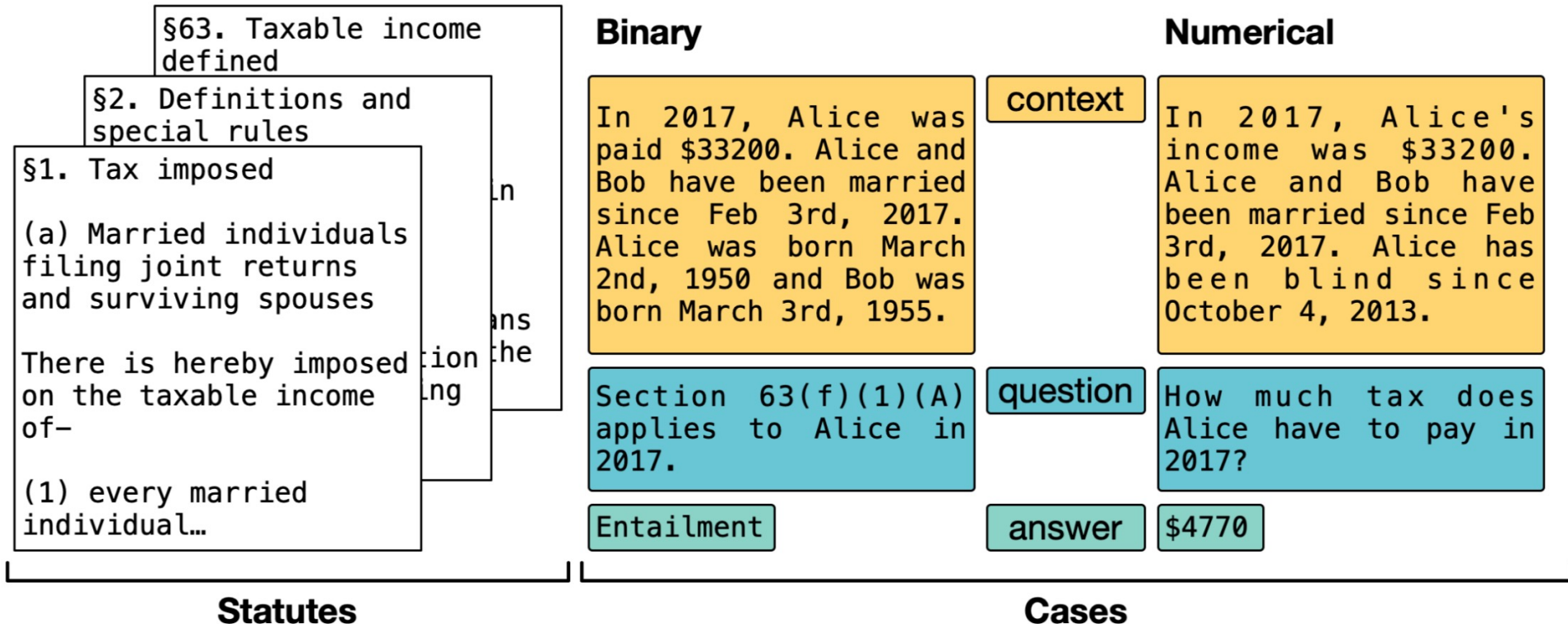


# Statutory Reasoning

Nils Holzenberger



DIG Seminar — September 9, 2021

# Best/outstanding paper awards NAACL 2021

- Video-aided Unsupervised Grammar Induction
- Unifying Cross-Lingual Semantic Role Labeling with Heterogeneous Linguistic Resources
- It's Not Just Size That Matters: Small Language Models Are Also Few-Shot Learners
- Learning How to Ask: Querying LMs with Mixtures of Soft Prompts
- How many data points is a prompt worth?
- Preregistering NLP research

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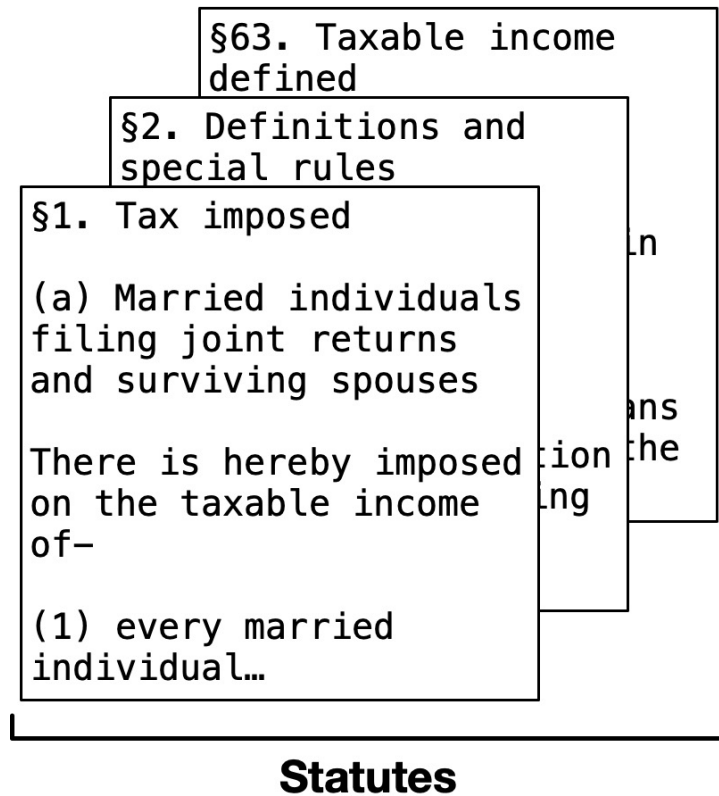
# Few-shot learning

- Learn a new task with up to a handful of examples ( $< 100$ )
- Leverage natural language description of the task
- Language descriptions come from annotation manuals or written ad-hoc by researchers
- There is a real-world task that requires few-shot learning with task descriptions

# Statutory reasoning

- Predict how laws apply to legal cases
- Legal professionals do this routinely
- Subset of legal reasoning
- Requires natural language understanding and logical reasoning
- Fundamental task for Legal NLP
  - Can be used to predict how new laws would interact with past cases, or hypothetical cases
  - Required to model the logic behind legal rules, eg to find loopholes in laws

# Statutory reasoning



## Binary case

In 2017, Alice was paid \$33200. Alice and Bob are married since Feb 3rd, 2017. Alice was born March 2nd, 1950 and Bob was born March 3rd, 1955.

Does section 63(f)(1) (A) apply to Alice in 2017?

Yes

## Numerical case

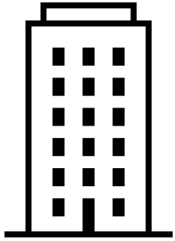
In 2017, Alice's income was \$33200. Alice and Bob are married since Feb 3rd, 2017. Alice is blind since October 4, 2013.

How much tax does Alice have to pay in 2017?

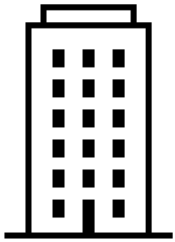
\$4770

- Predict how (tax) laws apply to cases
- Usual approach: annotate cases with rules and conclusions
- Unrealistic for statutory reasoning

# Background



Company X

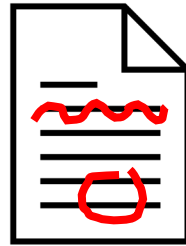


Company X



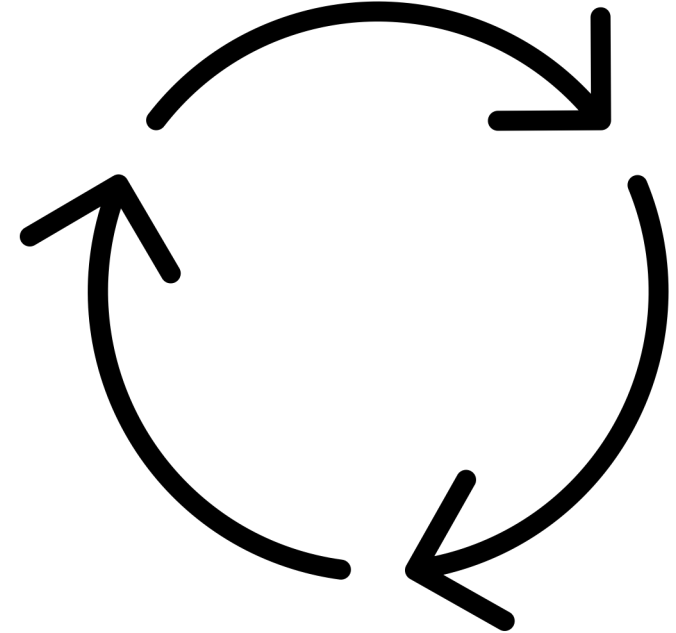
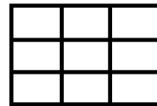
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Tax return

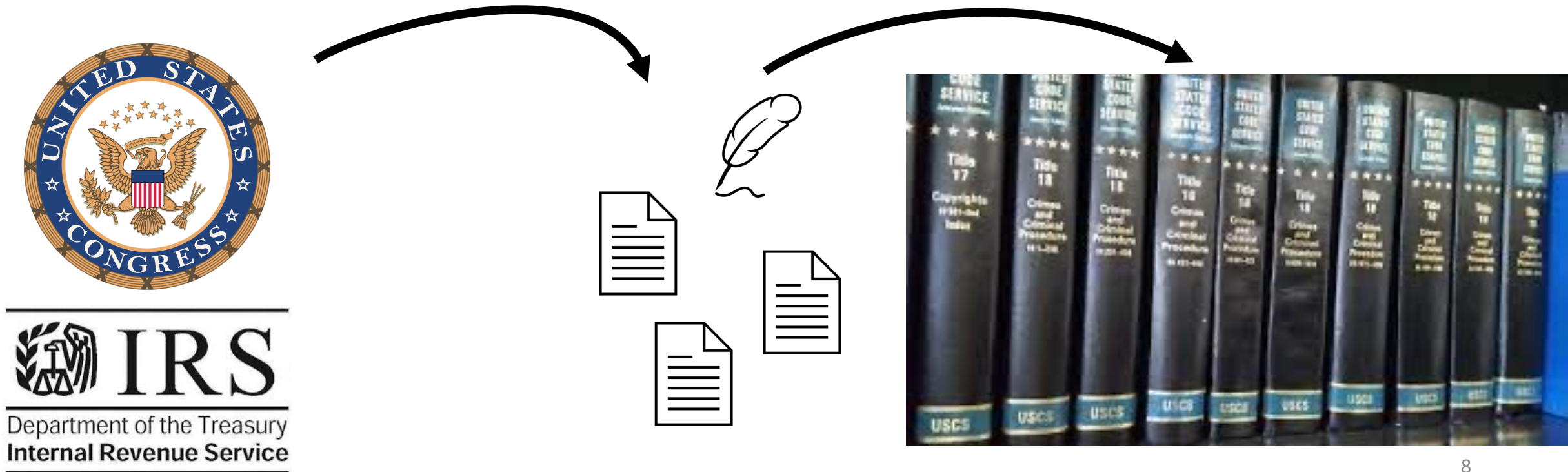
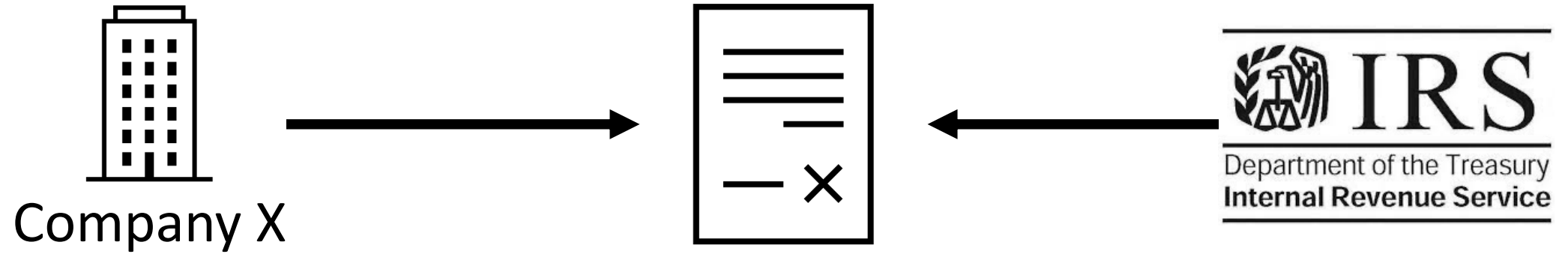


