantics. (Baroni et al. EACL 2012)

A man is pointing at a **silver** car. SUB(sedan, car) $\sqsubset$ yes

A man is pointing at a car. DEL(**silver**) $\sqsubset$ yes

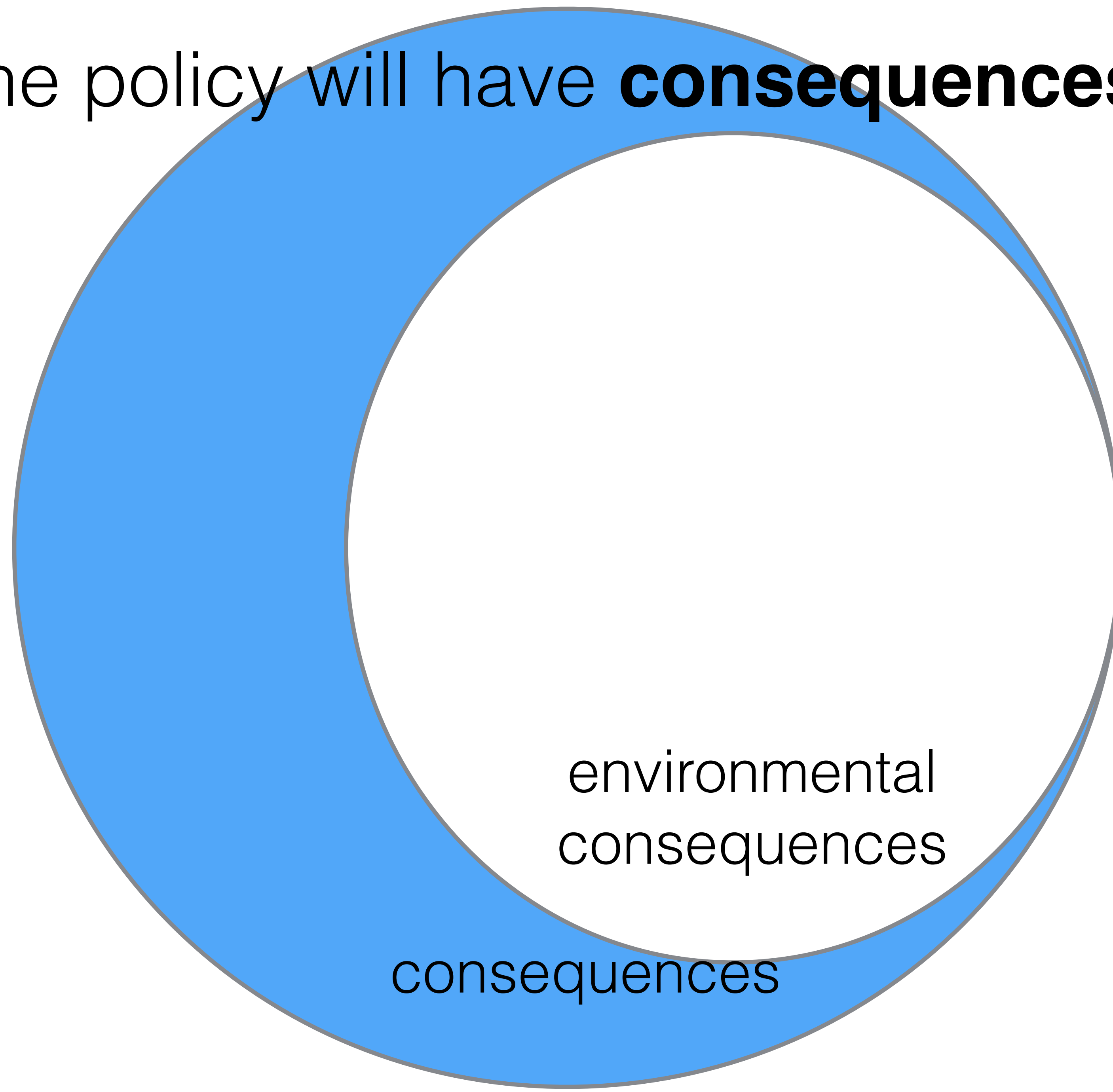
No man is pointing at a car.

BIUTEE: A Modular Open-Source System for Recognizing Textual Entailment (Stern and Dagan. ACL 2012)

Natural Language Inference. (MacCartney PhD Thesis 2009)

Denotational Semantics

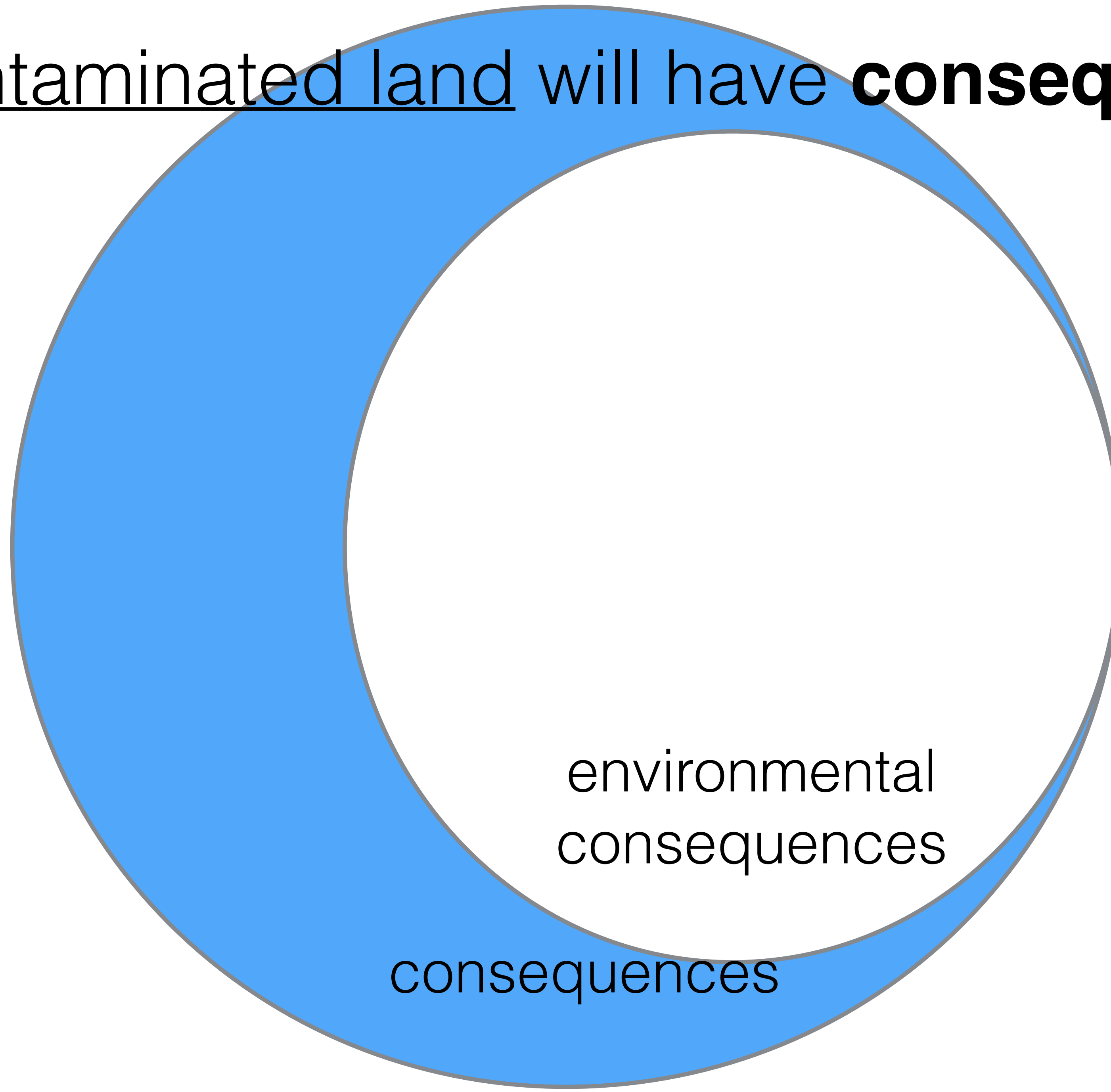
The policy will have **consequences**.



Does **consequence**
entail **environmental consequence**?

Denotational Semantics

The contaminated land will have **consequences**.



Does **consequence**
entail **environmental consequence**? ✔

Natural Logic Entailment Relations

N does not entail AN

N does entail AN

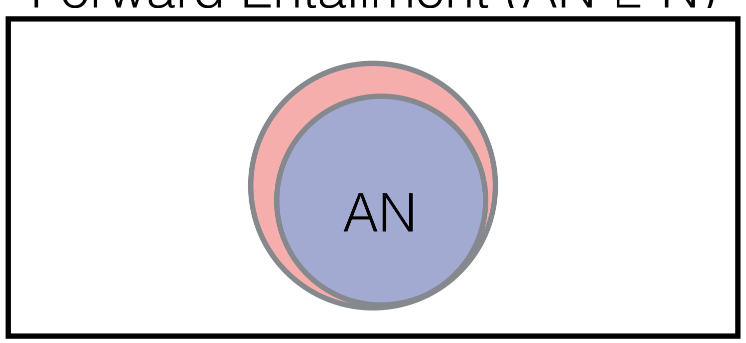
Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Natural Logic Entailment Relations

N does not entail AN

N does entail AN

Forward Entailment (AN ⊏ N)



brown dog

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Natural Logic Entailment Relations

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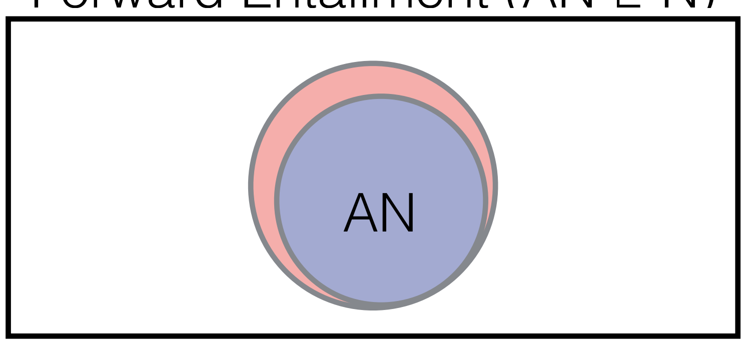
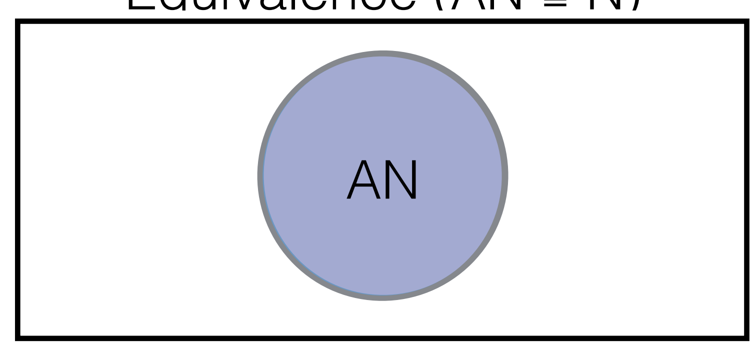
Forward Entailment (AN ⊏ N)



brown dog

N does entail AN

Equivalence (AN ≡ N)



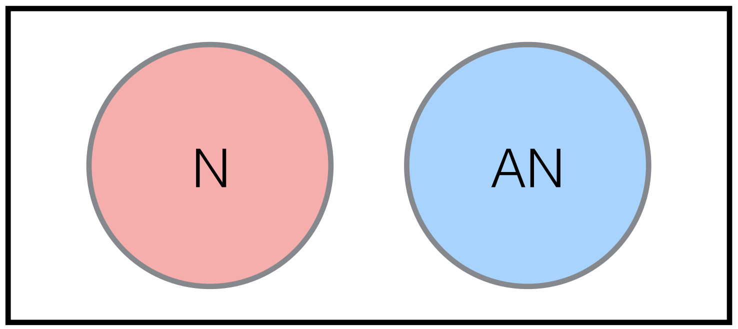
entire world

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Natural Logic Entailment Relations

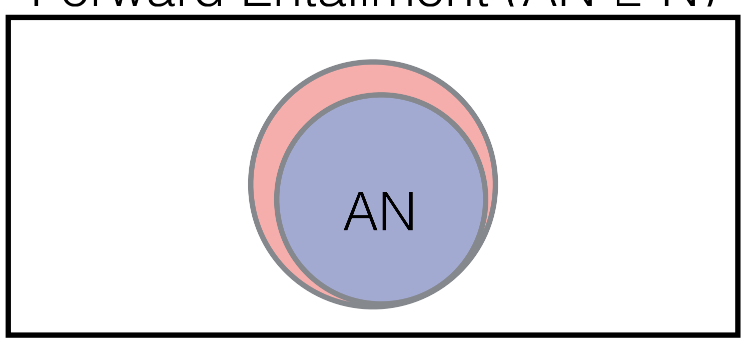
N does not entail AN

Alternation (N | AN)



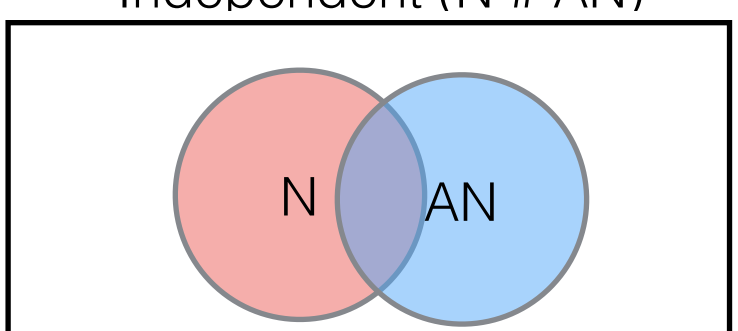
former senator

Forward Entailment (AN $\sqsubset$ N)



brown dog

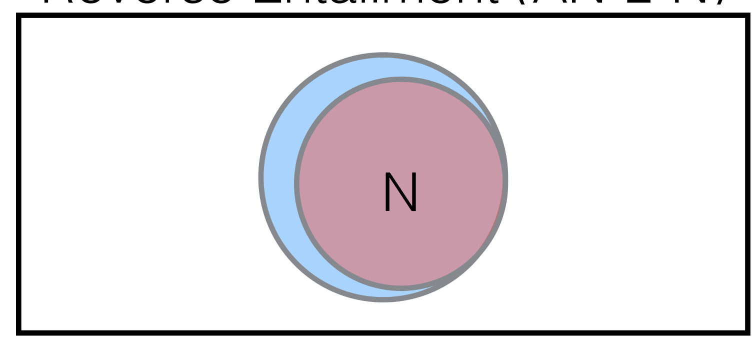
Independent (N # AN)



alleged criminal

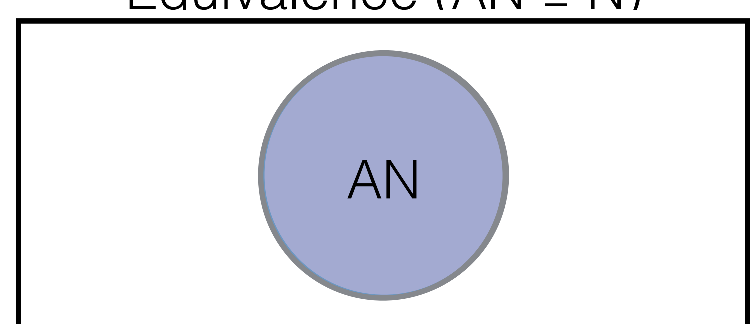
N does entail AN

Reverse Entailment (AN $\sqsupset$ N)



possible winner

Equivalence (AN $\equiv$ N)



entire world

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Experimental Design

Wellers hopes the **system** will be fully operational by 2015 .

Wellers hopes the **financial system** will be fully operational by 2015 .

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Experimental Design

Wellers hopes the **system** will be fully operational by 2015 .

Wellers hopes the **financial system** will be fully operational by 2015 .

Contradiction
Entailment
Can't Tell

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Experimental Design

Wellers hopes the **financial system** will be fully operational by 2015 .

Wellers hopes the **system** will be fully operational by 2015 .