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Tax return



# Background





# Background

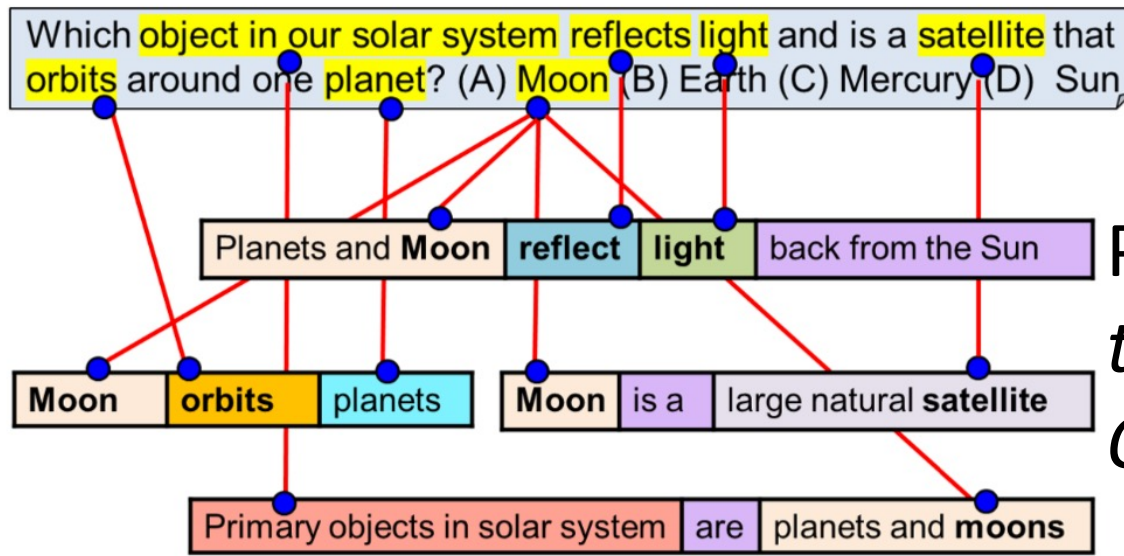
- Not many publicly settled cases
- New laws and regulations are added frequently
  - Congress + IRS update legislation based on loopholes discovered
  - Independently, economic changes drive policy-making
- Sparse data setting

# Background

- Few-shot learning is required
- Laws and regulations  $\approx$  task description
- Need to learn from cases and from semantics of rules
- Need to generalize to unseen rules

# NLP in general

- Reasoning with rules specified in natural language
- Rules true by virtue of being written down
- Cannot be picked up by statistical evidence as in linguistics
- Necessity to generalize to unseen rules



Peter Clark et al, *From 'F' to 'A' on the N.Y. Regents Science Exams: An Overview of the Aristo Project*, 2019

Figure 3: The Tuple Inference Solver retrieves tuples rele-



Andrew Blair-Stanek



Benjamin Van Durme



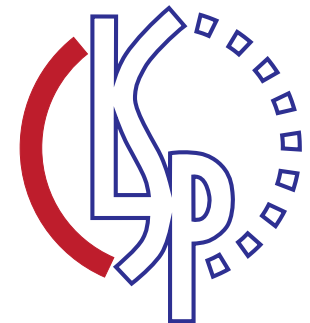
Nils Holzenberger



UNIVERSITY of MARYLAND  
FRANCIS KING CAREY  
SCHOOL OF LAW



JOHNS HOPKINS  
UNIVERSITY



advisorOf



advisorOf



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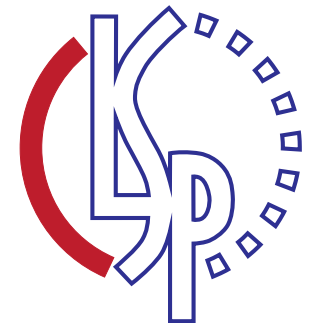
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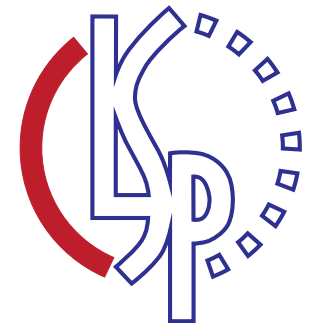
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SCHOOL OF LAW



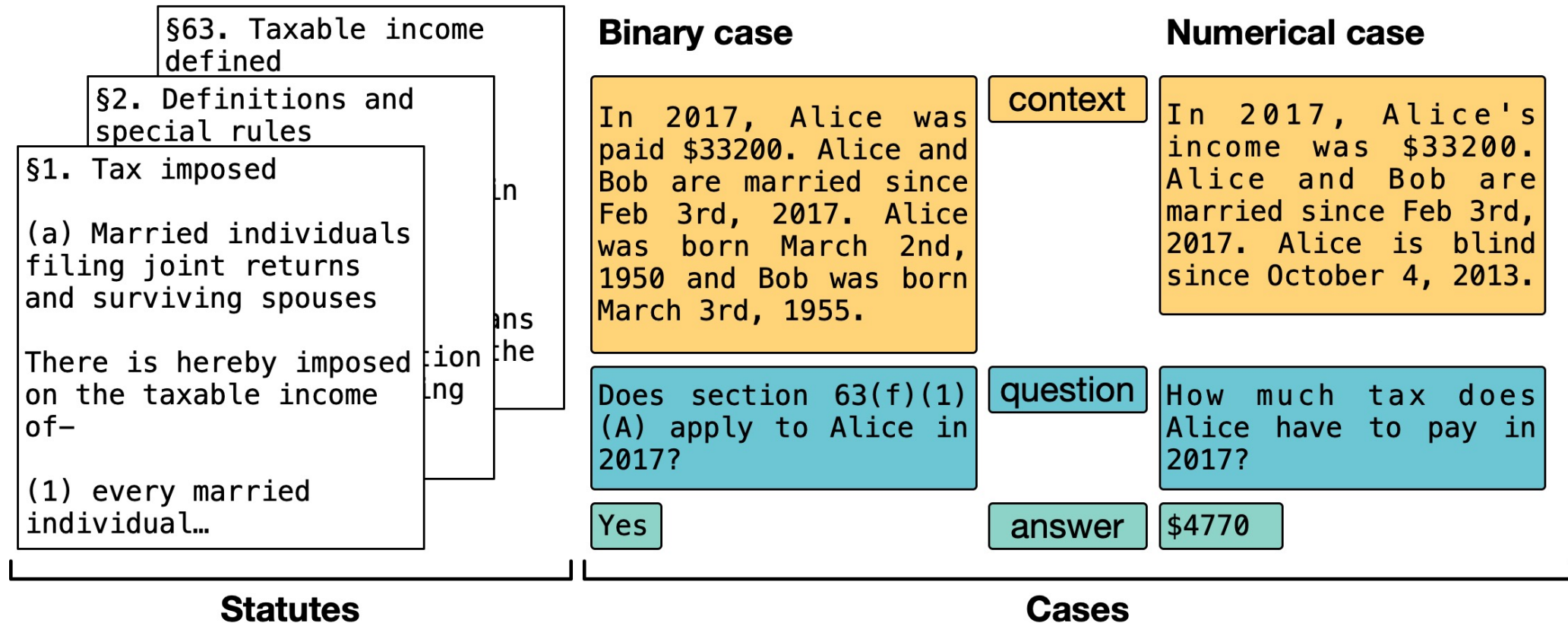
JOHNS HOPKINS  
UNIVERSITY





# A Dataset for Statutory Reasoning in Tax Law Entailment and Question Answering

Natural Legal Language Processing (NLLP) Workshop @ KDD 2020



# For discussion outside this talk

## Featured on AI2's NLP Highlights podcast



<https://soundcloud.com/nlp-highlights/122-statutory-reasoning-in-tax-law-with-nils-holzenberger>

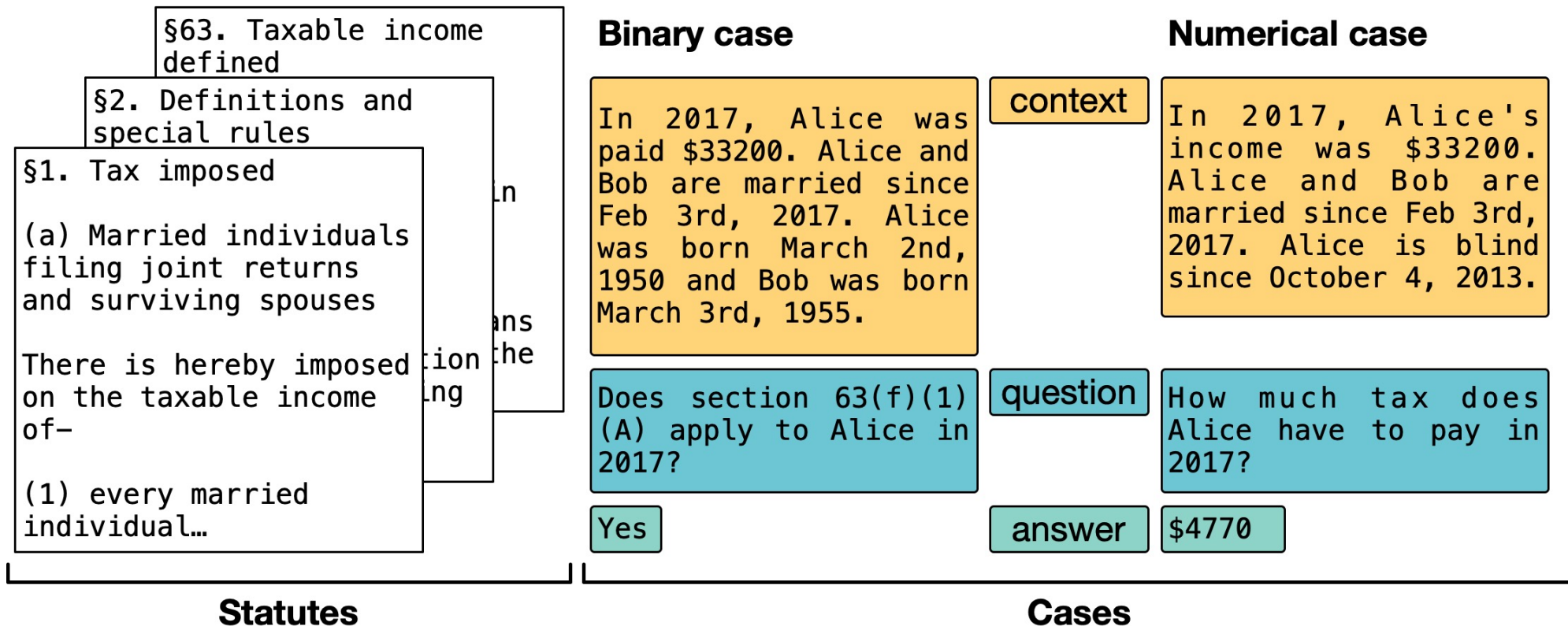


# Statutory Reasoning Assessment (SARA)

Manually select and abbreviate 9 sections of federal tax law

Author 376 synthetic cases covering subsections and tax computation

Tax law professor vets each case and statute interpretation



# Features of SARA

*How much tax do I owe?*

## §1. Tax imposed

(a) Married individuals filing joint returns and surviving spouses

There is hereby imposed on the taxable income of-

- (1) every married individual (as defined in section 7703) who makes a single return jointly with his spouse, and
- (2) every surviving spouse (as defined in section 2(a)),

a tax determined in accordance with the following:

- (i) 15% of taxable income if the taxable income is not over \$36,900;
- (ii) \$5,535, plus 28% of the excess over \$36,900 if the taxable income is over \$36,900 but not over \$89,150;
- (iii) \$20,165, plus 31% of the excess over \$89,150 if the taxable income is over \$89,150 but not over \$140,000; ....

# Features of SARA

- Hierarchical structure

## §1. Tax imposed

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# Features of SARA

- Hierarchical structure
- Numerical reasoning

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# Features of SARA

- Hierarchical structure
  - Numerical reasoning
- 

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- (iii) \$20,165, plus 31% of the excess over \$89,150 if the taxable income is over \$89,150 but not over \$140,000; ....

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references

## §1. Tax imposed

(a) Married individuals filing joint returns and surviving spouses

There is hereby imposed on the taxable income of-

- (1) every married individual (as defined in section 7703) who makes a single return jointly with his spouse, and
- (2) every surviving spouse (as defined in section 2(a)),

a tax determined in accordance with the following:

- (i) 15% of taxable income if the taxable income is not over \$36,900;
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# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references

## §1. Tax imposed

(a) Married individuals filing joint returns and surviving spouses

There is hereby imposed on the **taxable income** of-

- (1) every married individual (as defined in **section 7703**) who makes a single return jointly with his spouse, and
- (2) every **surviving spouse (as defined in section 2(a))**,

a tax determined in accordance with the following:

- (i) 15% of taxable income if the taxable income is not over \$36,900;
- (ii) \$5,535, plus 28% of the excess over \$36,900 if the taxable income is over \$36,900 but not over \$89,150;
- (iii) \$20,165, plus 31% of the excess over \$89,150 if the taxable income is over \$89,150 but not over \$140,000; ....

*implicit (§63)*

*explicit*



# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references

## §2. Definitions and special rules

### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer-

(A) whose spouse died during either of the two years immediately preceding the taxable year, and

(B) who maintains as his home a household which constitutes for the taxable year the principal place of abode (as a member of such household) of a dependent

- (i) who (within the meaning of section 152) is a son, stepson, daughter, or stepdaughter of the taxpayer, and
- (ii) with respect to whom the taxpayer is entitled to a deduction for the taxable year under section 151.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense

## §2. Definitions and special rules

### (a) Definition of surviving spouse

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# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense

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For purposes of section 1, the term "surviving spouse" means a taxpayer-

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(i) who (within the meaning of section 152) is a son, stepson, daughter, or stepdaughter of the taxpayer, and

(ii) with respect to whom the taxpayer is entitled to a deduction for the taxable year under section 151.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense

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### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer-

(A) whose spouse died during either of the two years immediately preceding the taxable year, and

(B) who maintains as his home a household which constitutes for the taxable year the principal place of abode (as a member of such household) of a dependent

[...]

For purposes of this paragraph, an individual shall be considered as maintaining a household only if over half of the cost of maintaining the household during the taxable year is furnished by such individual.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense
- Temporal reasoning

## §2. Definitions and special rules

### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer-

(A) whose spouse died during either of the two years immediately preceding the taxable year, and

(B) who maintains as his home a household which constitutes for the taxable year the principal place of abode (as a member of such household) of a dependent  
[...]

For purposes of this paragraph, an individual shall be considered as maintaining a household only if over half of the cost of maintaining the household during the taxable year is furnished by such individual.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense
- Temporal reasoning

## §2. Definitions and special rules

### (a) Definition of surviving spouse

[...]

#### (2) Limitations

Notwithstanding paragraph (1), for purposes of section 1 a taxpayer shall not be considered to be a surviving spouse-

(A) if the taxpayer has remarried at any time before the close of the taxable year, or

(B) unless, for the taxpayer's taxable year during which his spouse died, a joint return could have been made. A husband and wife may make a single return jointly of income taxes, even though one of the spouses has neither gross income nor deductions, except that no joint return shall be made if either the husband or wife at any time during the taxable year is a nonresident alien.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense
- Temporal reasoning
- Exceptions and substitutions

## §2. Definitions and special rules

### (a) Definition of surviving spouse

[...]

#### (2) Limitations

**Notwithstanding paragraph (1), for purposes of section 1 a taxpayer shall not be considered to be a surviving spouse-**

(A) if the taxpayer has remarried at any time before the close of the taxable year, or

(B) unless, for the taxpayer's taxable year during which his spouse died, a joint return could have been made. A husband and wife may make a single return jointly of income taxes, even though one of the spouses has neither gross income nor deductions, except that no joint return shall be made if either the husband or wife at any time during the taxable year is a nonresident alien.

# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense
- Temporal reasoning
- Exceptions and substitutions

## §2. Definitions and special rules

[...]

### (b) Definition of head of household

[...]

### (3) Limitations

Notwithstanding paragraph (1), for purposes of this subtitle a taxpayer shall not be considered to be a head of a household-

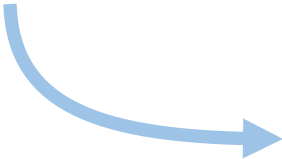
(A) if at any time during the taxable year he is a nonresident alien; or

(B) by reason of an individual who would not be a dependent for the taxable year but for subparagraph (H) of section 152(d)(2).



# Features of SARA

- Hierarchical structure
- Numerical reasoning
- Cross-references
- Common sense
- Temporal reasoning
- Exceptions and substitutions
- **(Some) conditional counterfactuals**



## §2. Definitions and special rules

[...]

### (b) Definition of head of household

[...]

#### (3) Limitations

Notwithstanding paragraph (1), for purposes of this subtitle a taxpayer shall not be considered to be a head of a household-

(A) if at any time during the taxable year he is a nonresident alien; or

(B) by reason of an individual who would not be a dependent for the taxable year but for subparagraph (H) of section 152(d)(2).

# Features of SARA

- Lawyers and legal scholars argue about **individual words**
- There are a lot more official interpretations of statutes than there are statutes (Treasury Regulations vs Internal Revenue Code)
- Tax law statutes are **much more dense** than the language that NLP generally deals with

# Statutory Reasoning Assessment

- SARA designed to require natural language understanding and logical reasoning
- Write Prolog solver:
  - Translate statutes to a set of Prolog predicates
  - Translate facts in case to a knowledge graph

# Translating statutes

“(b) Heads of households

There is hereby imposed on the taxable income of every head of a household (as defined in section 2(b)) a tax determined in accordance with the following:

- (i) 15% of taxable income if the taxable income is not over \$29,600;
- (ii) \$4,440, plus 28% of the excess over \$29,600 if the taxable income is over \$29,600 but not over \$76,400;
- (iii) \$17,544, plus 31% of the excess over \$76,400 if the taxable income is over \$76,400 but not over \$127,500;
- ...”



```
s1_b(Taxp, Taxy, Taxinc, Tax) :-  
    s2_b(Taxp, _, Taxy),  
    s63(Taxp, Taxy, Taxinc),  
    (  
        s1_b_i(Taxinc, Tax);  
        s1_b_ii(Taxinc, Tax);  
        s1_b_iii(Taxinc, Tax);  
        s1_b_iv(Taxinc, Tax);  
        s1_b_v(Taxinc, Tax)  
    ).
```

# Translating facts of a case

“Bob and Alice got married on August 24<sup>th</sup>, 1970”



```
marriage_(alice_and_bob).  
agent_(alice_and_bob, alice).  
agent_(alice_and_bob, bob).  
start_(alice_and_bob, “1970-08-24”).
```

# Can we automatically solve SARA?

- Prolog solver, by design, achieves 100% accuracy on the task
- New laws and cases are added frequently
- Automatic semantic parsing not yet good enough
- Recast Statutory Reasoning and apply off-the-shelf ML solutions

# Machine Reading/Language Models

## Binary

In 2017, Alice was paid \$33200. Alice and Bob have been married since Feb 3rd, 2017. Alice was born March 2nd, 1950 and Bob was born March 3rd, 1955.

context

Section 63(f)(1)(A) applies to Alice in 2017.

question

Entailment

answer

Adapt Recognizing Textual Entailment models?

# Machine Reading/Language Models

## Numerical

context

In 2017, Alice's income was \$33200. Alice and Bob have been married since Feb 3rd, 2017. Alice has been blind since October 4, 2013.

question

How much tax does Alice have to pay in 2017?

answer

\$4770

Supervised Regression?

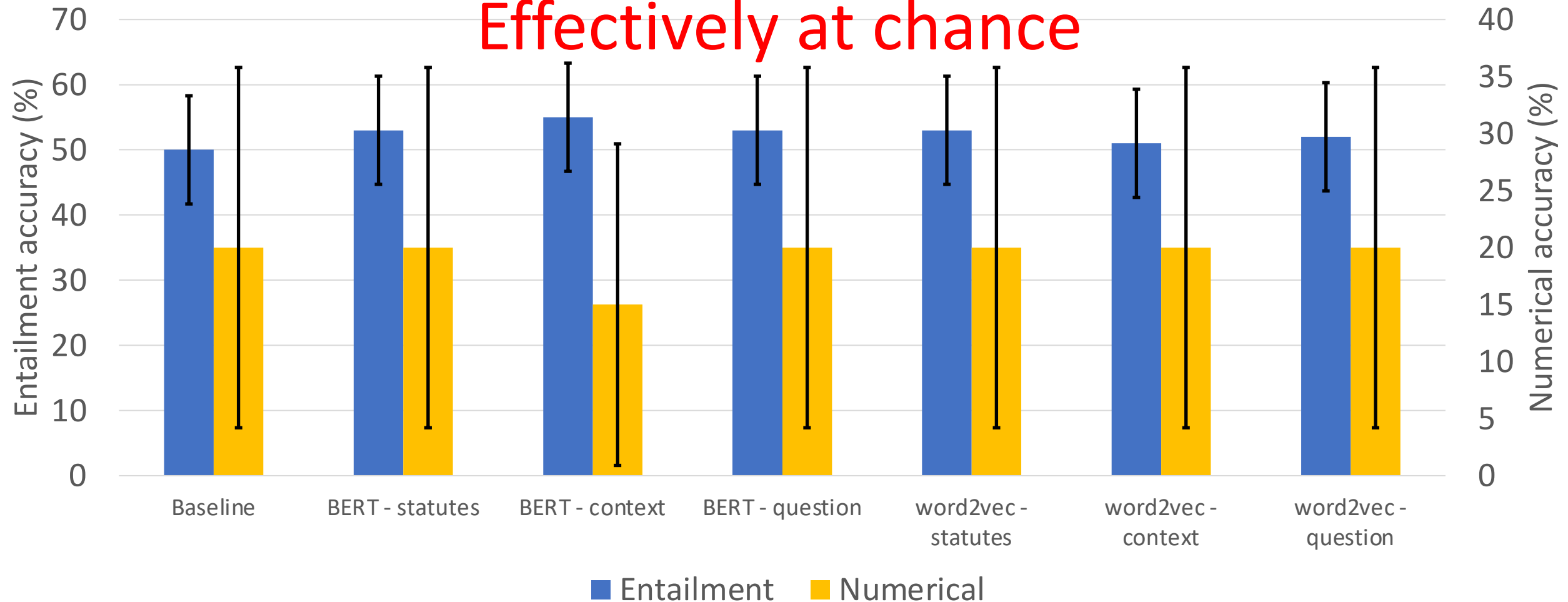
Accuracy as *Substantial over/understatement of tax §6662(d)*