Contradiction
Entailment
Can’t Tell

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Experimental Design

~200 human annotators
~5,000 sentences
4 genres

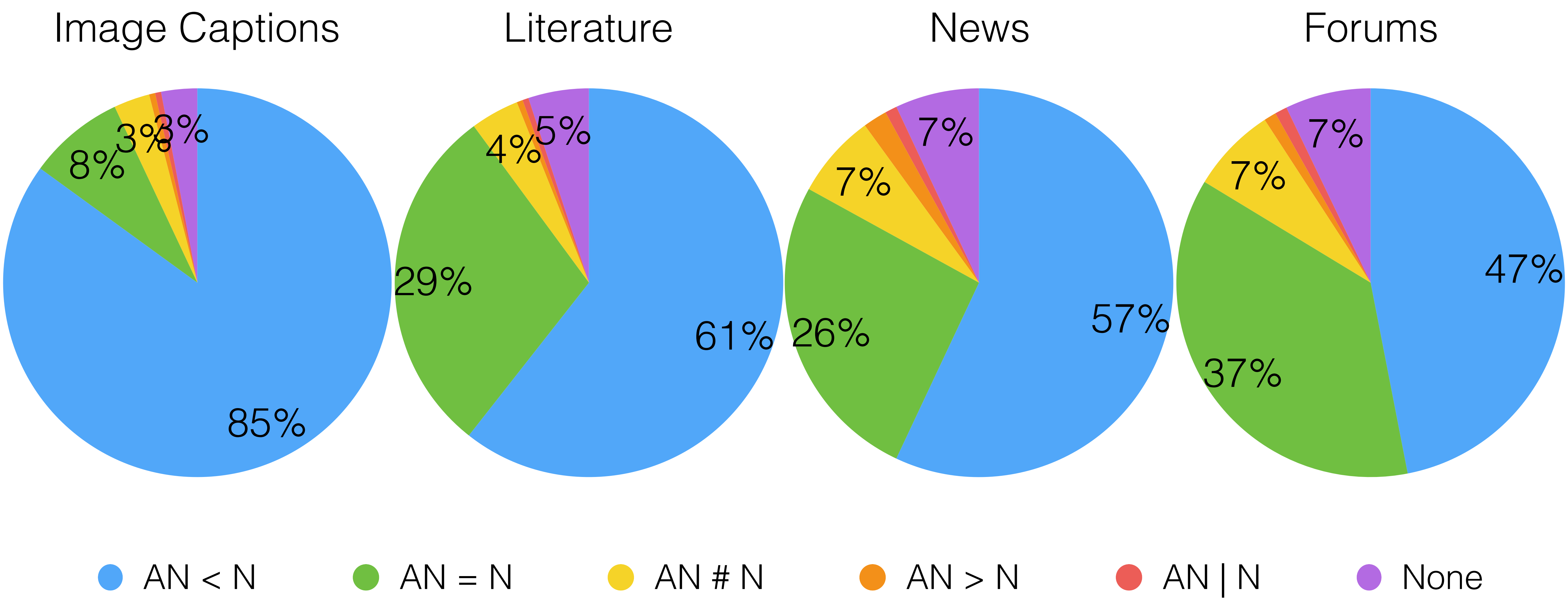
Wellers hopes the **financial system** will be fully operational by 2015 .

Wellers hopes the **system** will be fully operational by 2015 .

Contradiction
Entailment
Can't Tell

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

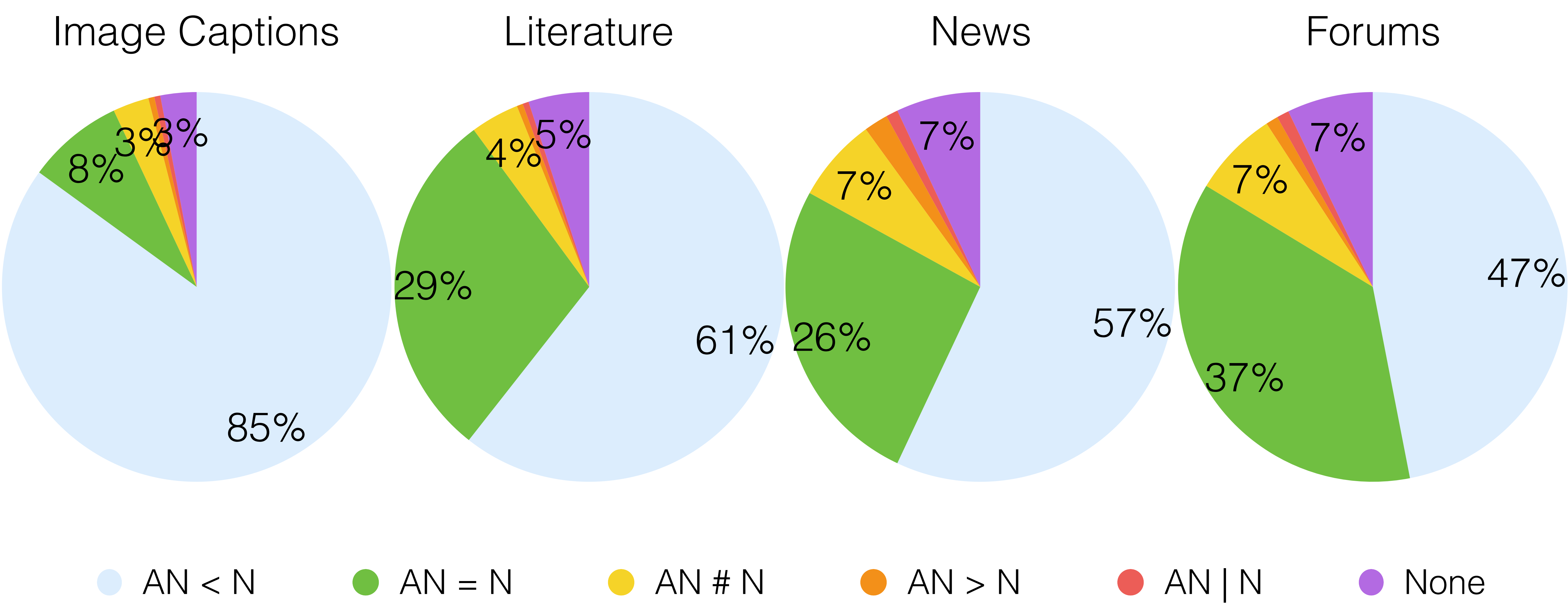
Empirical Analysis



Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Empirical Analysis

Up to 53% error rate by assuming all adjectives are restrictive.



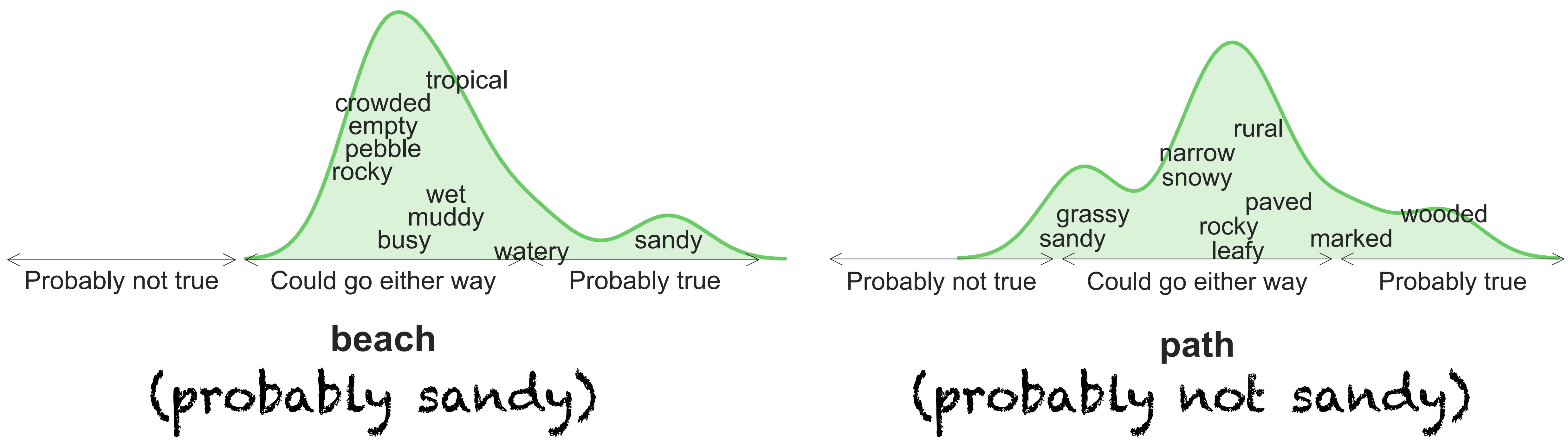
Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N entail AN?

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N entail AN?

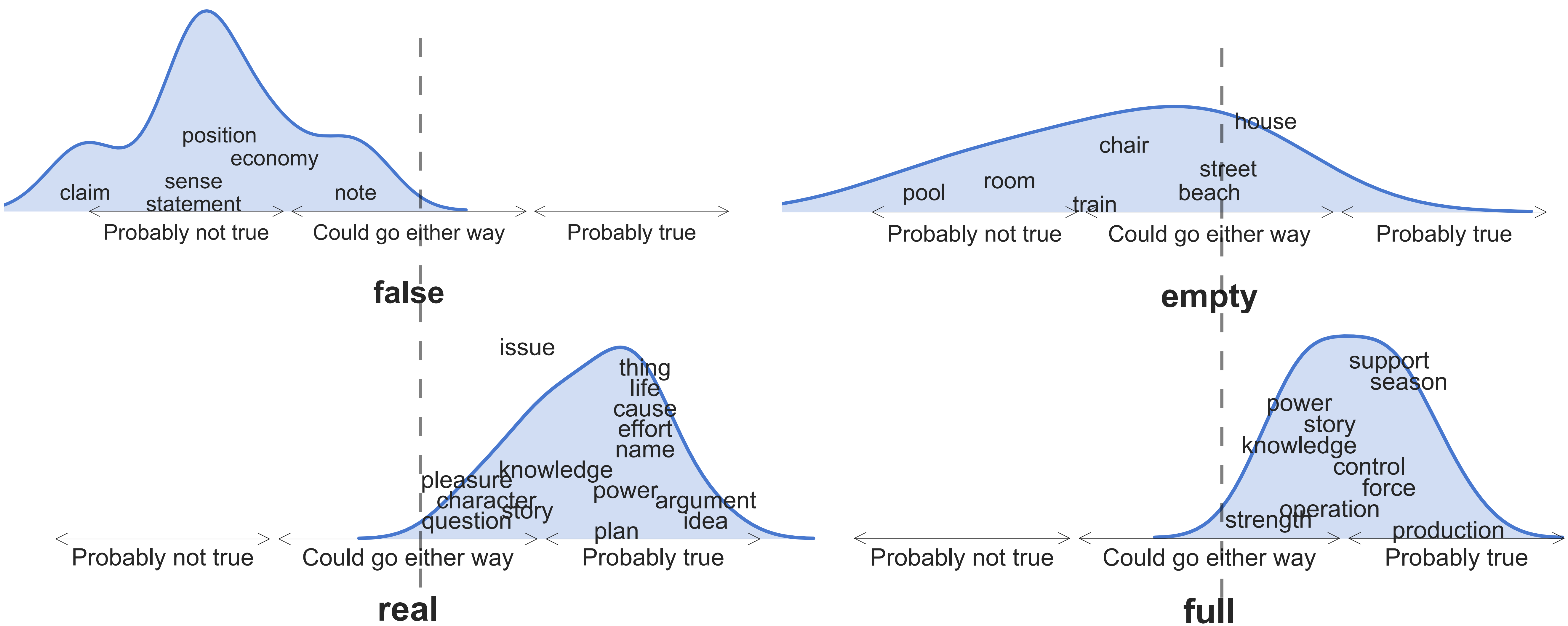
Sometimes, it is a property of the adjective and noun…



Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N entail AN?

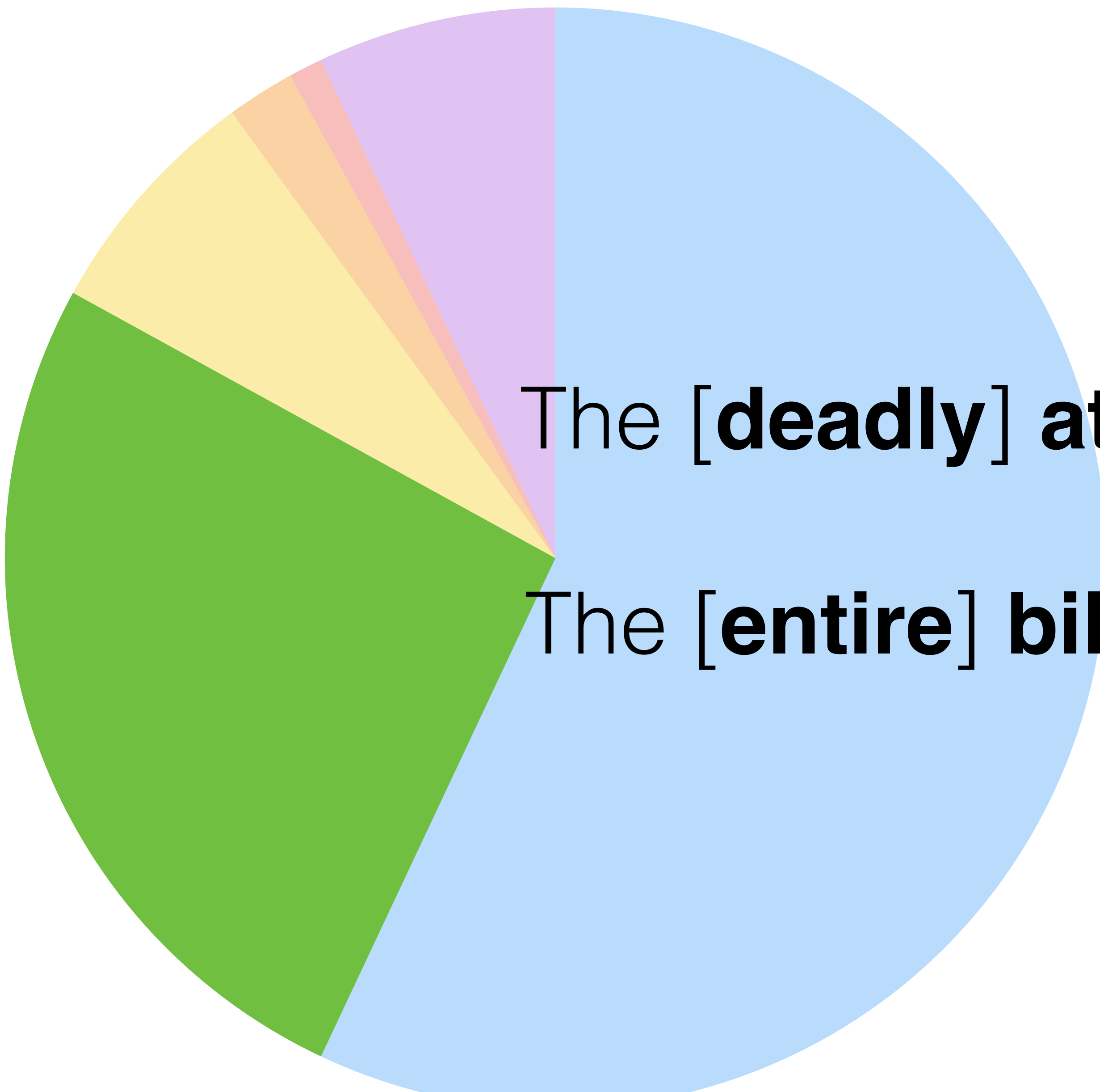
…or even just the adjective.



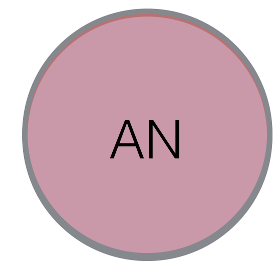
Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N entail AN?

Other times, it is a property of the context+word knowledge.