# Machine Reading/Language Models

General-domain models

Effectively at chance



Training domain specific encoders, e.g., LegalBERT

# LegalBERT

## Step 1: Preprocess case.law



### Our data

360 years of United States caselaw

#### State and Federal Totals

6,708,785  
Unique cases

582  
Reporters

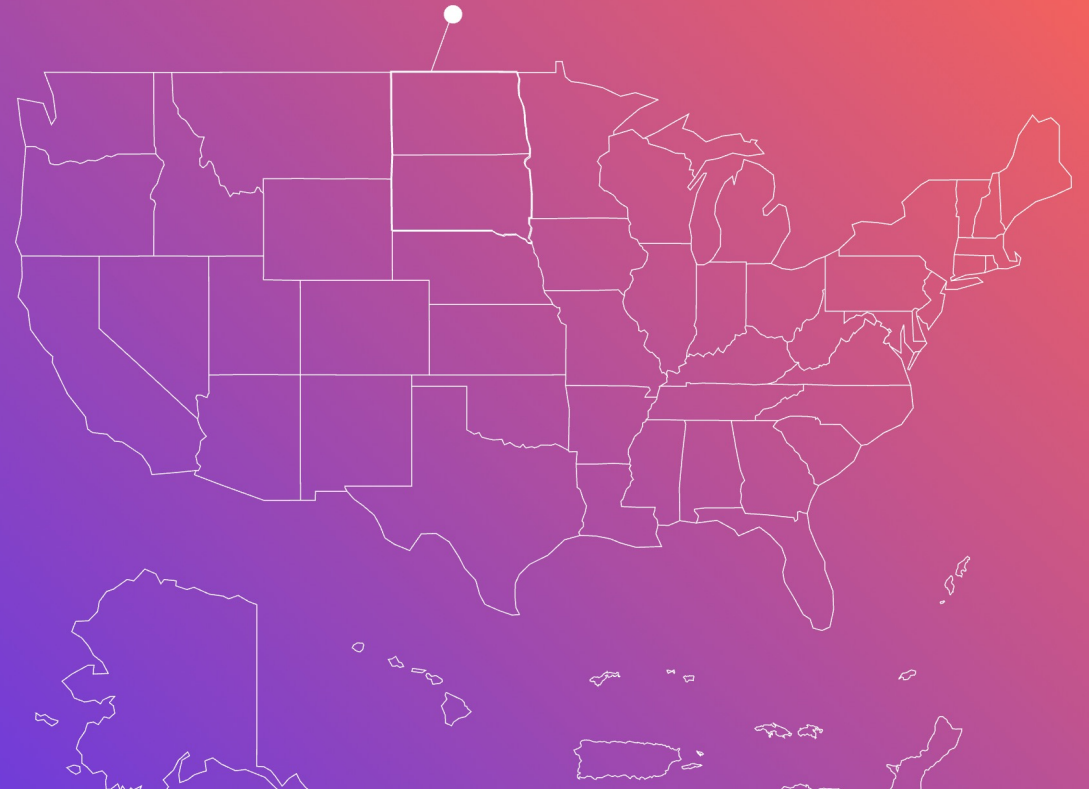
35,549,133  
Pages scanned

#### Federal Totals

1,760,899  
Unique cases

74  
Reporters

10,075,368  
Pages scanned



# LegalBERT

Step 1: Preprocess case.law



Step 2: Continued training of BERT Base Cased

- Cases starting in 1970
- 400+ tokens per case
- 900,000,000 tokens in total



# LegalBERT

Step 1: Preprocess case.law

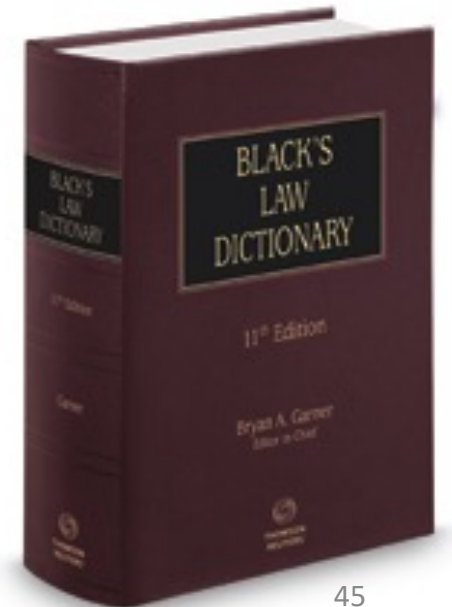


Step 2: Continued training of BERT Base Cased



Step 3: Evaluate on legal term discovery

- Purchase, scan, OCR legal dictionary
- Define 'legal term' recognitions as B-I-O sequence tagging
- Results: better than lawyers, LegalBERT > BERT



# LegalBERT

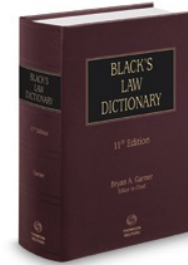
Step 1: Preprocess case.law



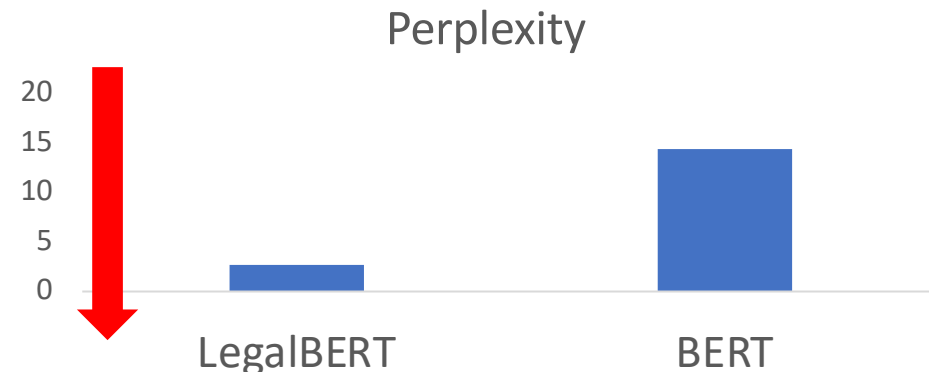
Step 2: Continued training of BERT Base Cased



Step 3: Evaluate on legal term discovery



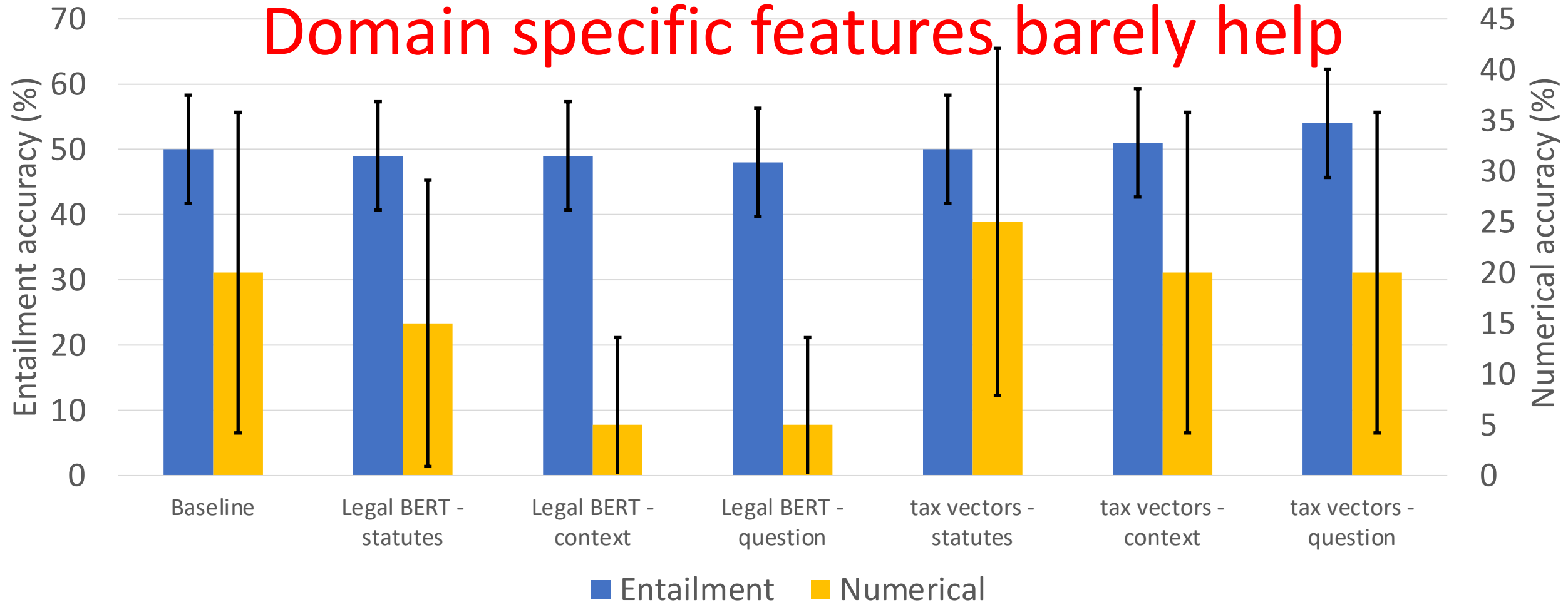
Step 4: Measure on SARA examples



# Machine Reading/Language Models

## Legal-domain models

Domain specific features barely help



# Statutory reasoning?

- Off-the-shelf and domain adapted machine reading struggles
- Ablation experiments suggest that statutes are being ignored
- Natural language understanding + logical reasoning are sufficient
- Transformers can learn to reason with rules in natural language  
Peter Clark *et al.* *Transformers as Soft Reasoners over Language*. IJCAI 2020.



# Contributions

- A benchmark for statutory reasoning
  - A closed set of statutes for tax law
  - Test cases covering the entirety of the statutes
- A Prolog-based solver
- Corpora to train legal-domain language models
- Legal-domain language models

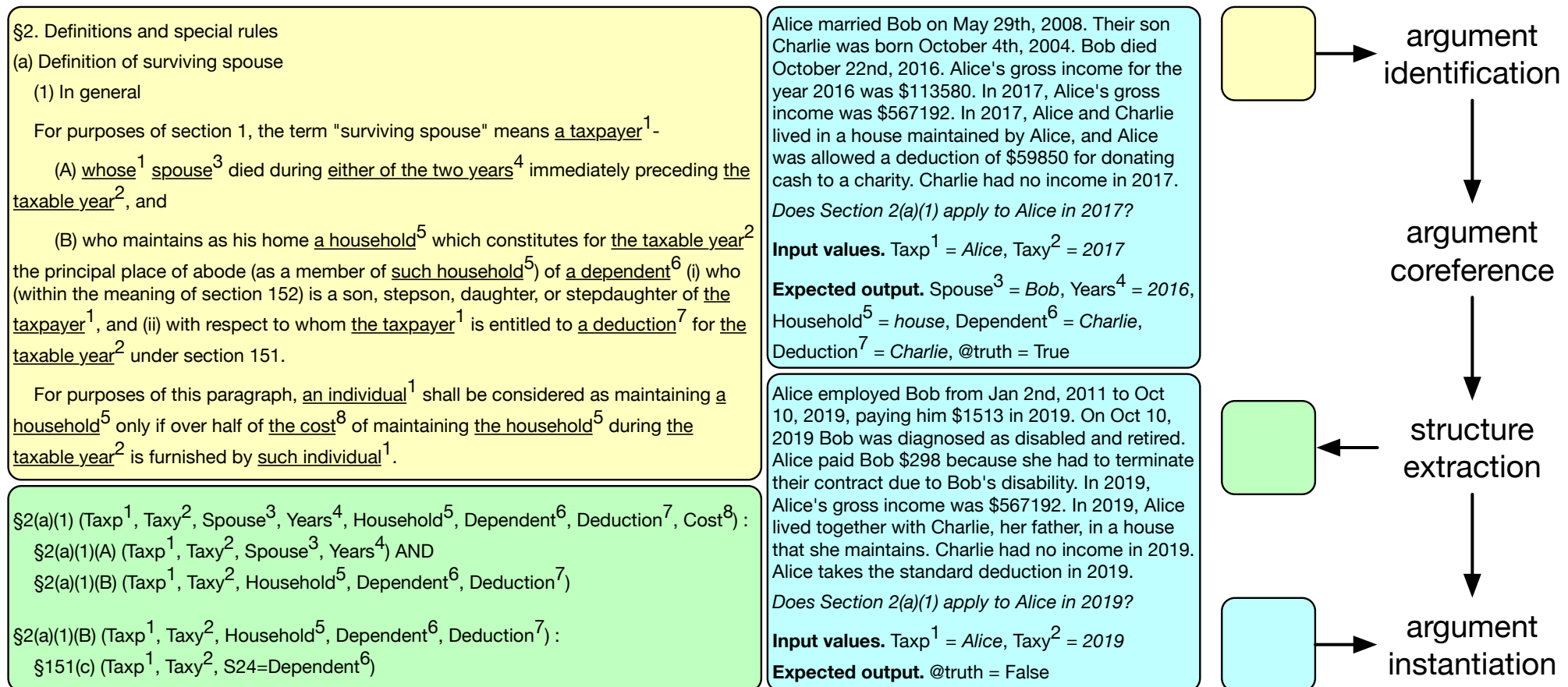
# Statutory reasoning?

What to do?

- Semantic parsing for legal texts?
- New science in efficiently creating a lot more data?
- New science in machine reading to be far more data efficient?
- Breaking the task into smaller parts?

# Factoring Statutory Reasoning as Language Understanding Challenges

## ACL 2021



# Factoring Statutory Reasoning

Rather than “language in, answer out” model, let’s break into subparts:

1. Argument (entity mention) identification within statutes
2. Argument coreference within statutes
3. Conversion of statutes into structured neural module networks
4. Instantiating statutes with arguments from case

Legal Information Extraction

Semantic Parsing

Machine Reading

# Argument Identification

For purposes of *this chapter*, the term "employment" means *any service, of whatever nature,*

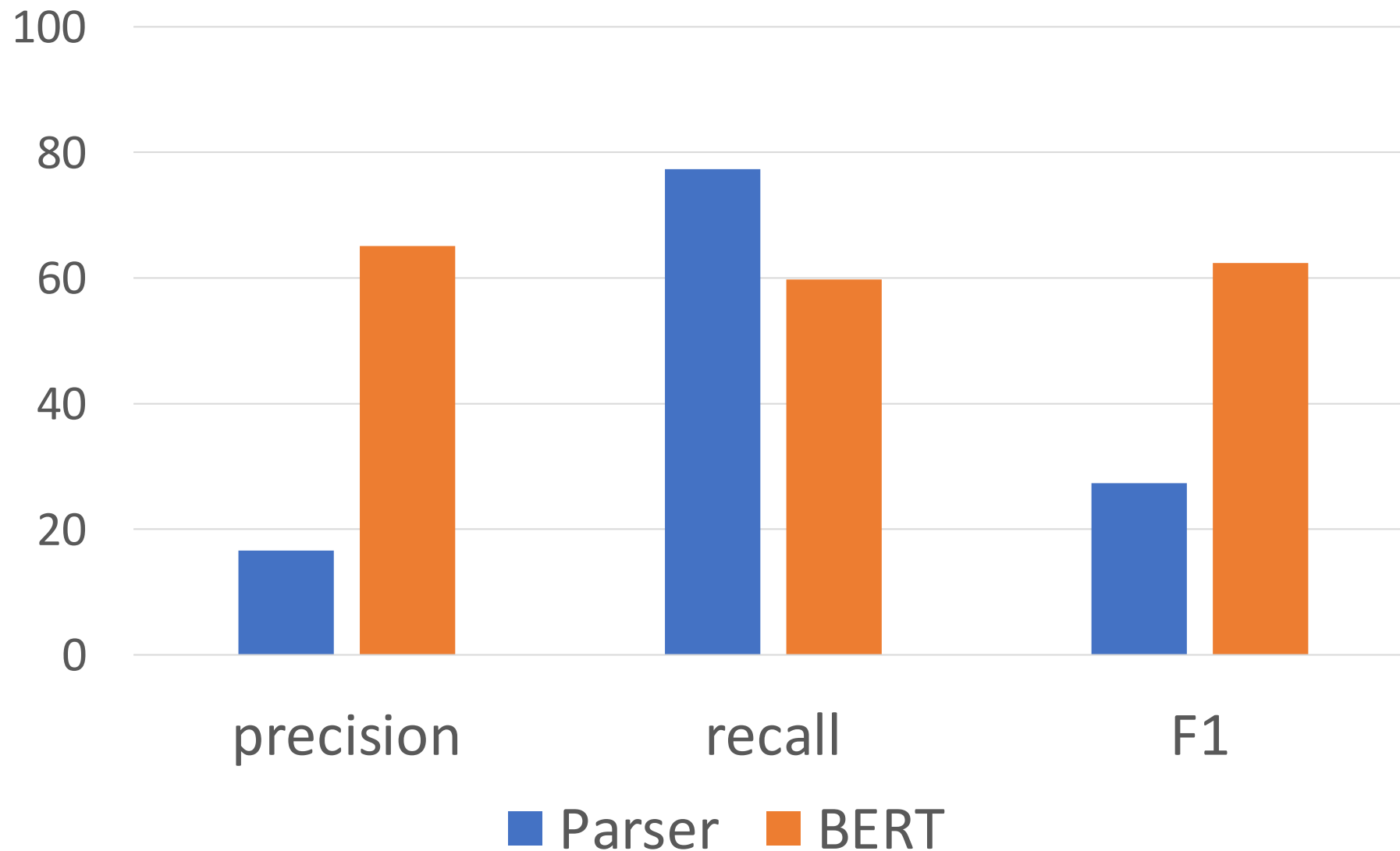
(A) performed by *an employee for the person employing him, irrespective of the citizenship or residence of either, within the United States, and*

(B) performed *outside the United States (except in a contiguous country with which the United States has an agreement relating to unemployment compensation)* by *a citizen of the United States as an employee of an American employer, except- [...]*

Concrete references

Case-specific values

# Argument identification baselines



# Argument coreference

## §2. Definitions and special rules

### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer<sup>1</sup> -

(A) whose<sup>1</sup> spouse<sup>3</sup> died during either of the two years<sup>4</sup> immediately preceding the taxable year<sup>2</sup>, and

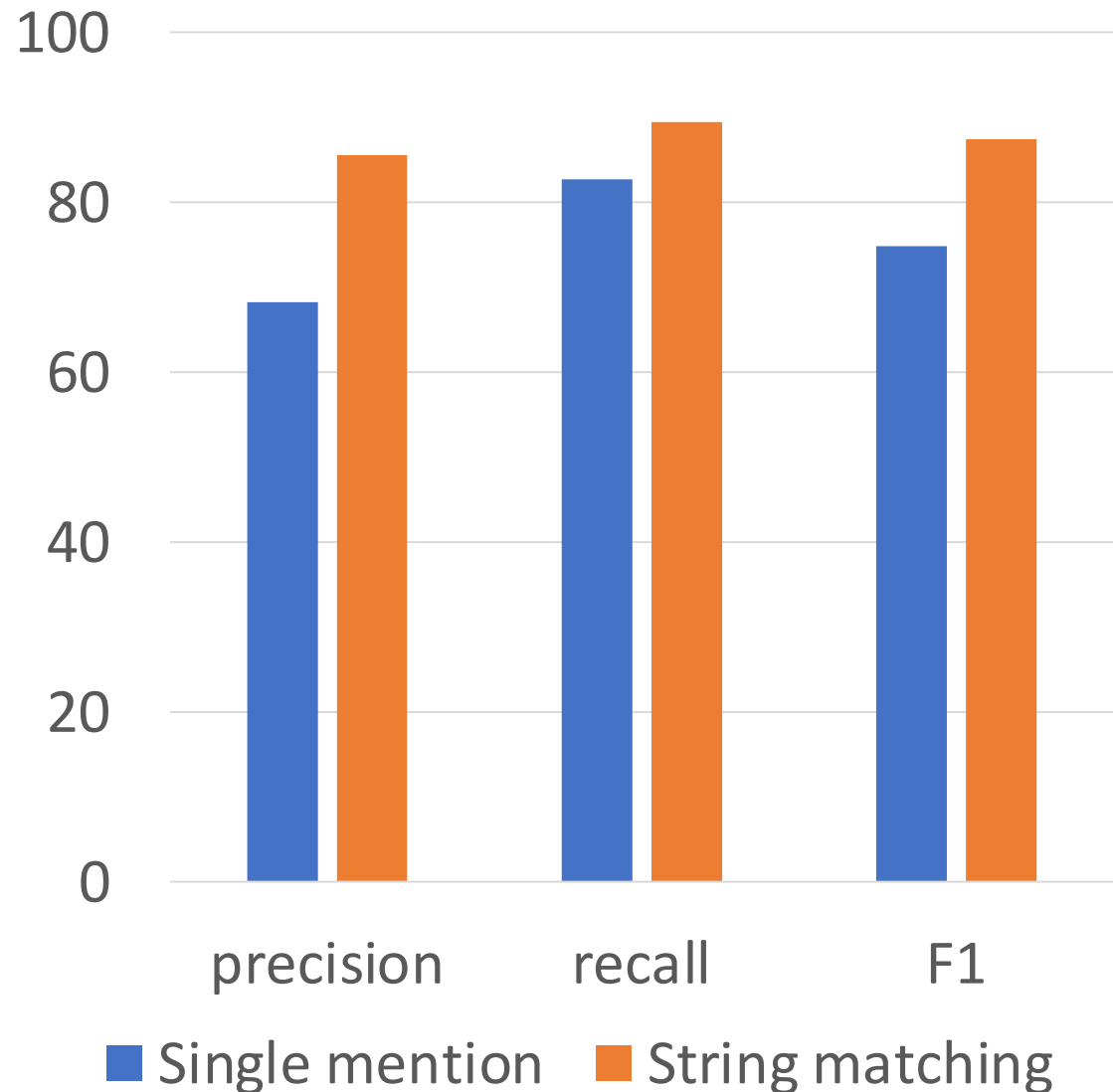
(B) who maintains as his home a household<sup>5</sup> which constitutes for the taxable year<sup>2</sup> the principal place of abode (as a member of such household<sup>5</sup>) of a dependent<sup>6</sup> (i) who (within the meaning of section 152) is a son, stepson, daughter, or stepdaughter of the taxpayer<sup>1</sup>, and (ii) with respect to whom the taxpayer<sup>1</sup> is entitled to a deduction<sup>7</sup> for the taxable year<sup>2</sup> under section 151.

For purposes of this paragraph, an individual<sup>1</sup> shall be considered as maintaining a household<sup>5</sup> only if over half of the cost<sup>8</sup> of maintaining the household<sup>5</sup> during the taxable year<sup>2</sup> is furnished by such individual<sup>1</sup>.