Equivalence



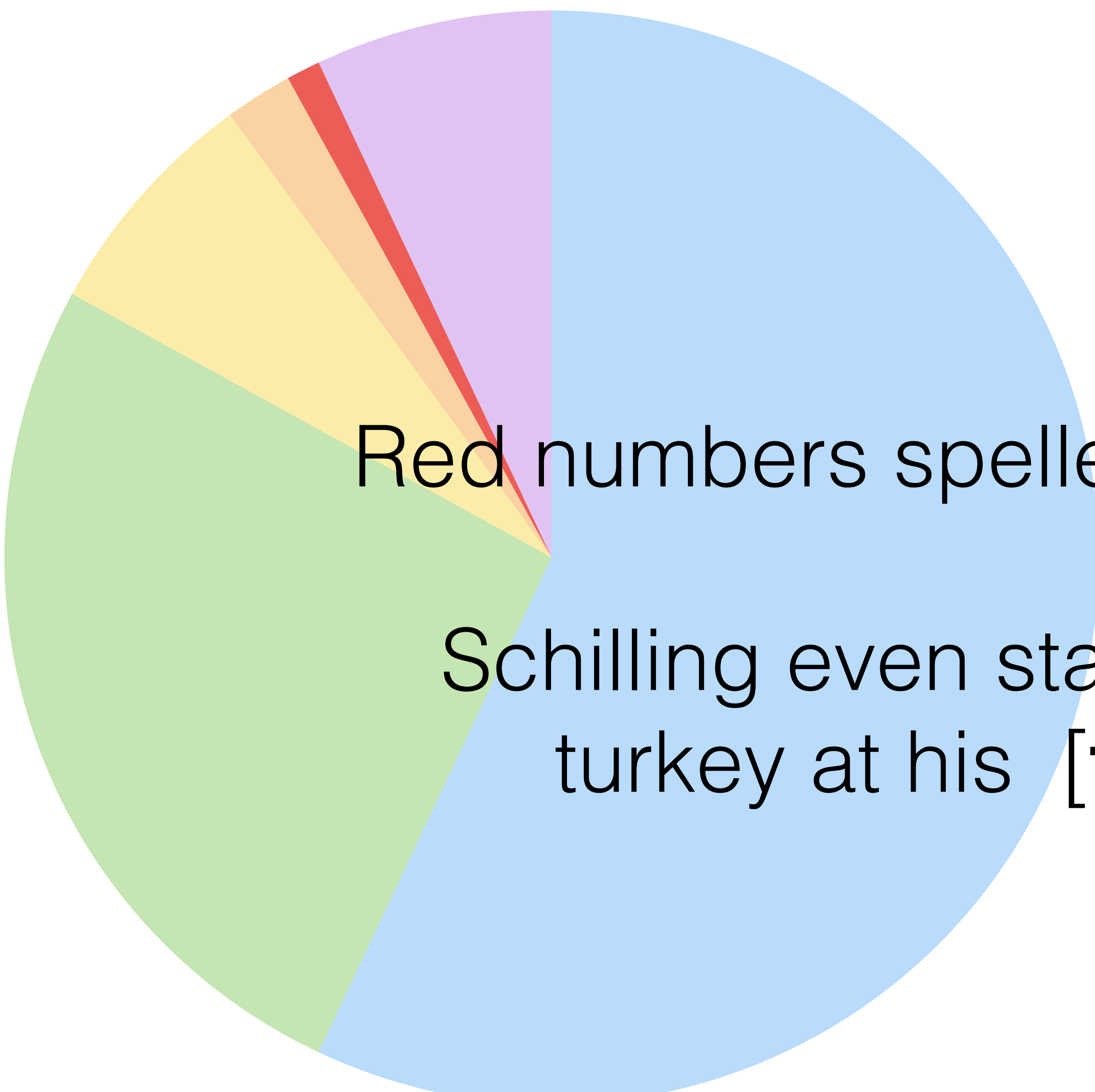
The [**deadly**] **attack** killed at least 12 civilians.

The [**entire**] **bill** is now subject to approval by the parliament.

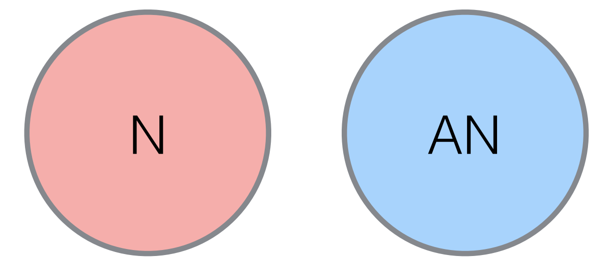
Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N NOT entail AN?

Other times, it is a property of the context+word knowledge.



Alternation



Red numbers spelled out their [**perfect**] **record**: 9-2.

Schilling even stayed busy after serving Epstein turkey at his [**former**] **home** on Thursday.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

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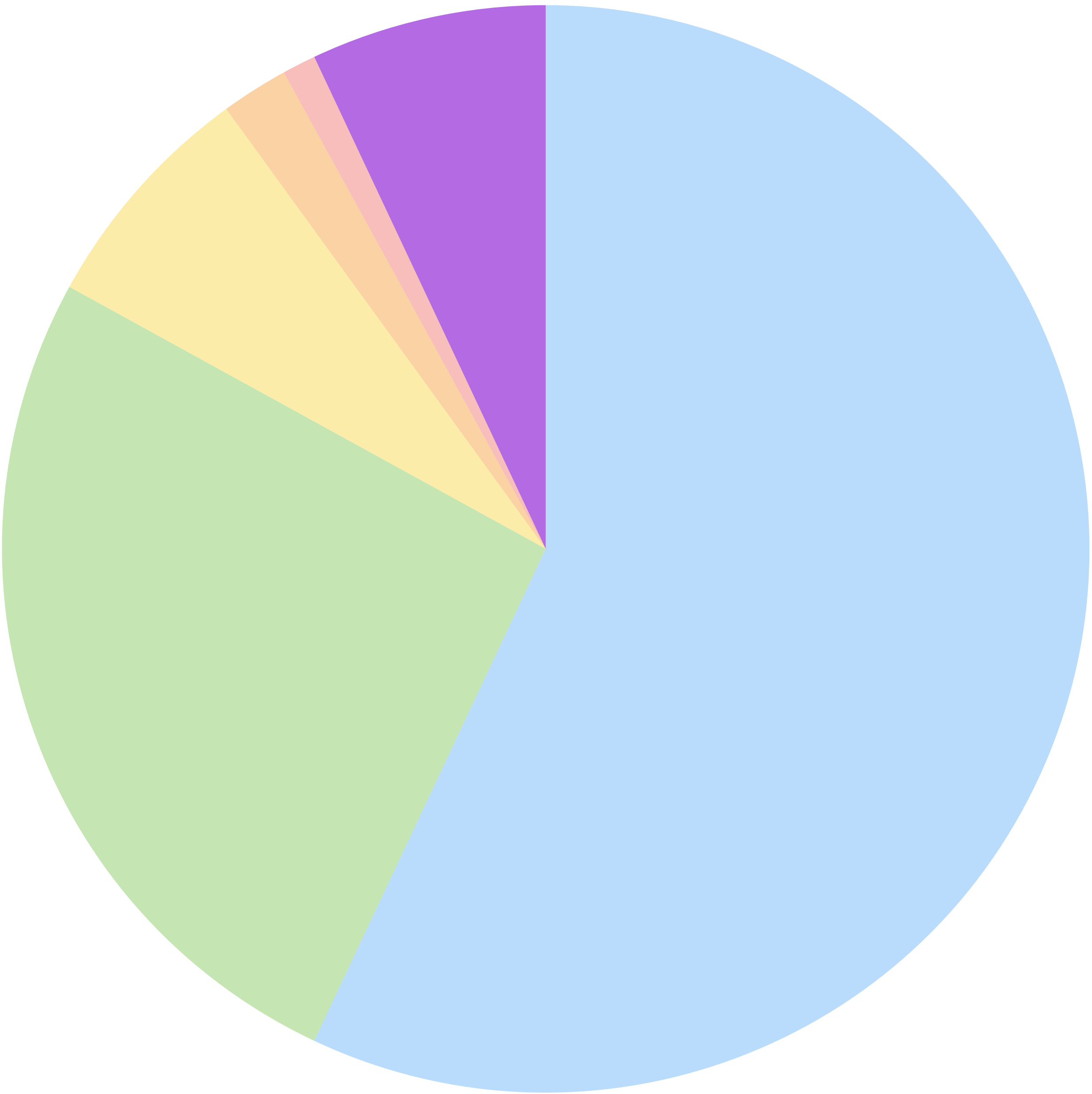

Undefined Relations

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N NOT entail AN?

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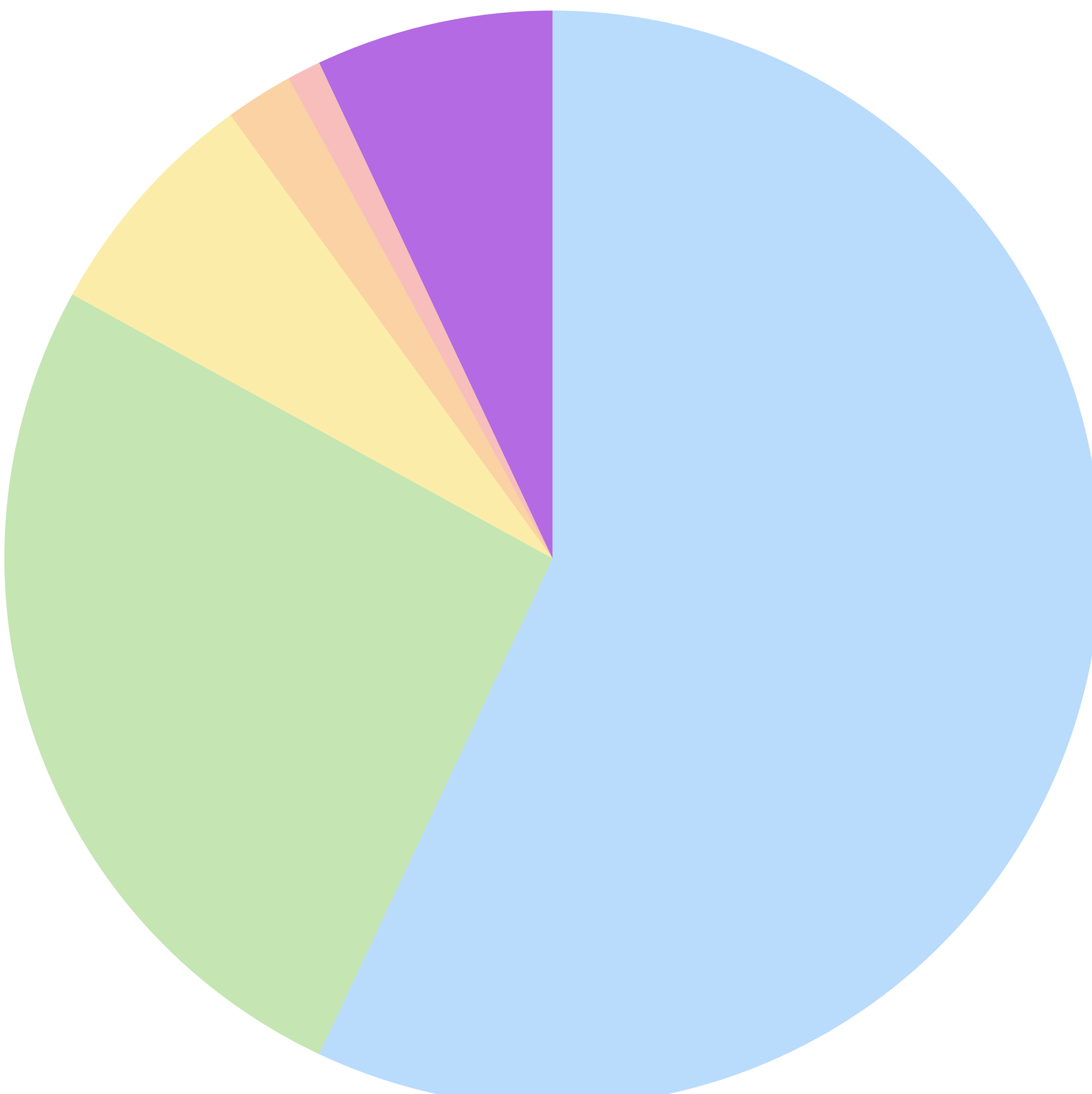


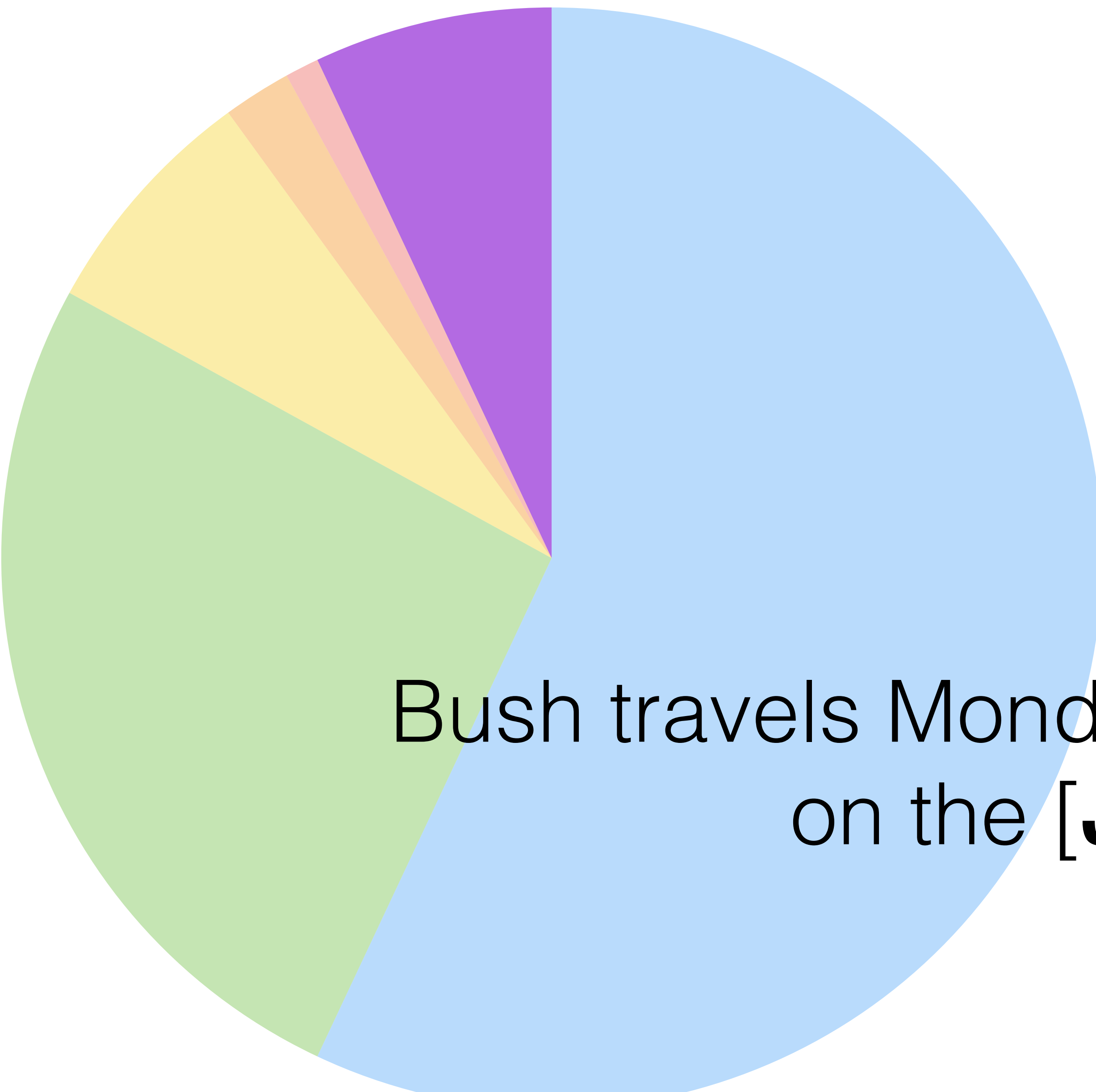
Undefined Relations

No N is an AN,
but every AN is an N.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When does N NOT entail AN?

Other times, it is a property of the context+word knowledge.



Undefined Relations

No N is an AN,
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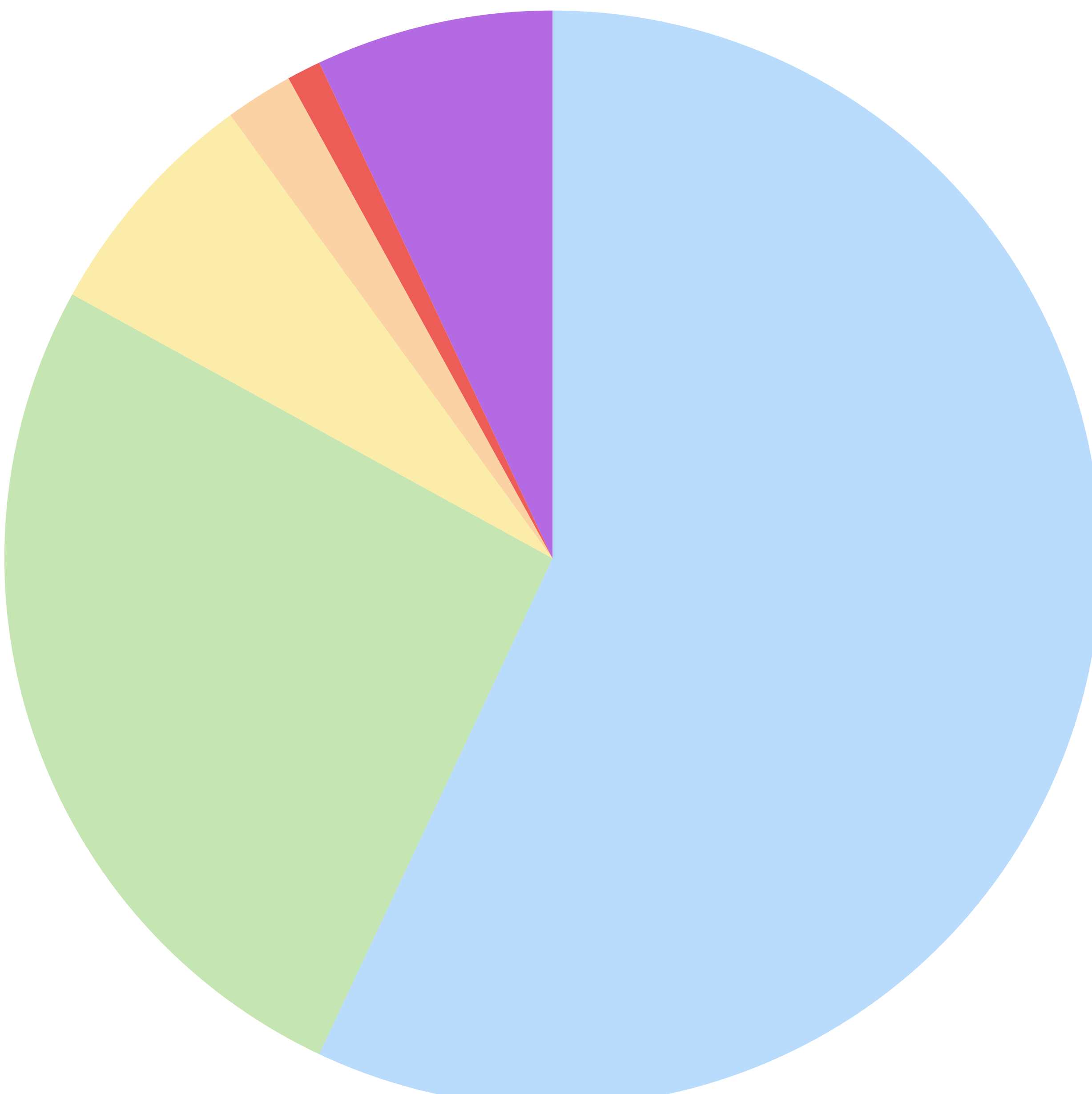
Bush travels Monday to Michigan to make remarks on the [**Japanese**] **economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

When ~~does~~ should N NOT entail AN?



fake
former
artificial
counterfeit
possible
probable
unlikely
likely
…

A dictionary of nonsubsective adjectives. (Nayak et al. Tech Report 2014)

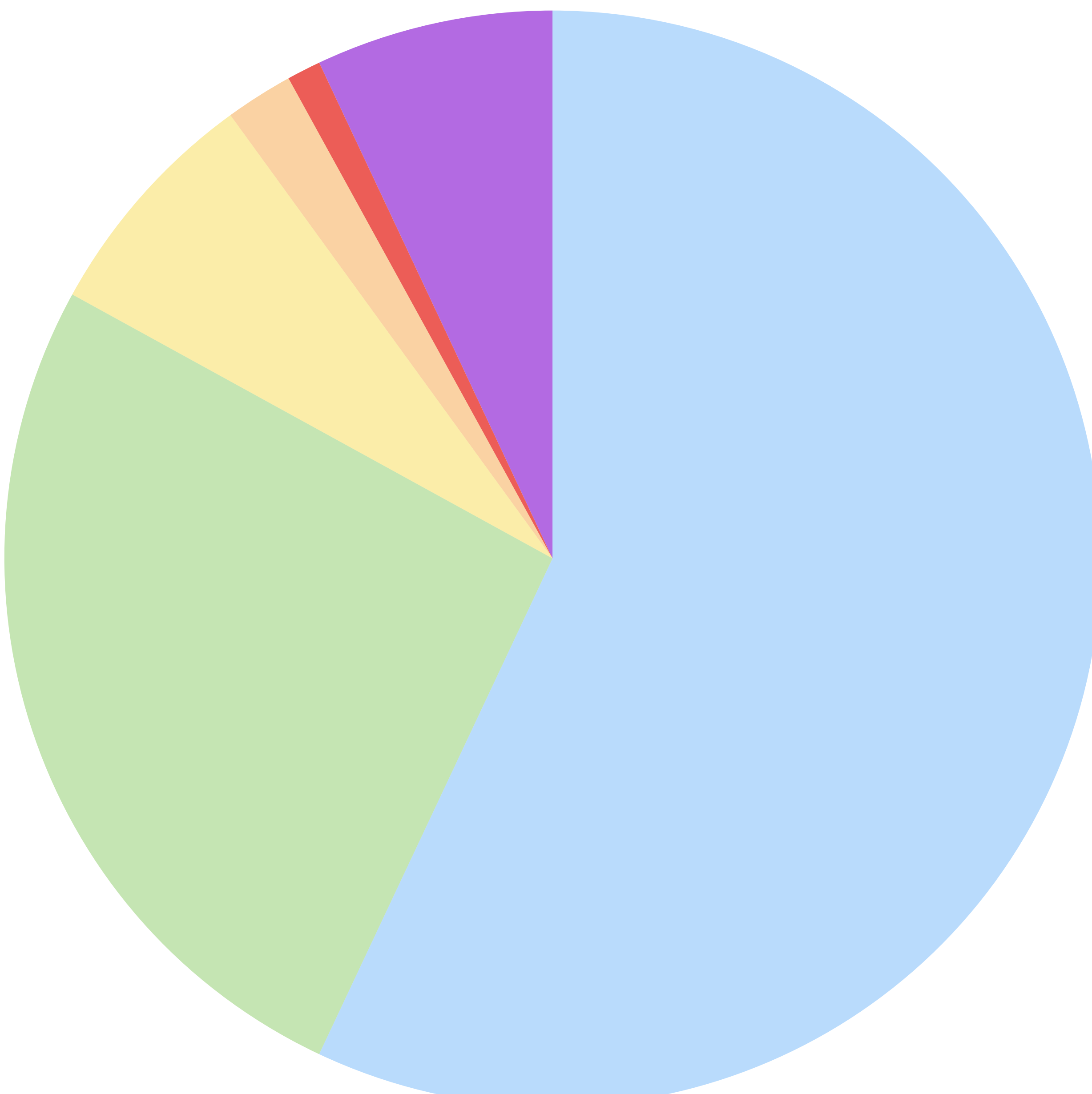
DEL(**possible**)

Last December they had argued that the council had failed to consider **possible** effects of contaminated land at the site.

The council considered environmental consequences.

(non-subsective) modifiers

When ~~does~~ should N NOT entail AN?



fake
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artificial
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likely
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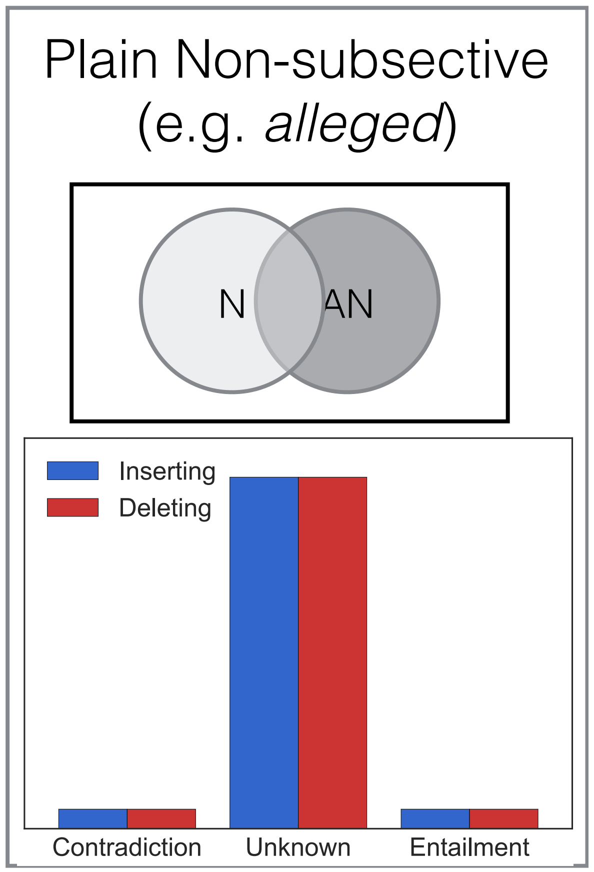
A dictionary of nonsubsective adjectives. (Nayak et al. Tech Report 2014)

When ~~does~~ should N NOT entail AN?

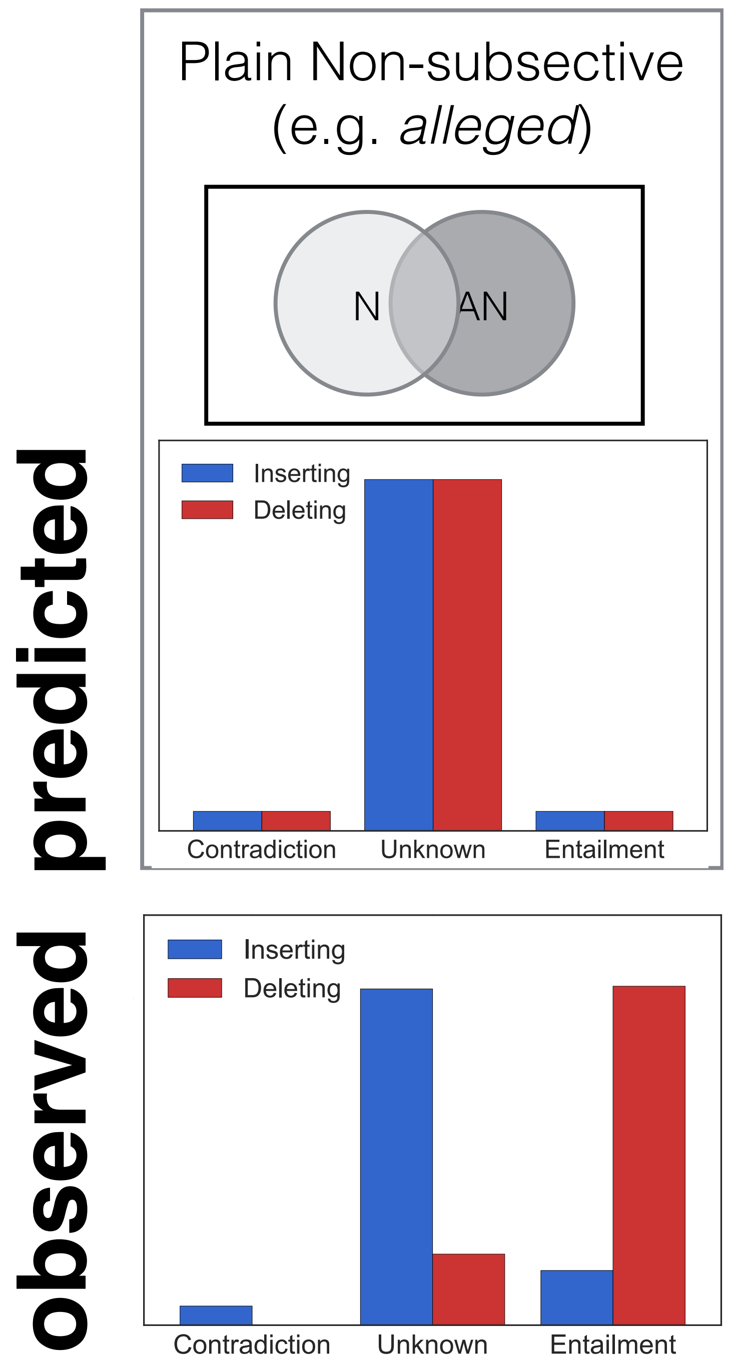
predicted



She was the **expected winner**.
She was the **winner**.

*So-Called Non-Subsective Adjectives. (Pavlick and Callison-Burch *SEM 2016, Best Paper!)*

When ~~does~~ should N NOT entail AN?



She was the **expected winner**.
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Actually behave like normal, subsective adjectives (e.g. red).

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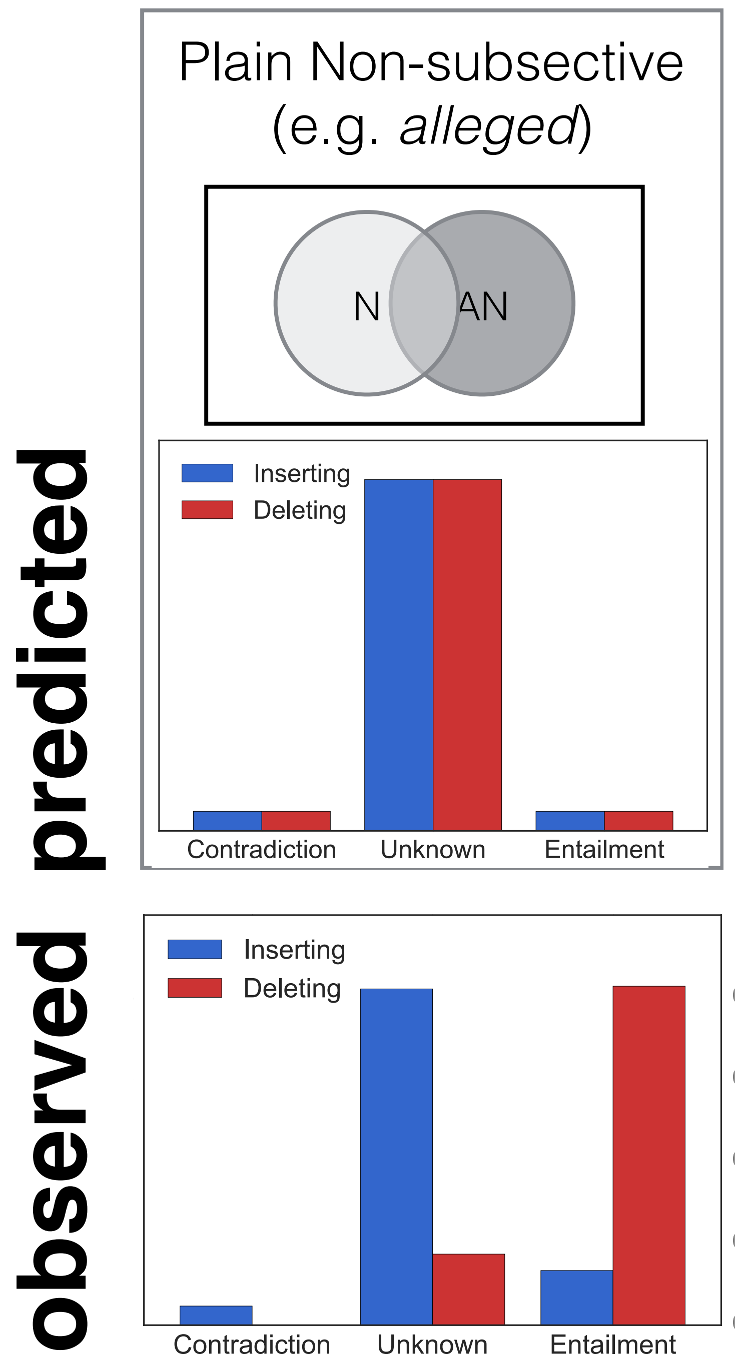
When ~~does~~ should N NOT entail AN?



She was the **expected winner**.
She was the **winner**.

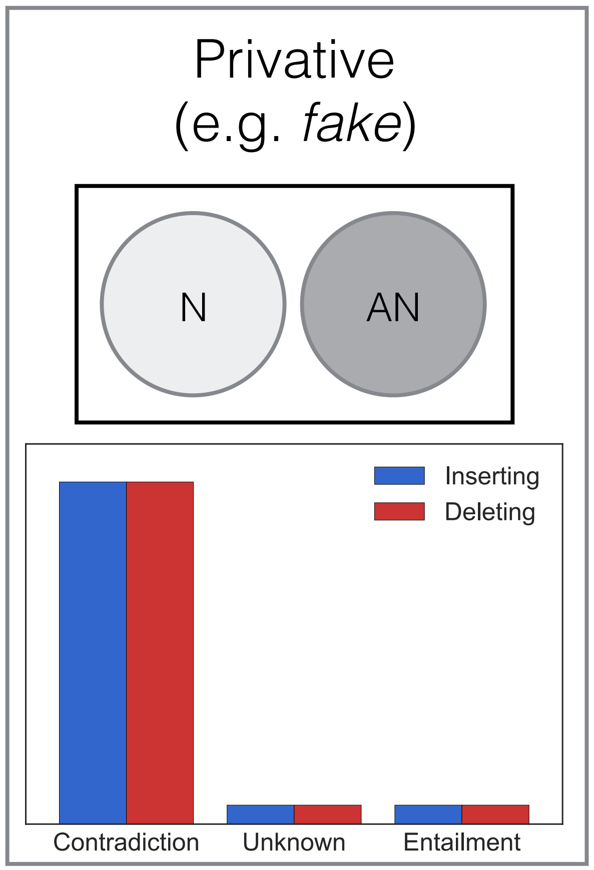
Actually behave like normal, subsective adjectives (e.g. red).

To <u>deal with</u> an **expected surge** in unemployment, the plan includes a huge temporary jobs program.

*So-Called Non-Subsective Adjectives. (Pavlick and Callison-Burch *SEM 2016, Best Paper!)*

When ~~does~~ should N NOT entail AN?