# Argument coreference baselines

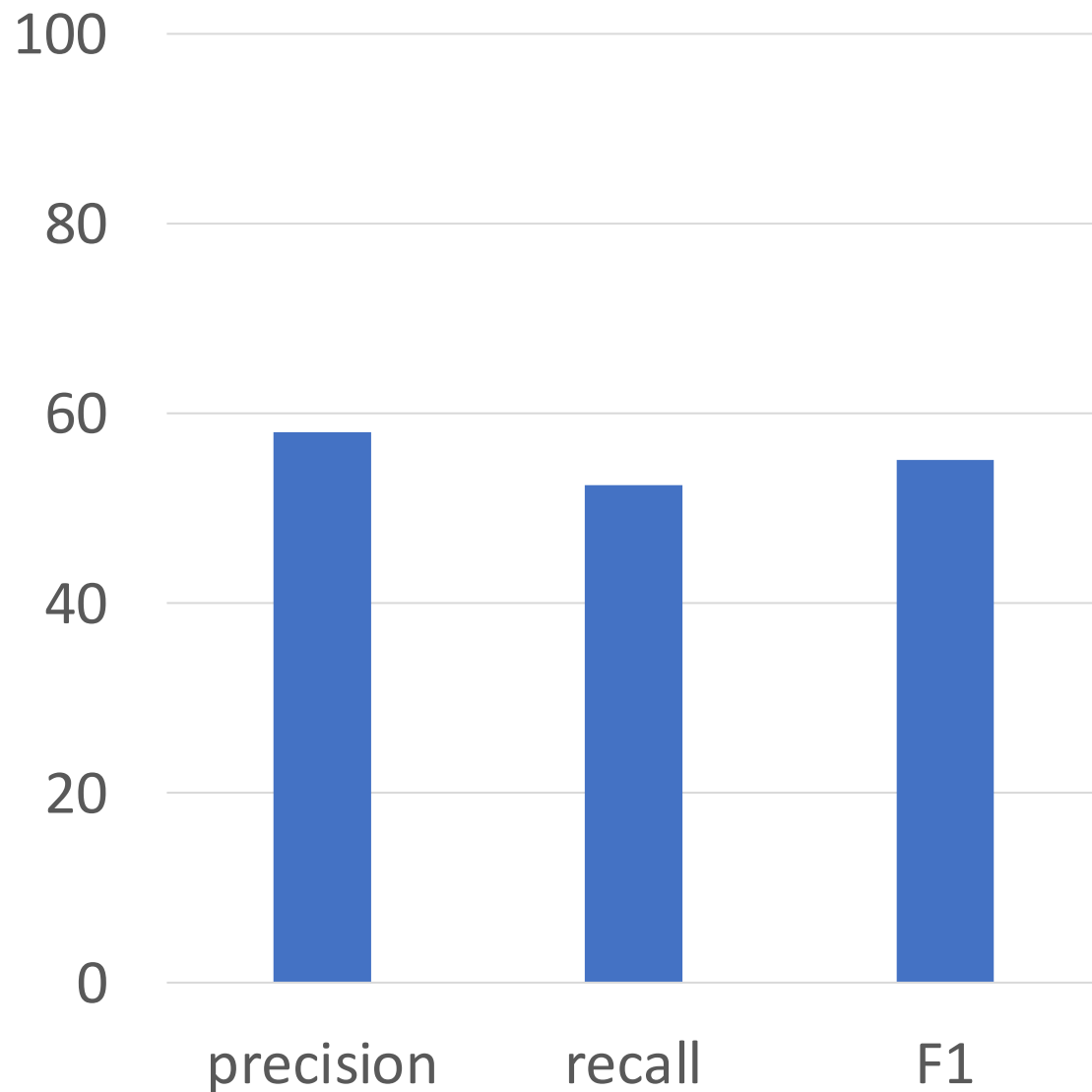
*Single mention*: predict no coreference links

*String matching*: strings are identical (except determiners)





# Combined argument identification and coreference



BERT-based argument  
identification with string-  
matching coreference

Perfectly resolves ~20% of  
subsections

# Statutes to structure

## §2. Definitions and special rules

### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer<sup>1</sup> -

(A) whose<sup>1</sup> spouse<sup>3</sup> died during either of the two years<sup>4</sup> immediately preceding the taxable year<sup>2</sup>, and

(B) who maintains as his home a household<sup>5</sup> which constitutes for the taxable year<sup>2</sup> the principal place of abode (as a member of such household<sup>5</sup>) of a dependent<sup>6</sup> (i) who (within the meaning of section 152) is a son, stepson, daughter, or stepdaughter of the taxpayer<sup>1</sup>, and (ii) with respect to whom the taxpayer<sup>1</sup> is entitled to a deduction<sup>7</sup> for the taxable year<sup>2</sup> under section 151.

For purposes of this paragraph, an individual<sup>1</sup> shall be considered as maintaining a household<sup>5</sup> only if over half of the cost<sup>8</sup> of maintaining the household<sup>5</sup> during the taxable year<sup>2</sup> is furnished by such individual<sup>1</sup>.

§2(a)(1) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>, Cost<sup>8</sup>) :

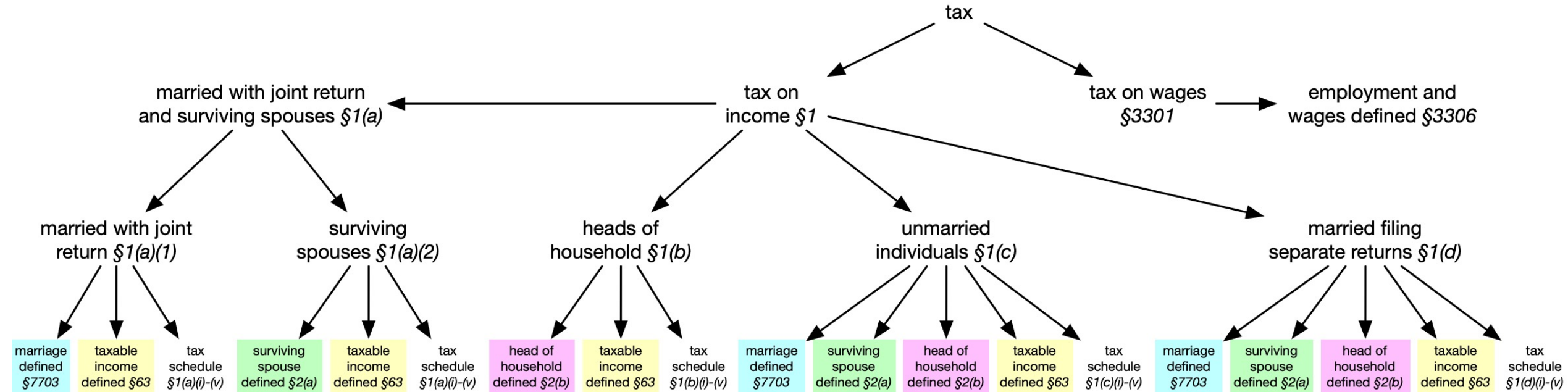
§2(a)(1)(A) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>) AND

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>)

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>) :

§151(c) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, S24=Dependent<sup>6</sup>)

# Structure extraction



§2(a)(1) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>, Cost<sup>8</sup>) :

§2(a)(1)(A) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>) AND

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>)

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>) :

§151(c) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, S24=Dependent<sup>6</sup>)



# Statutes to structure

- How to tie discovered arguments into structured modules for inference?
- We assume the Prolog structures, as if a tech-savvy Congress provided machine readable versions of policy
- Future work: semantic parsing for statutes

## §2. Definitions and special rules

### (a) Definition of surviving spouse

#### (1) In general

For purposes of section 1, the term "surviving spouse" means a taxpayer<sup>1</sup> -

(A) whose<sup>1</sup> spouse<sup>3</sup> died during either of the two years<sup>4</sup> immediately preceding the taxable year<sup>2</sup>, and

(B) who maintains as his home a household<sup>5</sup> which constitutes for the taxable year<sup>2</sup> the principal place of abode (as a member of such household<sup>5</sup>) of a dependent<sup>6</sup> (i) who (within the meaning of section 152) is a son, stepson, daughter, or stepdaughter of the taxpayer<sup>1</sup>, and (ii) with respect to whom the taxpayer<sup>1</sup> is entitled to a deduction<sup>7</sup> for the taxable year<sup>2</sup> under section 151.

For purposes of this paragraph, an individual<sup>1</sup> shall be considered as maintaining a household<sup>5</sup> only if over half of the cost<sup>8</sup> of maintaining the household<sup>5</sup> during the taxable year<sup>2</sup> is furnished by such individual<sup>1</sup>.

§2(a)(1) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>, Cost<sup>8</sup>) :

§2(a)(1)(A) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Spouse<sup>3</sup>, Years<sup>4</sup>) AND

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>)

§2(a)(1)(B) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, Household<sup>5</sup>, Dependent<sup>6</sup>, Deduction<sup>7</sup>) :

§151(c) (Taxp<sup>1</sup>, Taxy<sup>2</sup>, S24=Dependent<sup>6</sup>)

# Argument instantiation

## Given

- structured statutes
- a case

## how to

- apply the statute
- provide values for arguments

Alice married Bob on May 29th, 2008. Their son Charlie was born October 4th, 2004. Bob died October 22nd, 2016. Alice's gross income for the year 2016 was \$113580. In 2017, Alice's gross income was \$567192. In 2017, Alice and Charlie lived in a house maintained by Alice, and Alice was allowed a deduction of \$59850 for donating cash to a charity. Charlie had no income in 2017.

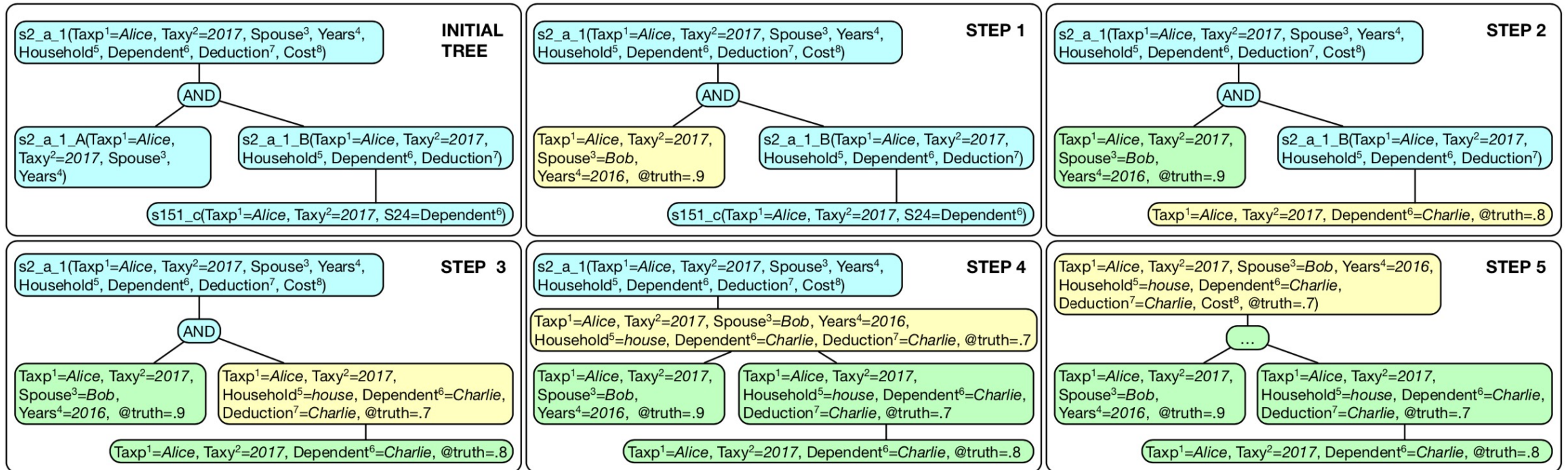
*Does Section 2(a)(1) apply to Alice in 2017?*

**Input values.**  $\text{Taxp}^1 = \text{Alice}$ ,  $\text{Taxy}^2 = 2017$

**Expected output.**  $\text{Spouse}^3 = \text{Bob}$ ,  $\text{Years}^4 = 2016$ ,  
 $\text{Household}^5 = \text{house}$ ,  $\text{Dependent}^6 = \text{Charlie}$ ,  
 $\text{Deduction}^7 = \text{Charlie}$ ,  $\text{@truth} = \text{True}$

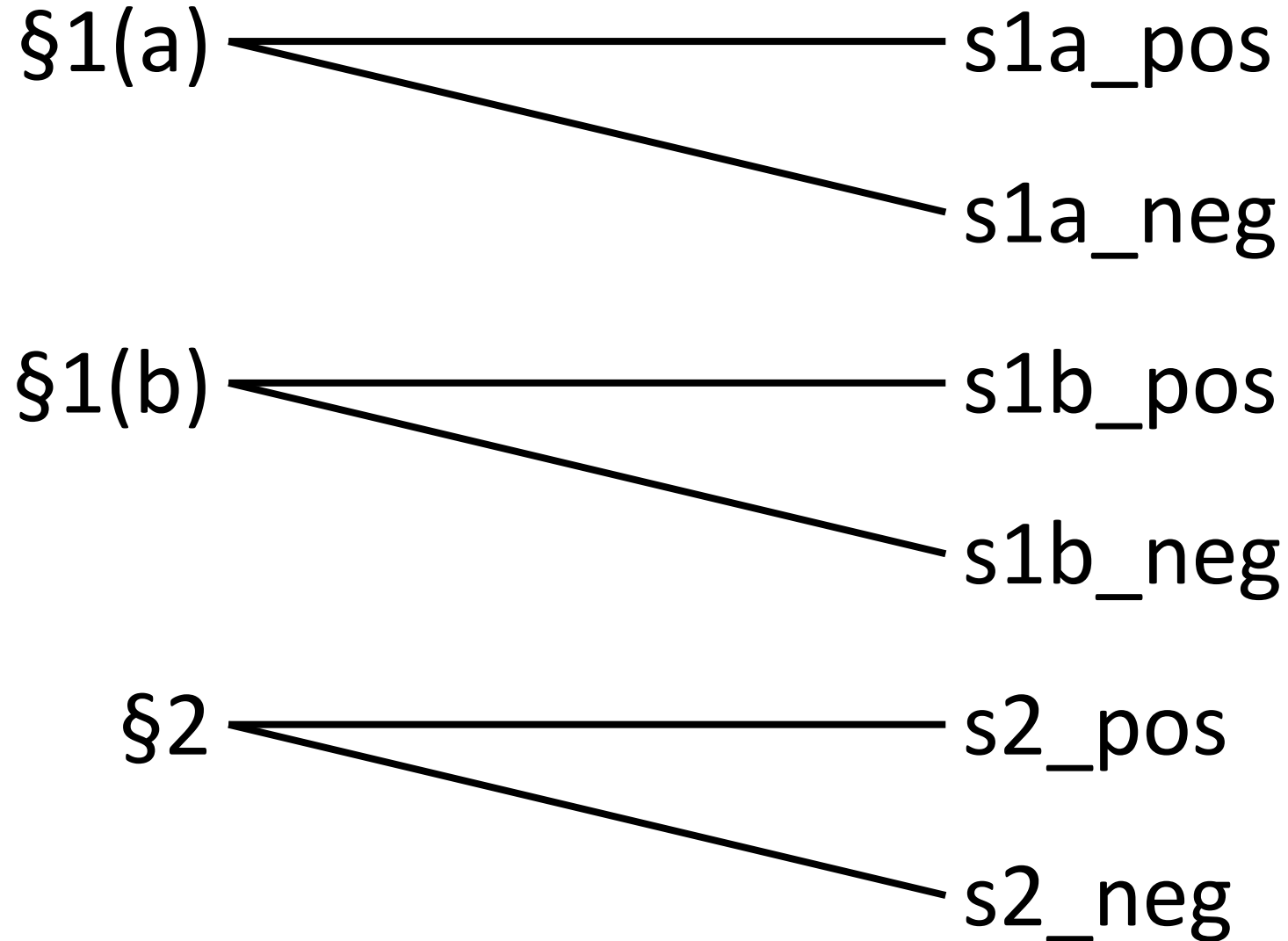
# Argument instantiation — machine reading

Two nested for loops: one that iterates over subsections, guided by the dependency annotations; one that iterates over a subsection's arguments and finds their values



# To train Neural Modules: data augmentation

Natural  
language

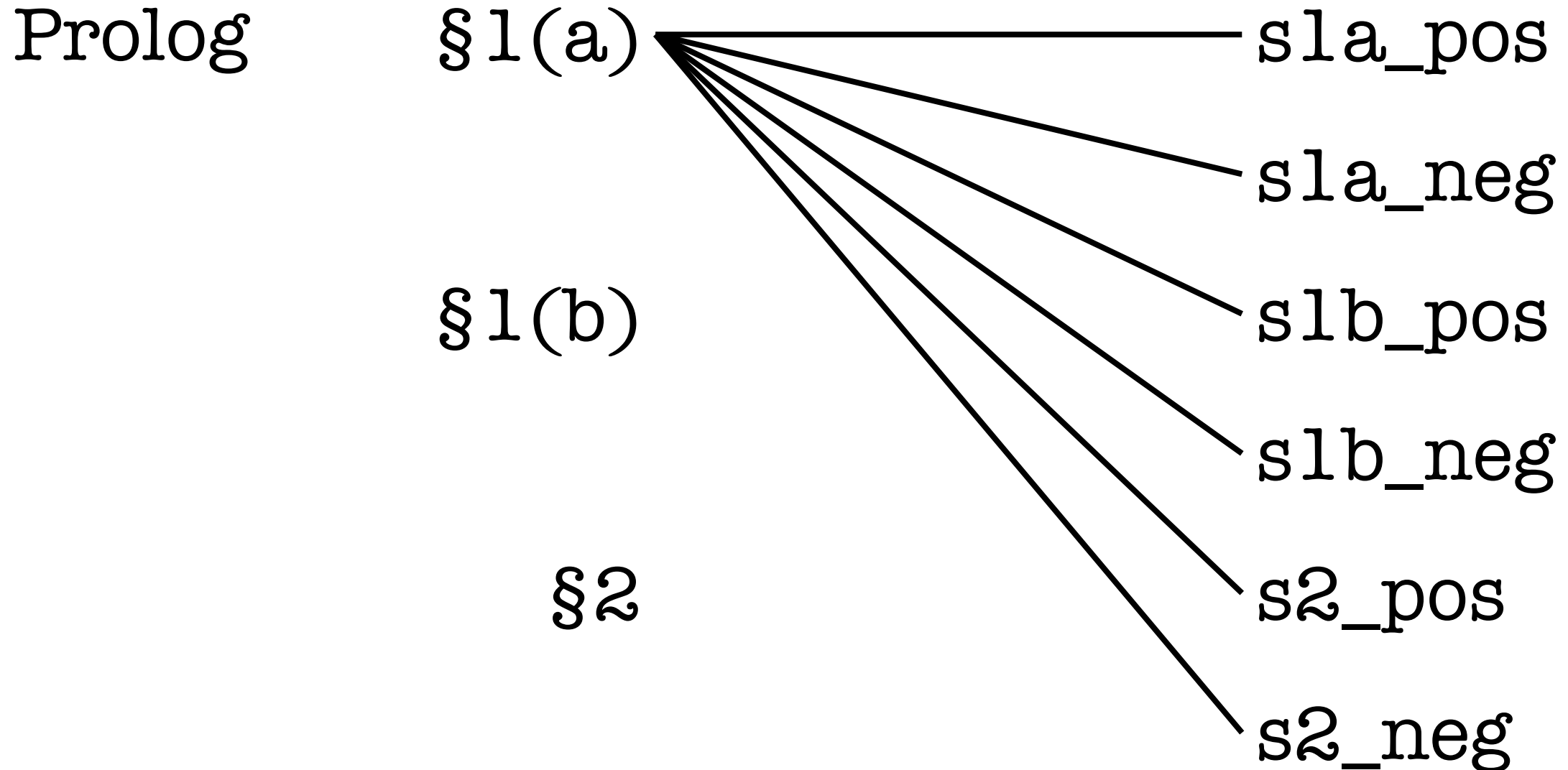


# To train Neural Modules: data augmentation

Prolog	§ 1(a)	sla_pos
		sla_neg
	§ 1(b)	s1b_pos
		s1b_neg
	§ 2	s2_pos
		s2_neg



# To train Neural Modules: data augmentation



# To train Neural Modules: data augmentation

Prolog

§1(a)

§1(b)