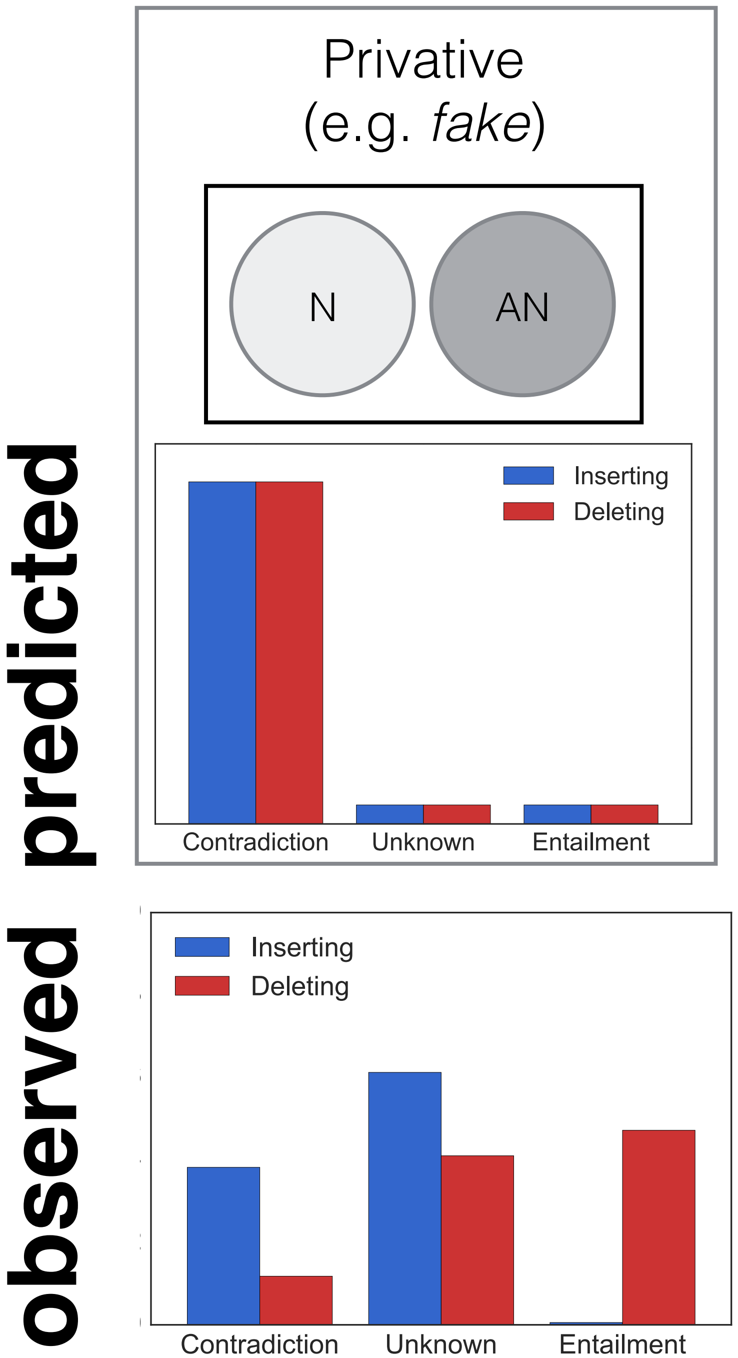
predicted



She was carrying a **fake gun**.
She was carrying a **gun**.

*So-Called Non-Subsective Adjectives. (Pavlick and Callison-Burch *SEM 2016, Best Paper!)*

When ~~does~~ should N NOT entail AN?



(a) Privative

She was carrying a **fake gun**.
She was carrying a **gun**.

Don't behave symmetrically.

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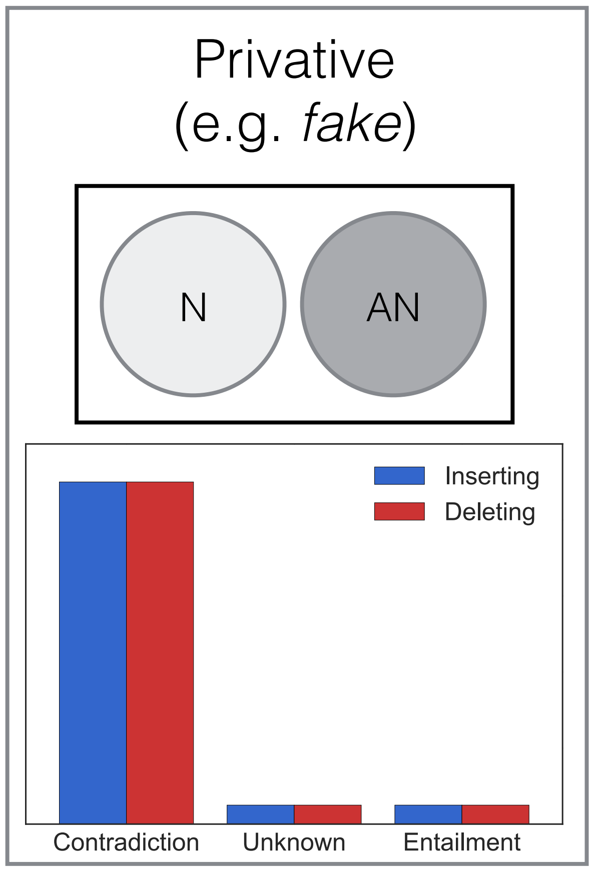
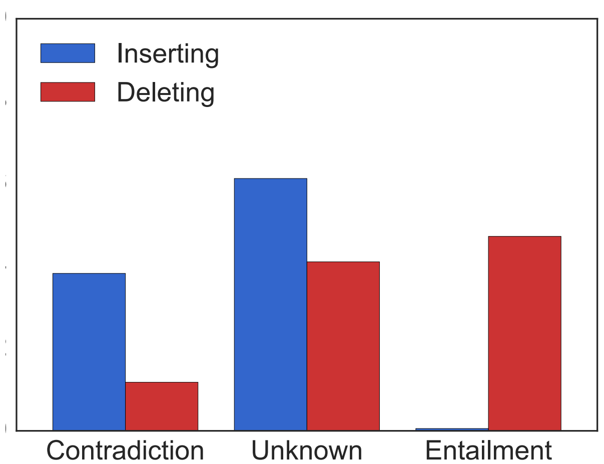
When ~~does~~ should N NOT entail AN?

predicted



observed



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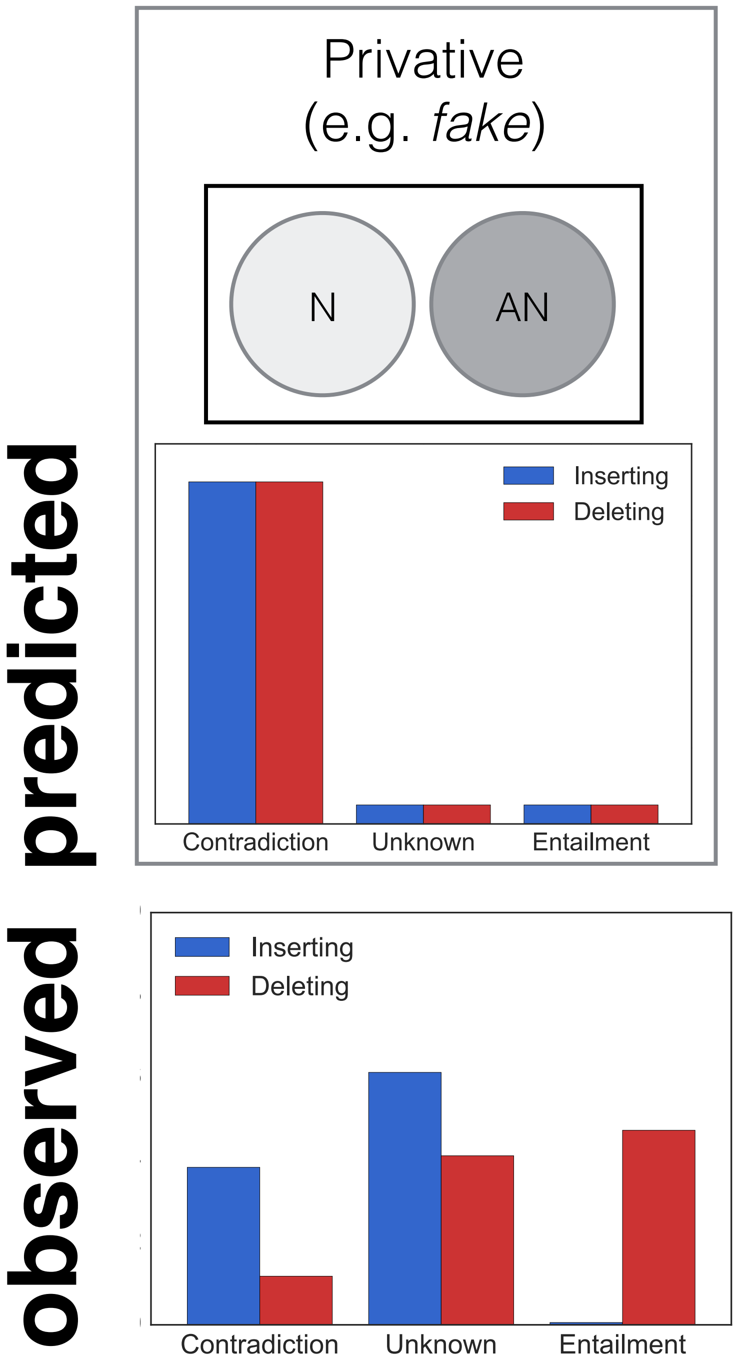
The 27-year-old Gazan seeks an **id** to get through security checkpoints and find work in Cairo.

Does he seek a **fake id?**

*So-Called Non-Subsective Adjectives. (Pavlick and Callison-Burch *SEM 2016, Best Paper!)*

When ~~does~~ should N NOT entail AN?



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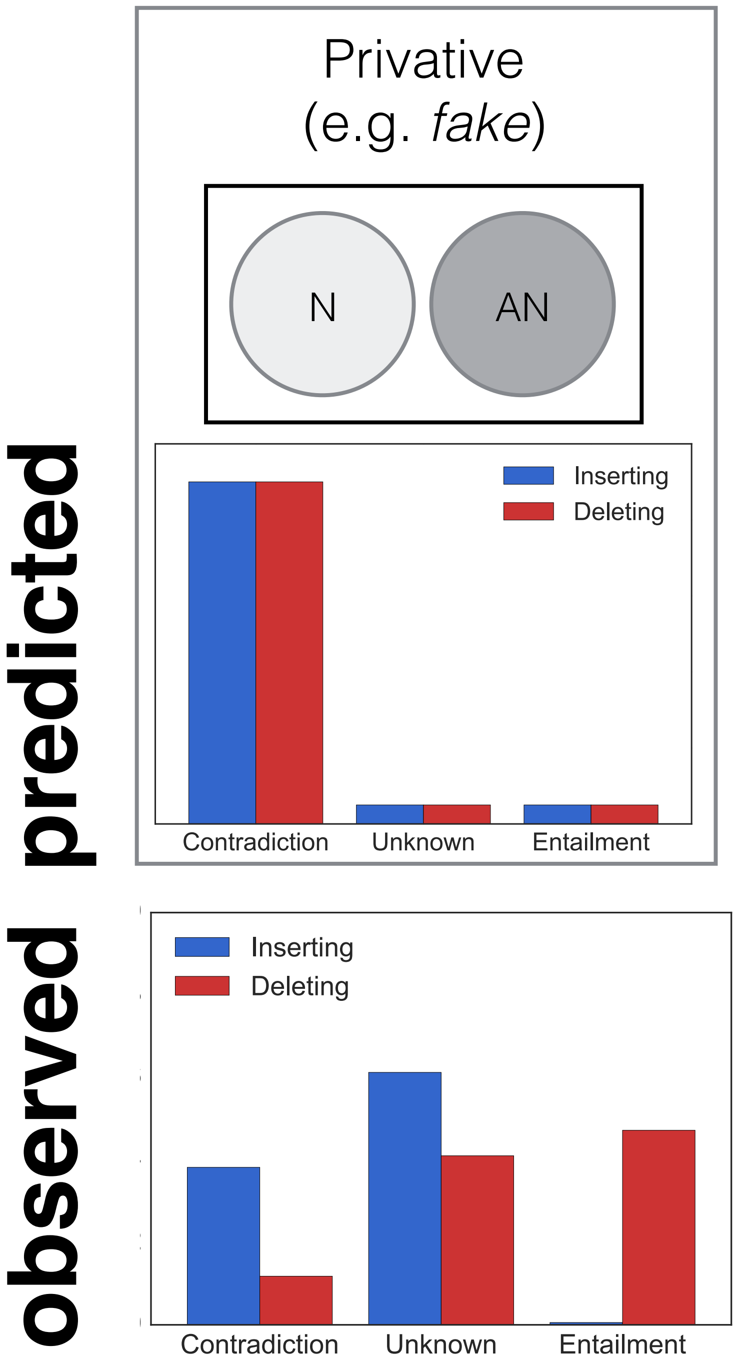

(a) Privative

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She was carrying a **gun**.

Don't behave symmetrically.

The 27-year-old Gazan seeks a **fake id** to get through security checkpoints and find work in Cairo.

Does he seek a **id?** ✔

*So-Called Non-Subsective Adjectives. (Pavlick and Callison-Burch *SEM 2016, Best Paper!)*

Does N entail AN?

Bush travels Monday to Michigan to make remarks on the **economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Bush travels Monday to Michigan to make remarks on the **economy**.

✔ Bush travels Monday to Michigan to make remarks on the **American economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Bush travels Monday to Michigan to make remarks on the **economy**.

✔ Bush travels Monday to Michigan to make remarks on the **American economy**.

✘ Bush travels Monday to Michigan to make remarks on the **Japanese economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Bush travels Monday to Michigan to make remarks on the **economy**.

5,378 naturally-occurring sentences
4,868 train / 510 test

Bush travels Monday to Michigan to make remarks on the **American economy**.

Bush travels Monday to Michigan to make remarks on the **Japanese economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Bush travels Monday to Michigan to make remarks on the **economy**.

5,378 naturally-occurring sentences
4,868 train / 510 test

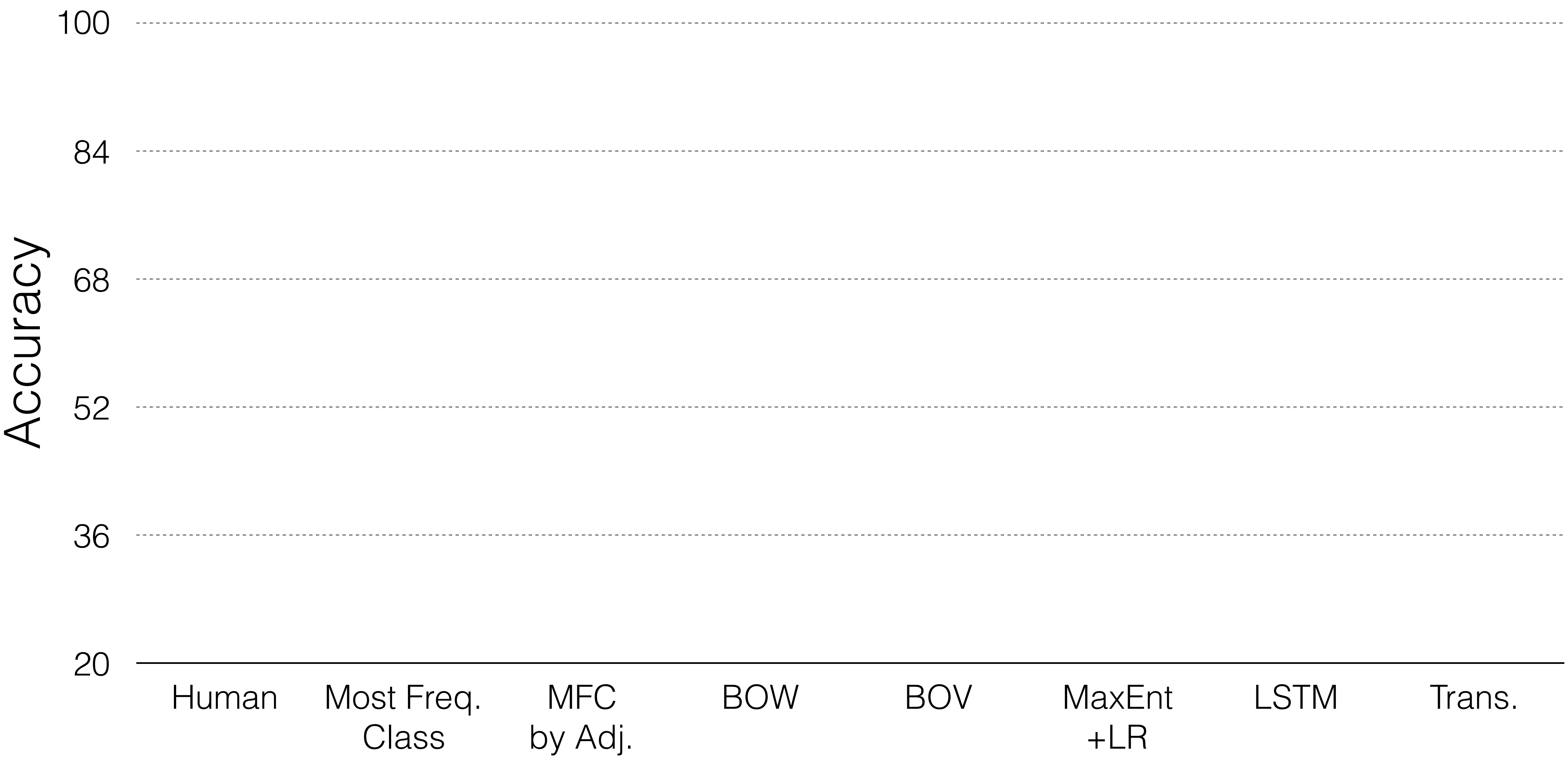
2,990 unique ANs
Disjoint ANs in train/test

✔ Bush travels Monday to Michigan to make remarks on the **American economy**.

✘ Bush travels Monday to Michigan to make remarks on the **Japanese economy**.

Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?



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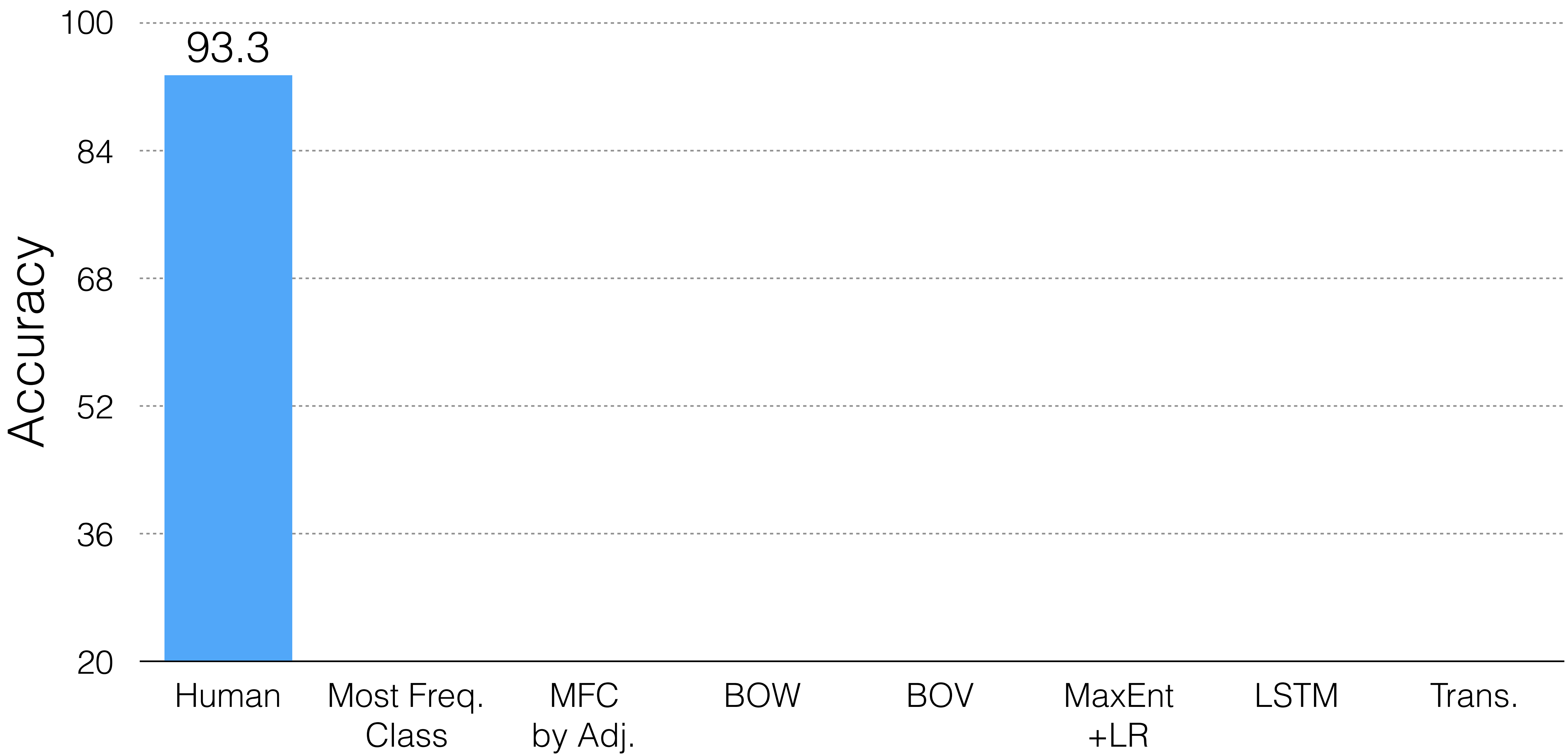

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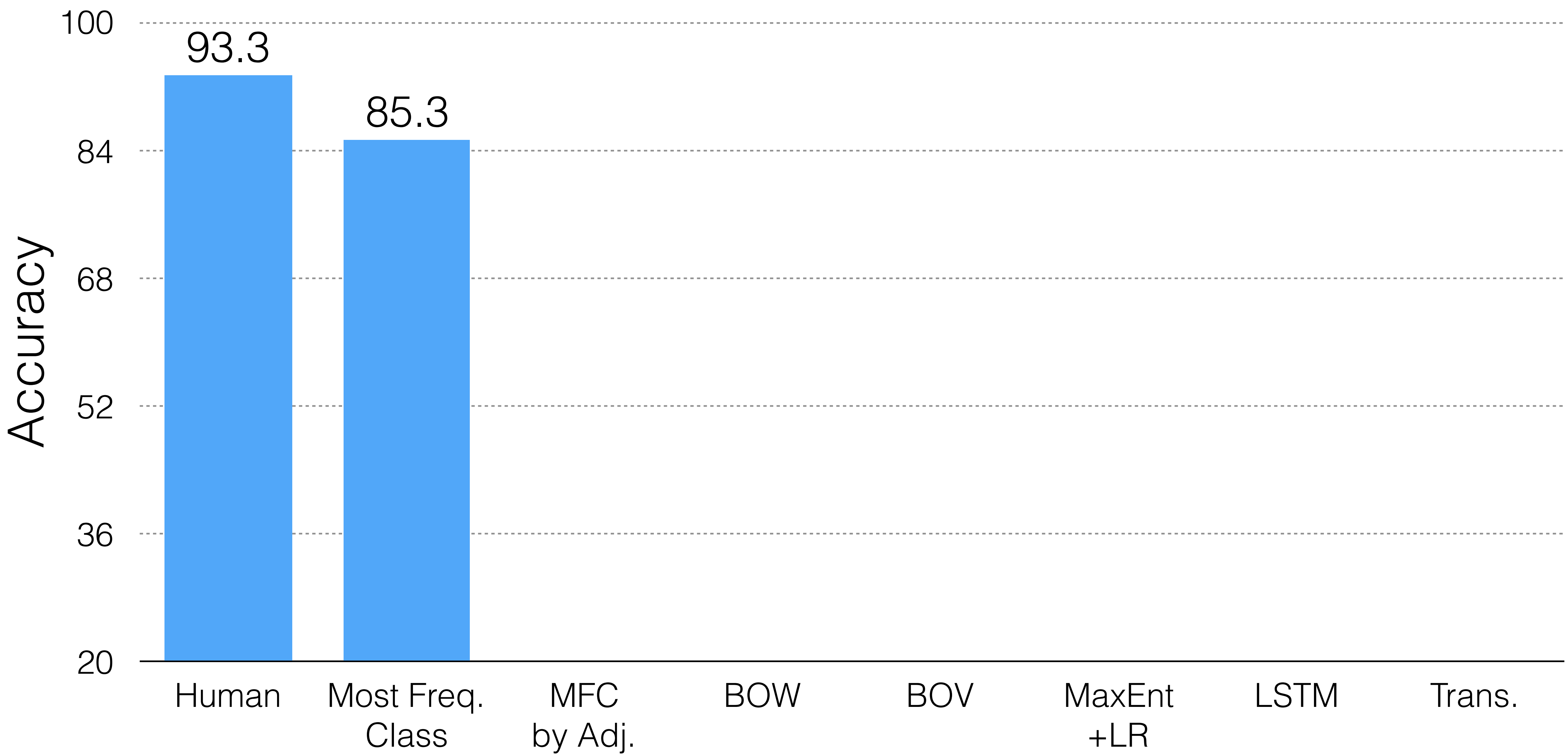

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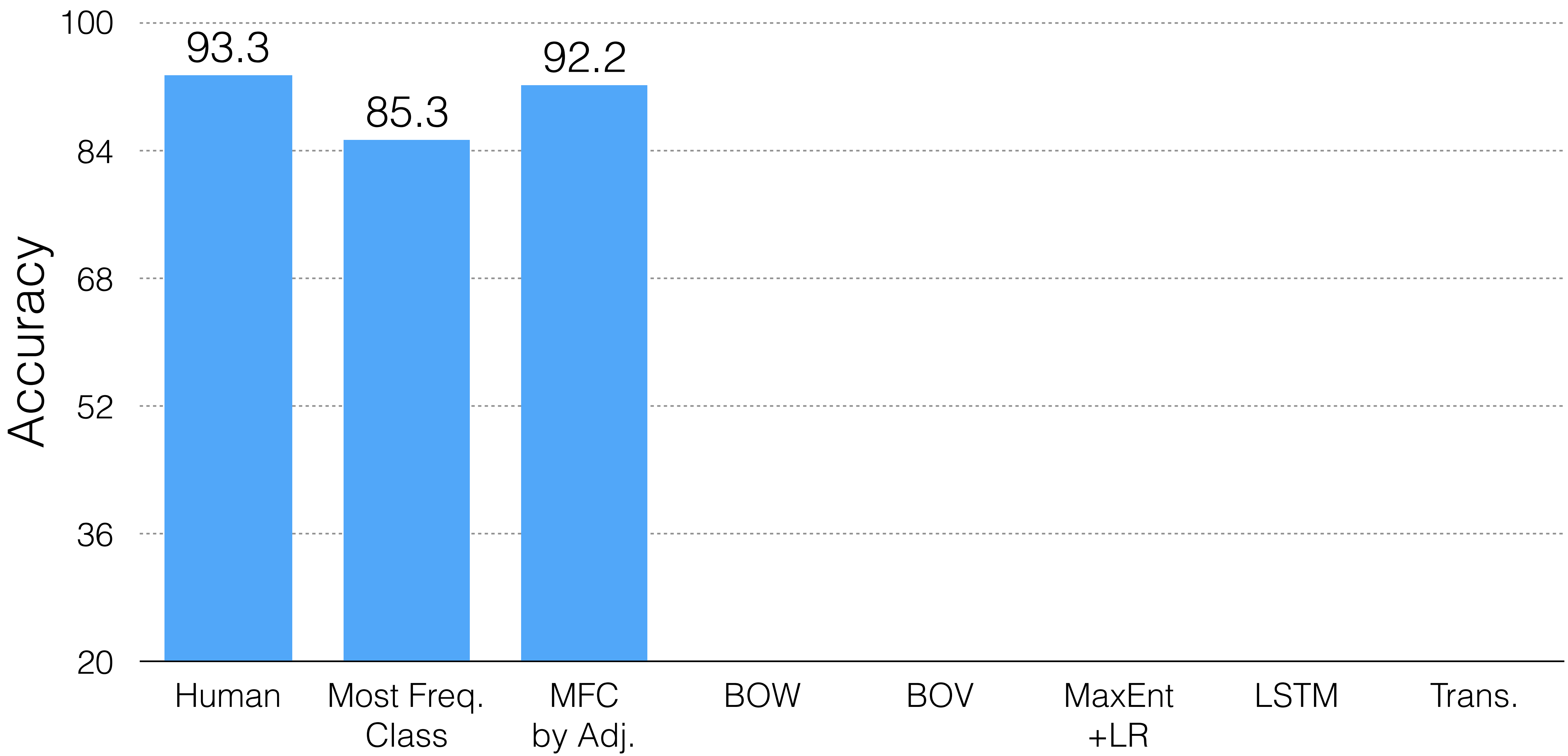

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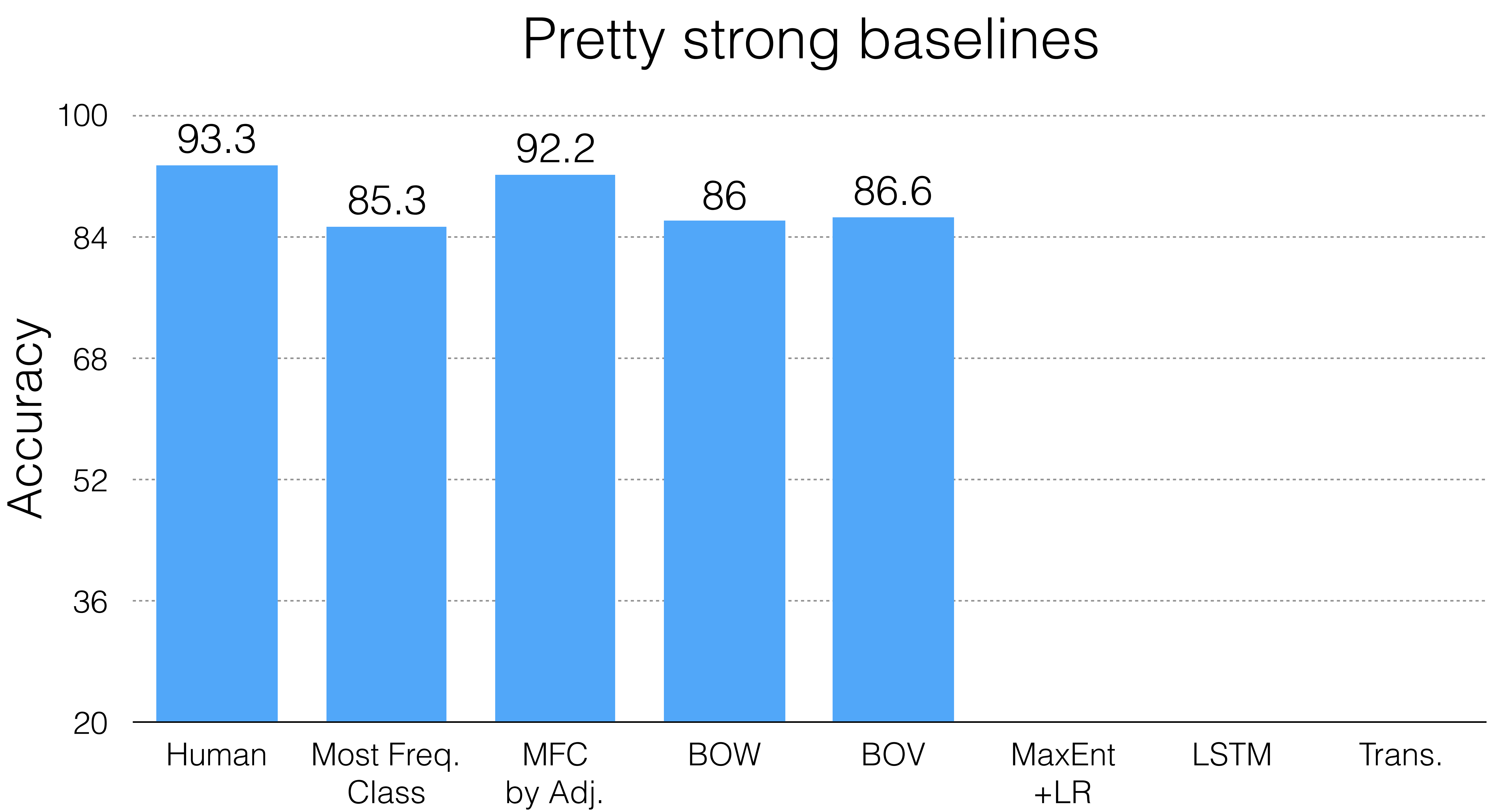
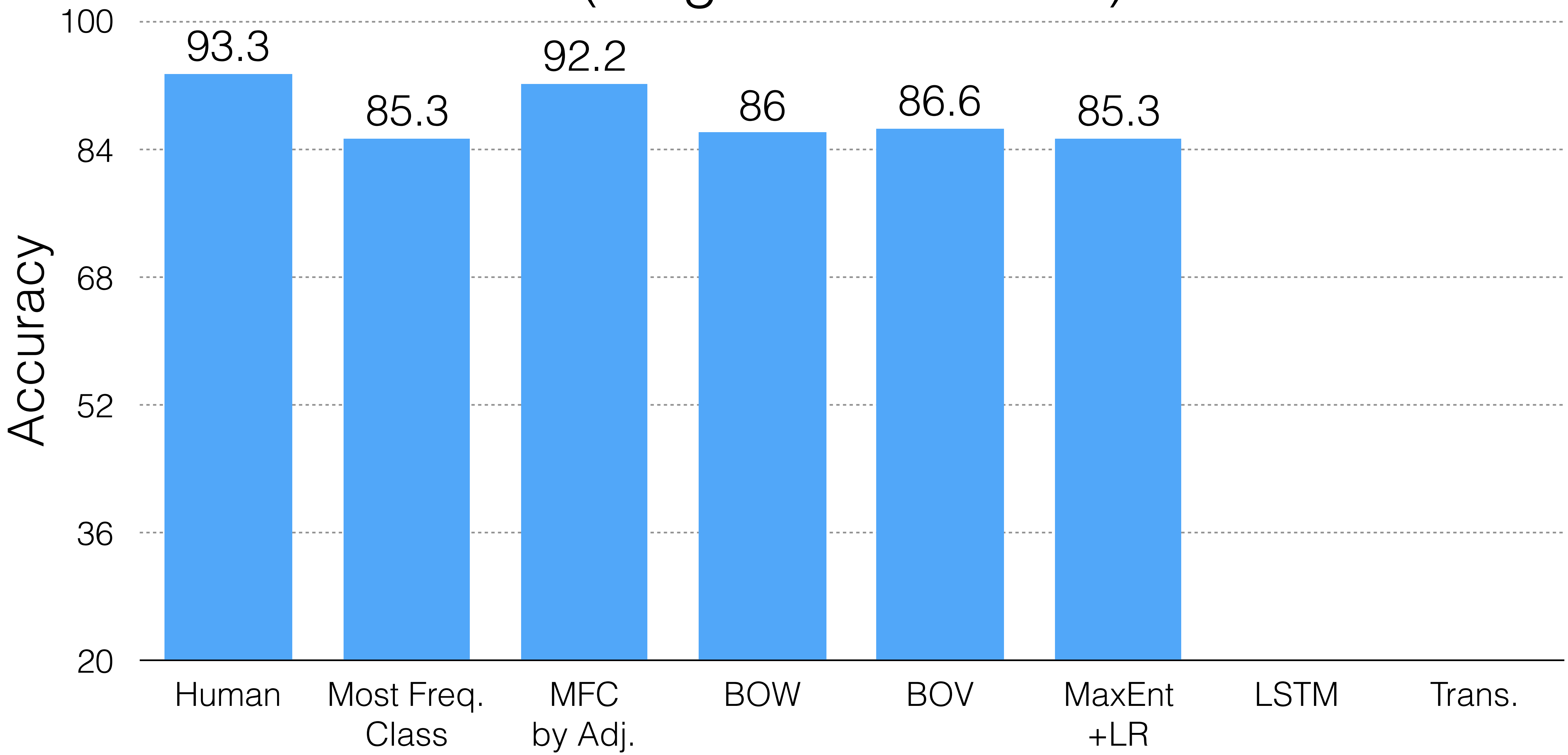


Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Supervised Model using involved NLP pipeline
(Magnini et al. 2014)



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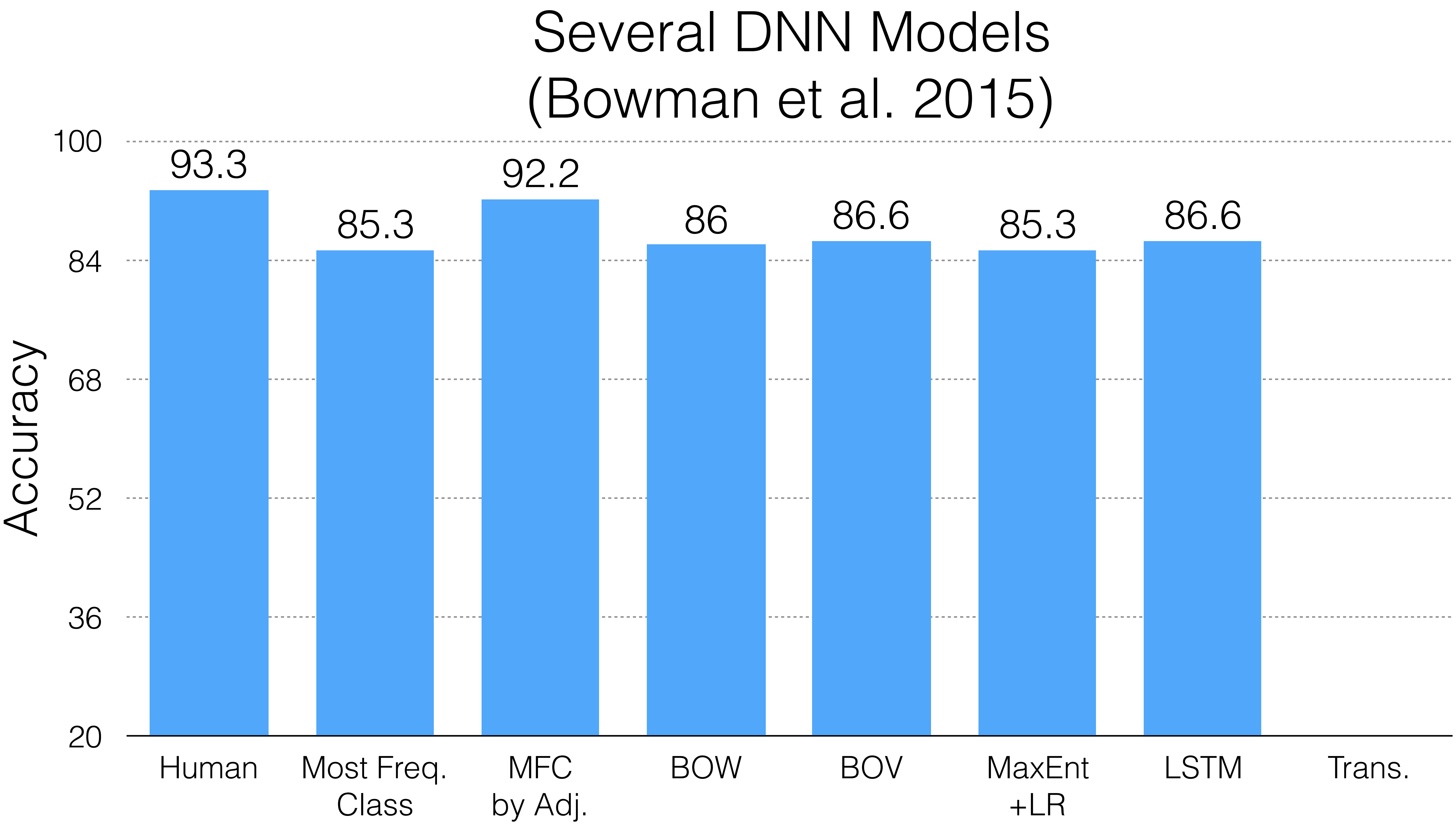
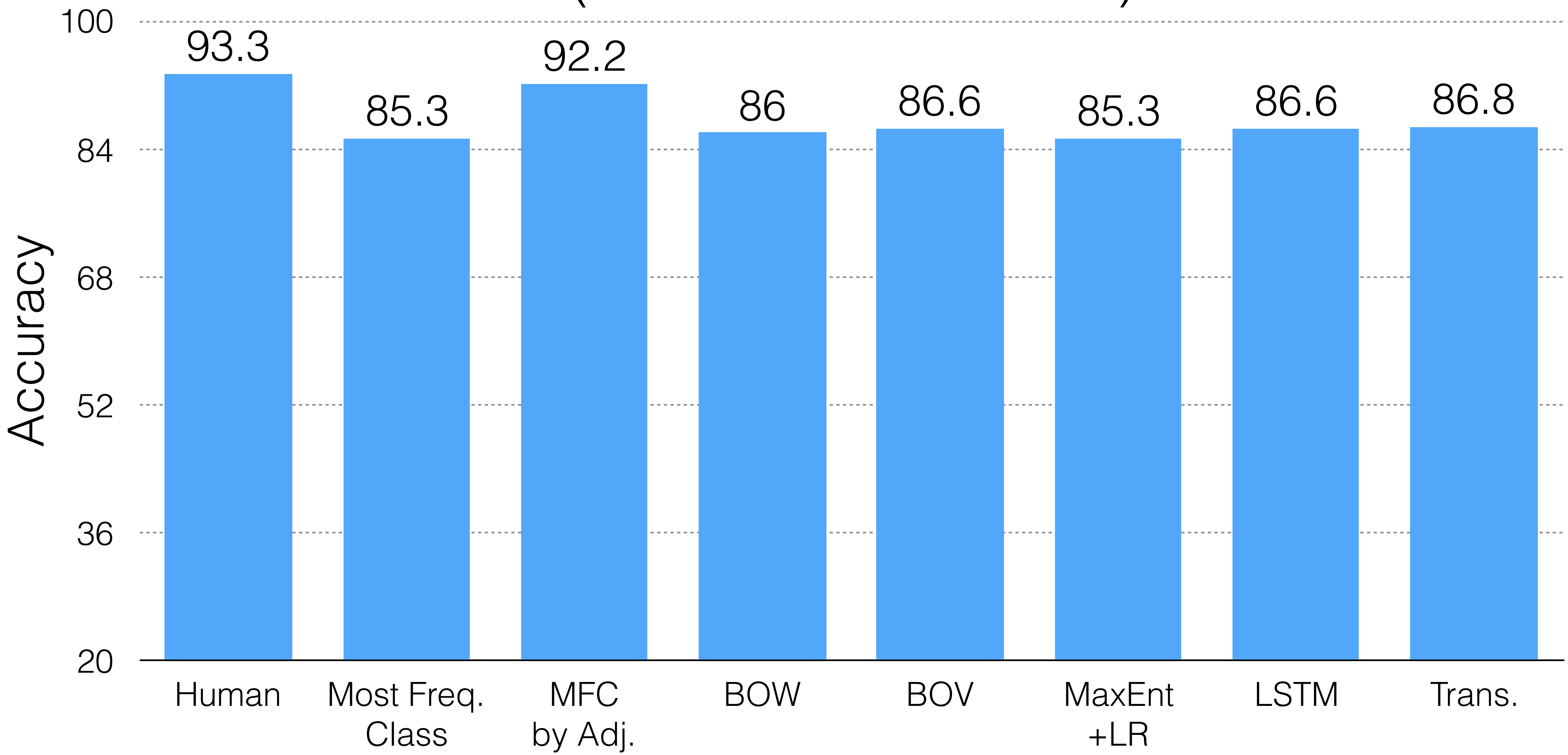
Does N entail AN?



Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Does N entail AN?

Several DNN Models, with transfer learning
(Bowman et al. 2015)



Compositional Entailment in Adjective Nouns. (Pavlick and Callison-Burch ACL 2016)

Summary

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- Humans are **flexible** with their language, they don’t abide by hard-and-fast logical rules of composition and entailment.

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Summary

- Humans are **flexible** with their language, they don't abide by hard-and-fast logical rules of composition and entailment.

- We can **acquire lexical entailments at scale**…

- …but lexical entailments are not enough. We need **composition** in order to model unseen phrases and full sentences.

- Inference involving composition is **too complex to capture using simple heuristics**, and requires models to incorporate **context and common sense** when performing reasoning.

Current Work

SUB(**consider**, **consider**)

Last December they had argued that the council had failed to **consider** possible effects of contaminated land at the site.

The council **considered** environmental consequences.

predicates

Projection through Predicates

		Input	Output
in France $\sqsubset$ in Europe	Forward		
in Europe $\sqsupset$ in France	Reverse		
in France | in Germany	Alternation		
in France # in the city	Independent		

Current Work-in-progress.

Projection through Predicates

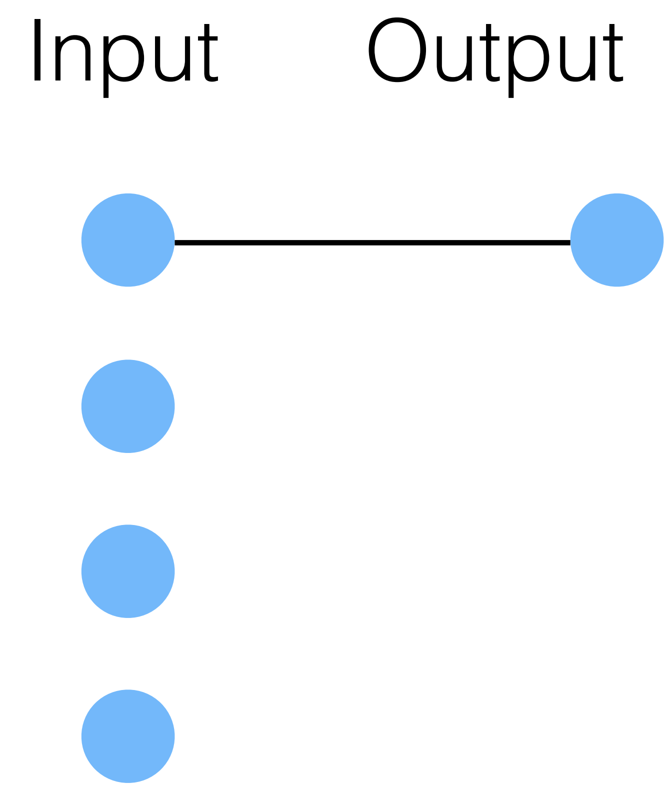
		Input	Output
in France ⊏ in Europe	Forward	●	
in Europe ⊐ in France	Reverse	●	
in France | in Germany	Alternation	●	
in France # in the city	Independent	●	

born

Current Work-in-progress.

Projection through Predicates

in France $\sqsubset$ in Europe	Forward
in Europe $\sqsupset$ in France	Reverse
in France | in Germany	Alternation
in France # in the city	Independent



$$\textbf{born}(\text{in France}) \sqsubset \textbf{born}(\text{in Europe})$$

Current Work-in-progress.

Projection through Predicates

		Input	Output
in France ⊏ in Europe	Forward		
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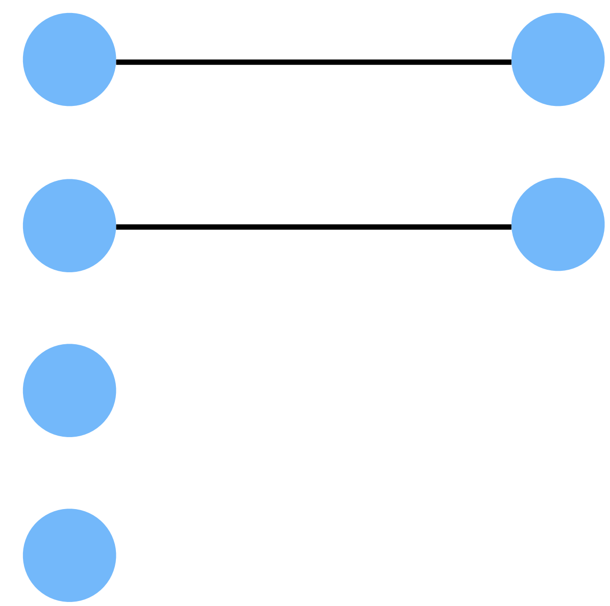
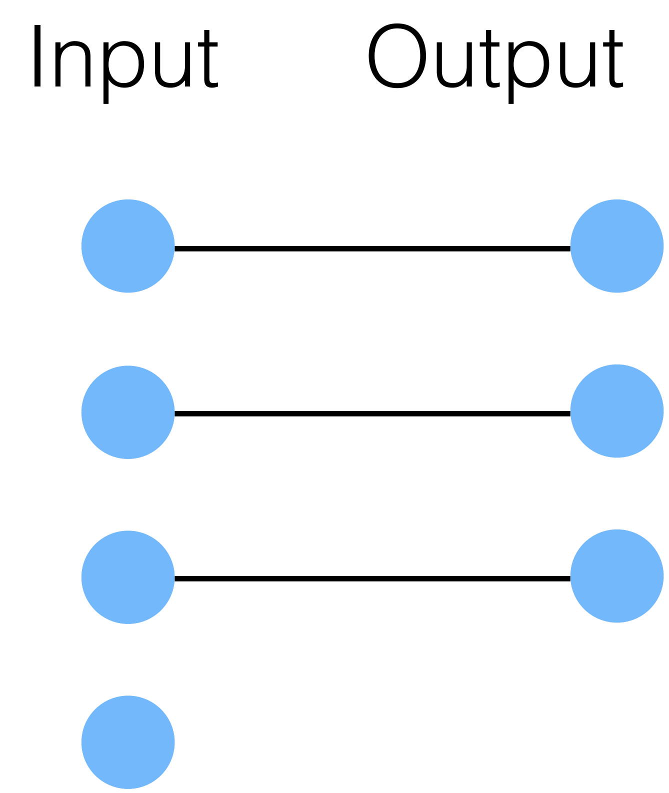


born(in Europe) ⊐ **born**(in France)

Current Work-in-progress.

Projection through Predicates

in France $\sqsubset$ in Europe	Forward
in Europe $\sqsupset$ in France	Reverse
in France | in Germany	Alternation
in France # in the city	Independent

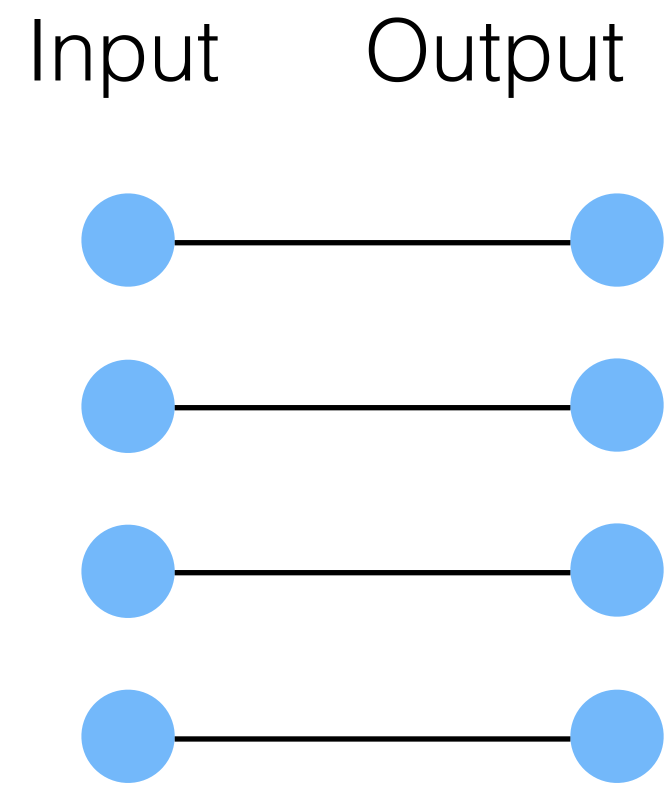


born(in France) | **born**(in Germany)

Current Work-in-progress.

Projection through Predicates

in France $\sqsubset$ in Europe	Forward
in Europe $\sqsupset$ in France	Reverse
in France | in Germany	Alternation
in France # in the city	Independent



born(in France) # **born**(in the city)

Current Work-in-progress.

Projection through Predicates

in France ⊏ in Europe	Forward
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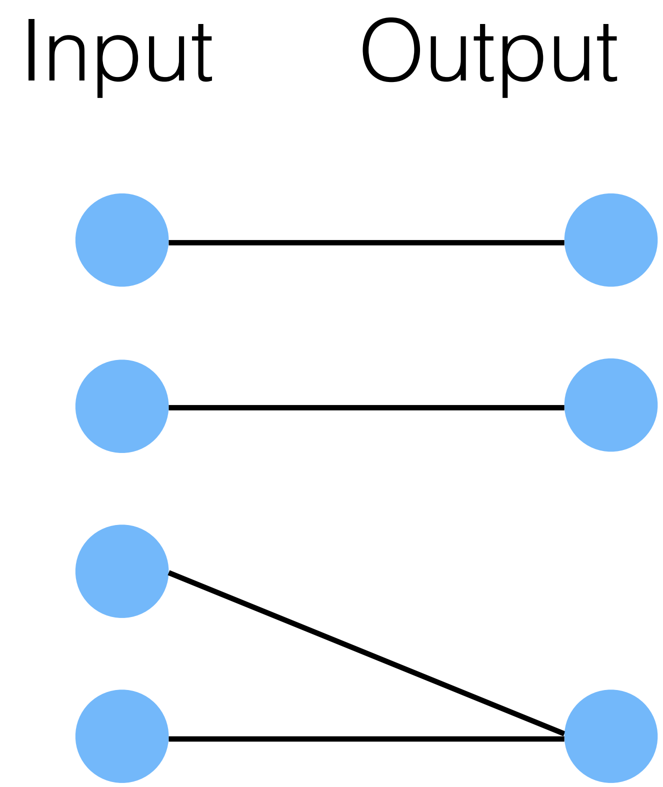
in France | in Germany	Alternation
in France # in the city	Independent

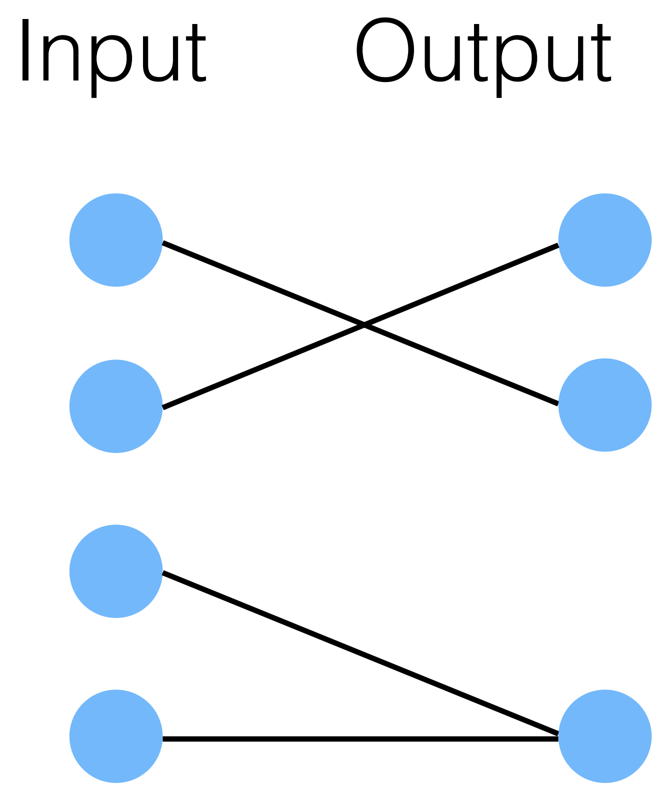


has traveled(in France)
has traveled(in Germany)

Current Work-in-progress.

Projection through Predicates

in France $\sqsubset$ in Europe	Forward
in Europe $\sqsupset$ in France	Reverse
in France | in Germany	Alternation
in France # in the city	Independent



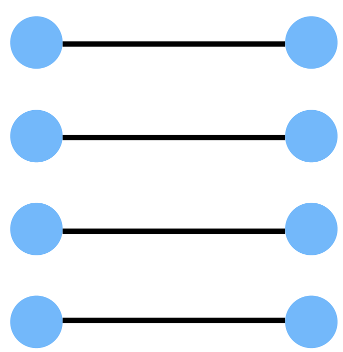
is banned(in France)

$\sqsupset$ **is banned**(in Europe)

Current Work-in-progress.

Projection through Predicates

Identity



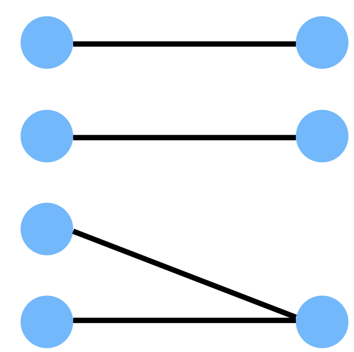
is a

lives in

was born in

is married to

Non-Exclusive,
Identity



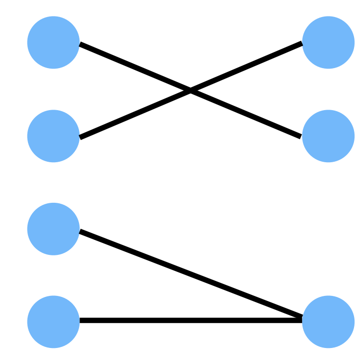
has a

considers

has visited

likes

Non-Exclusive,
Negation



lacks a

avoids

banned

dislikes

Current Work-in-progress.

DEL(**fail to**)

Last December they had argued that the council had **failed to** consider possible effects of contaminated land at the site.

The council considered environmental consequences.

“higher order” predicates

Implicative Verbs

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug.

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug.

She **wanted to** fix the bug.

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug.

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Did she fix the bug?

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug. ✔

She **wanted to** fix the bug. ✘

Did she fix the bug?

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug last night.

She **managed to** fix the bug tomorrow.

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **managed to** fix the bug last night. ✔

She **managed to** fix the bug tomorrow. ✘

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

She **wanted to** fix the bug last night. ✔

She **wanted to** fix the bug tomorrow. ✔

Implicative Verbs. (Karttunen Language 1971)

Implicative Verbs

decide to

try to

intend to

get to

venture to

plan to

promise to

want to

bother to

forget to

agree to

dare to

manage to

happen to

hope to

Tense Manages to Predict Implicatives. (Pavlick and Callison-Burch EMNLP 2016)

Implicative Verbs

venture to
forget to
manage to
bother to
happen to
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Implicative Verbs

Gallager **chose to accept** a full scholarship to play football for Temple University.

venture to
forget to
manage to
bother to
happen to
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decide to
dare to
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hope to

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hope to

Wilkins **was allowed to leave** in 1987 to join French outfit Paris Saint-Germain.

Tense Manages to Predict Implicatives. (Pavlick and Callison-Burch EMNLP 2016)

Implicative Verbs

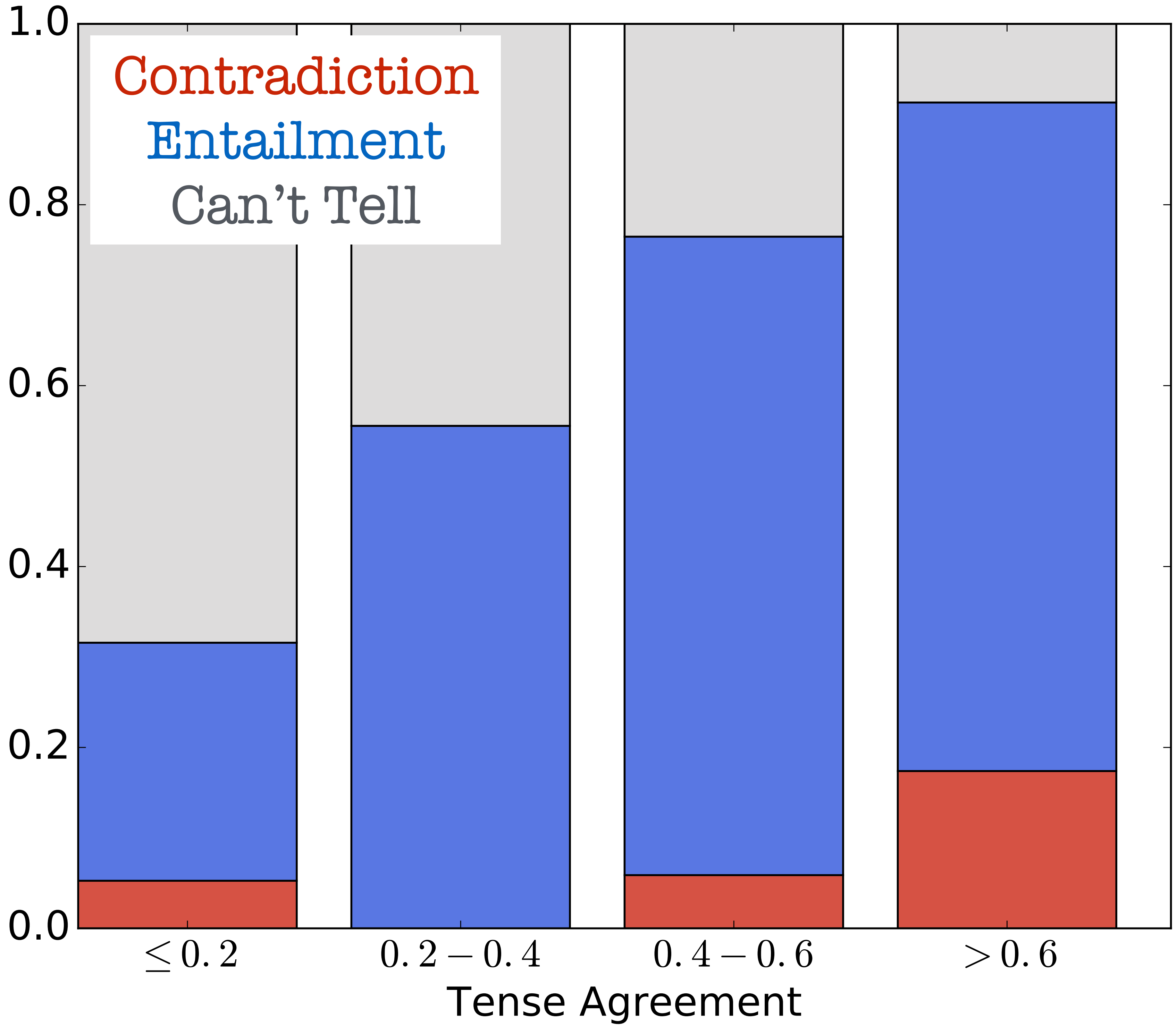
She **managed to** fix the bug.

She fixed the bug.

Contradiction
Entailment
Can't Tell

Tense Manages to Predict Implicatives. (Pavlick and Callison-Burch EMNLP 2016)

Implicative Verbs



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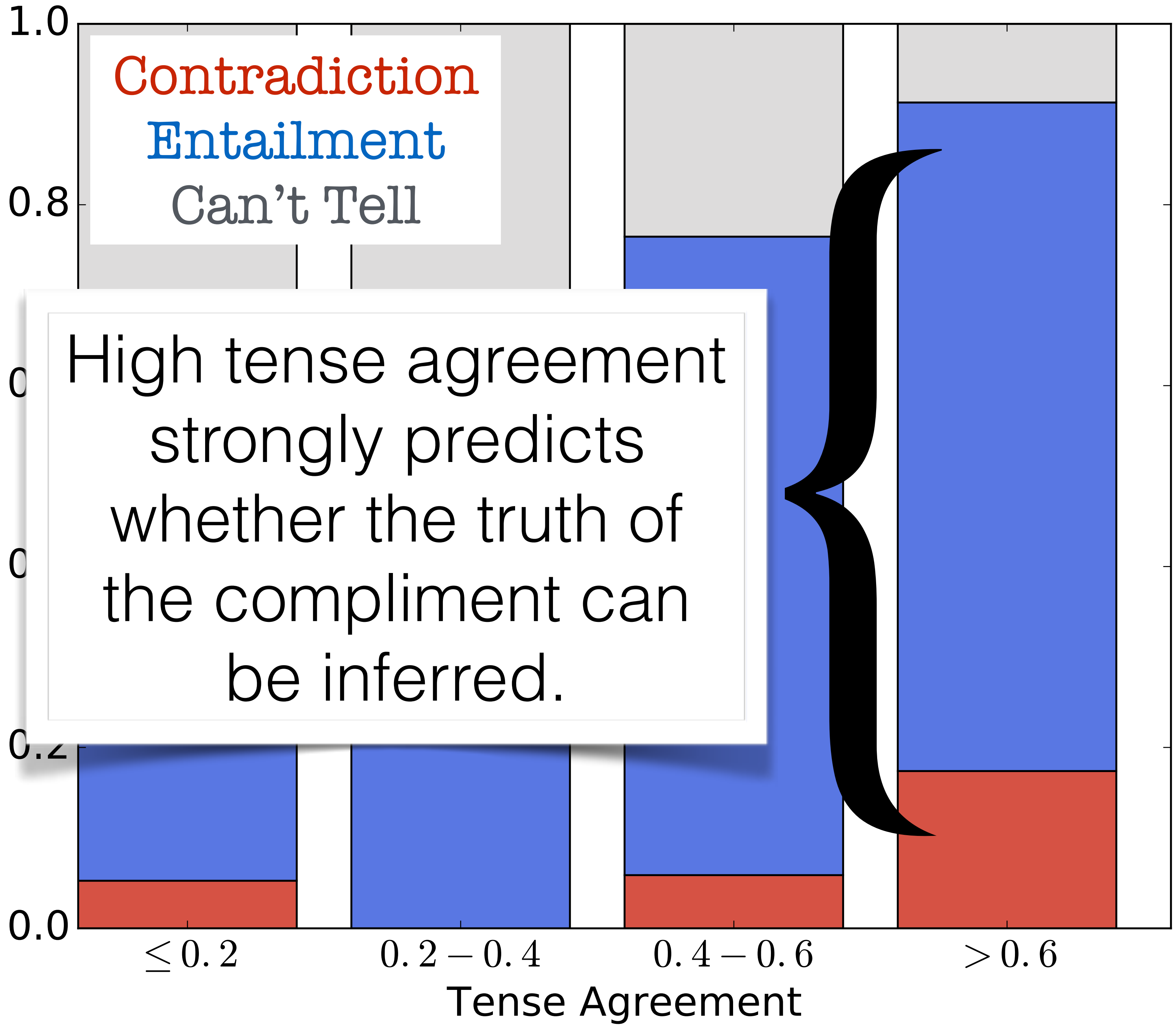

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Discussion

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- Humans are flexible with their language. Computers need to be flexible too.
- What aspects of meaning do we expect our semantic representations have built-in? What do we expect to have to deal with in context, at runtime?
- What types of semantic tasks should we need to optimize for explicitly? Shouldn't some things come "for free" when we train for harder tasks?

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Thank you!