§2

s1a\_pos

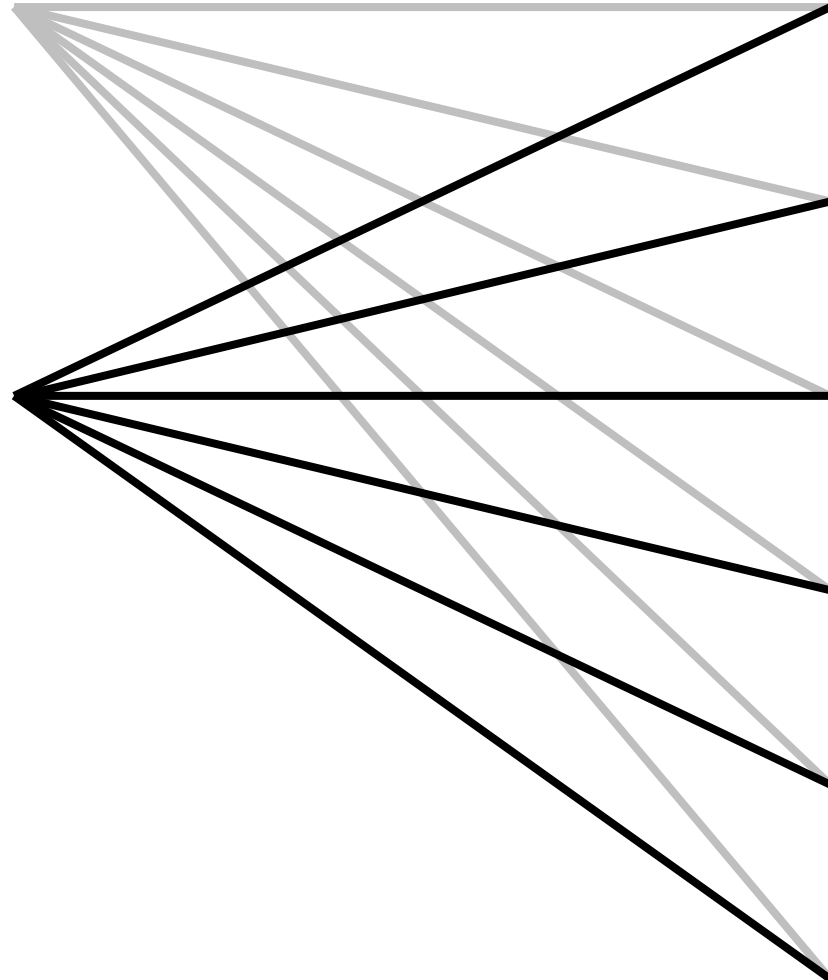
s1a\_neg

s1b\_pos

s1b\_neg

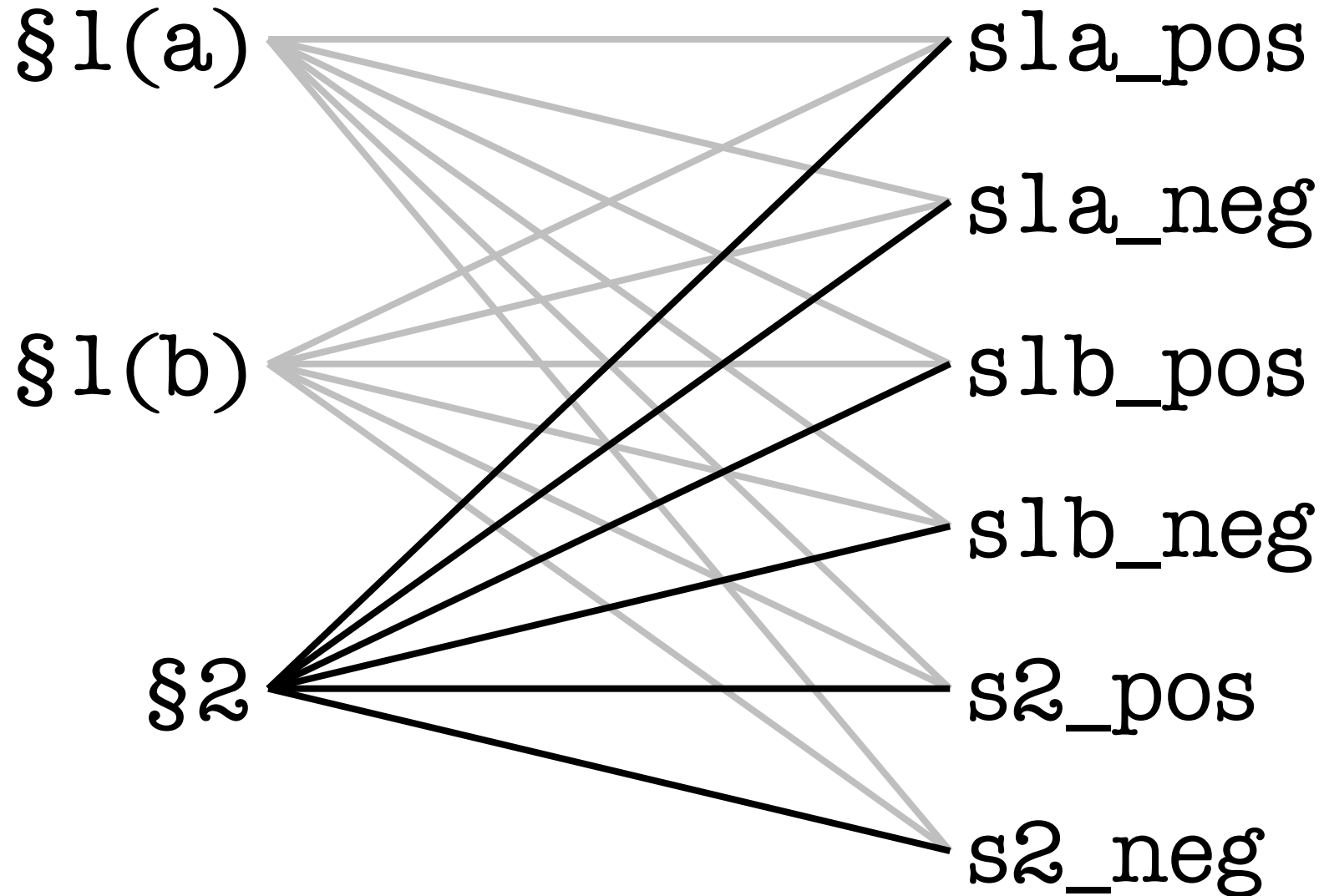
s2\_pos

s2\_neg

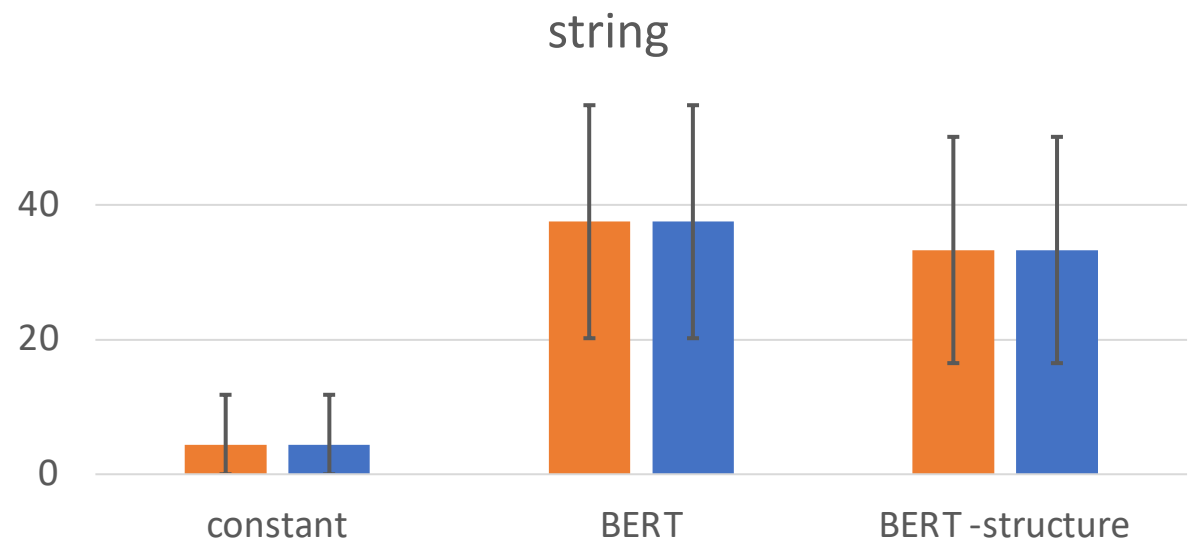
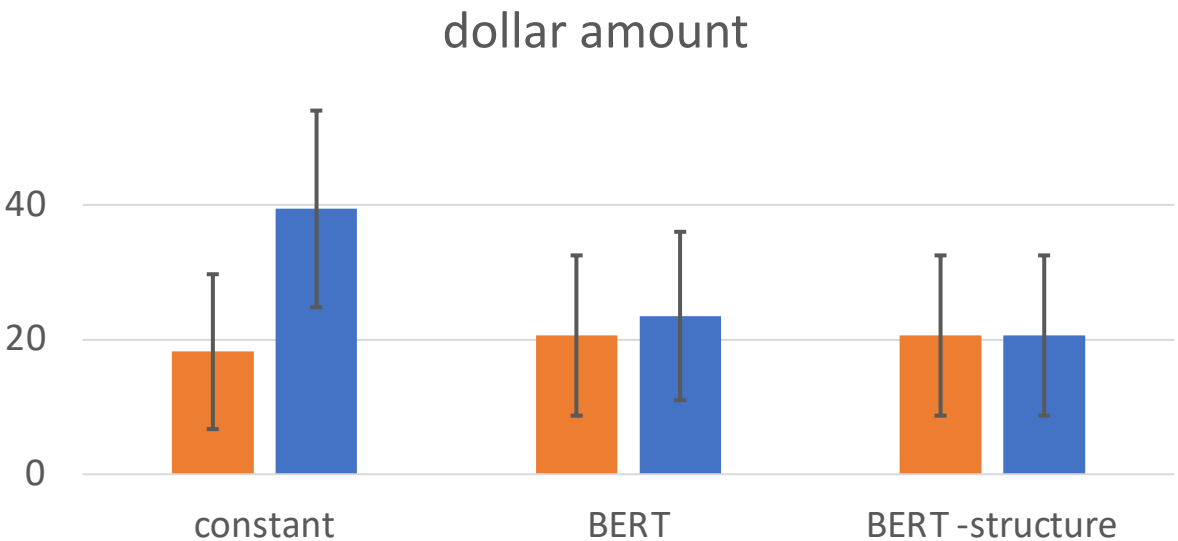
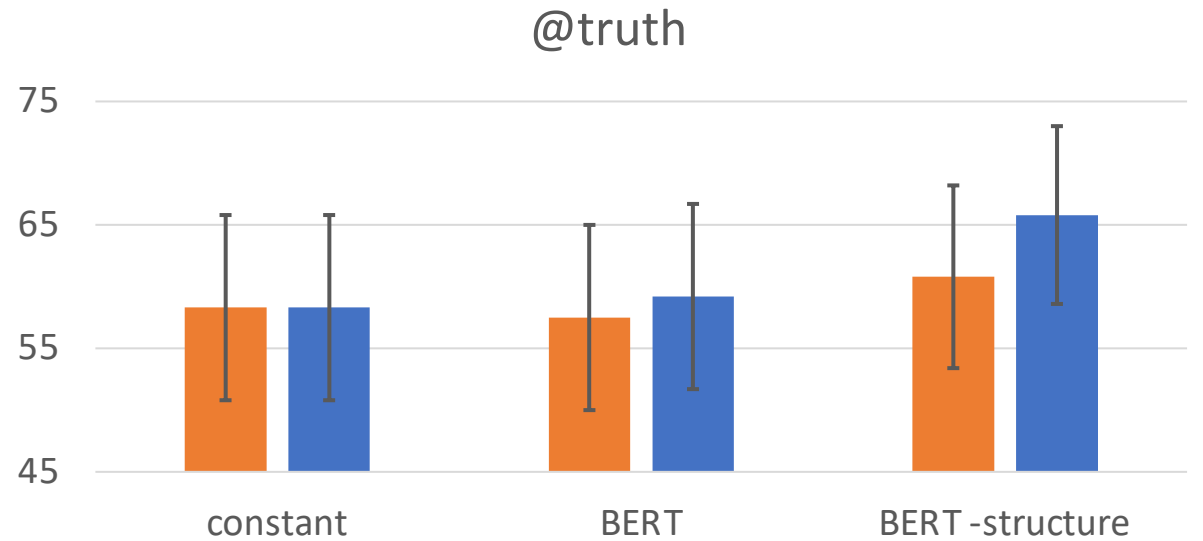
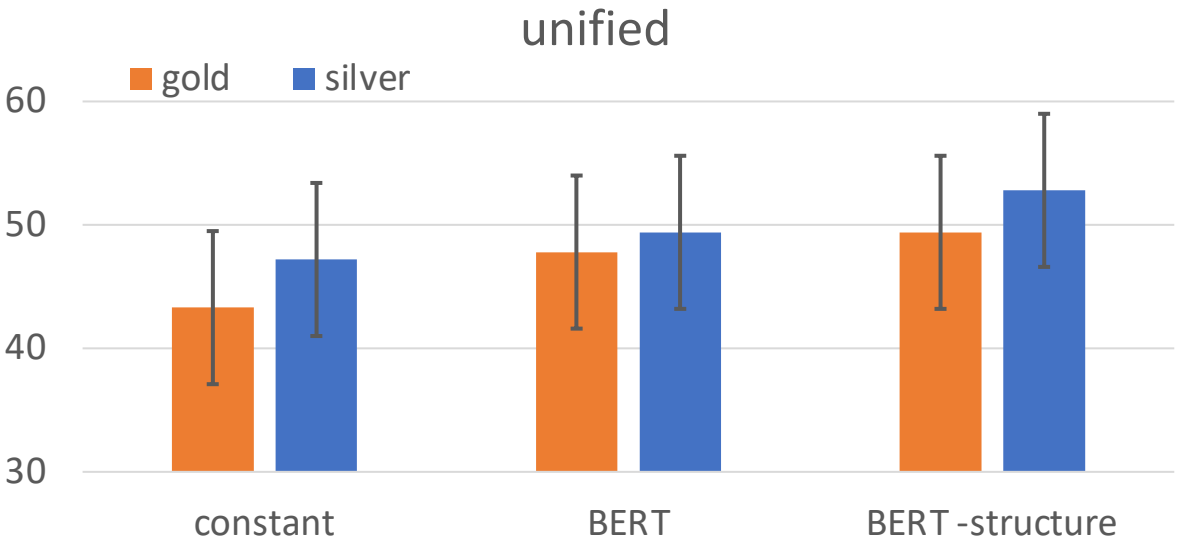


# To train Neural Modules: data augmentation

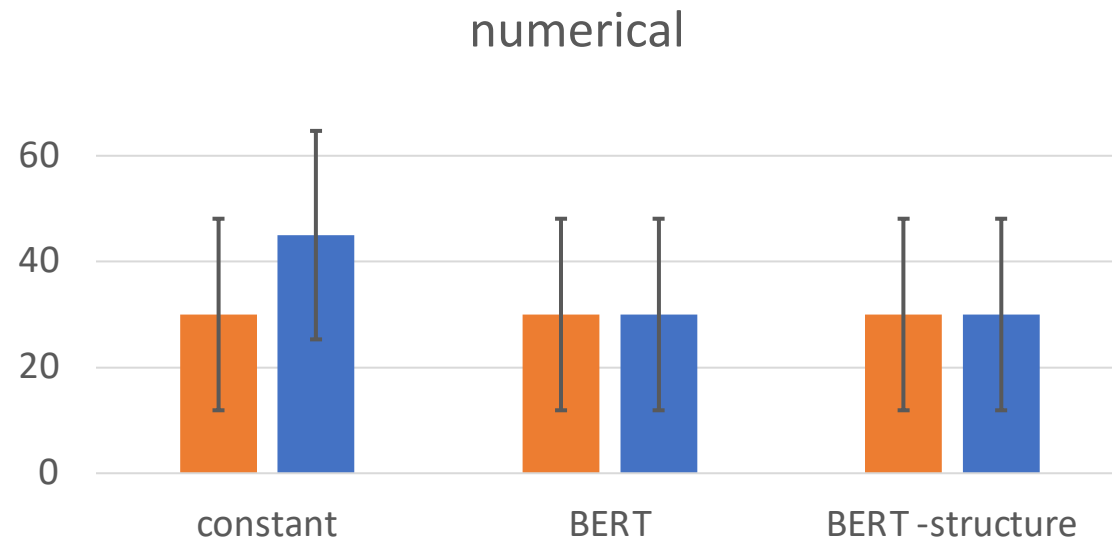
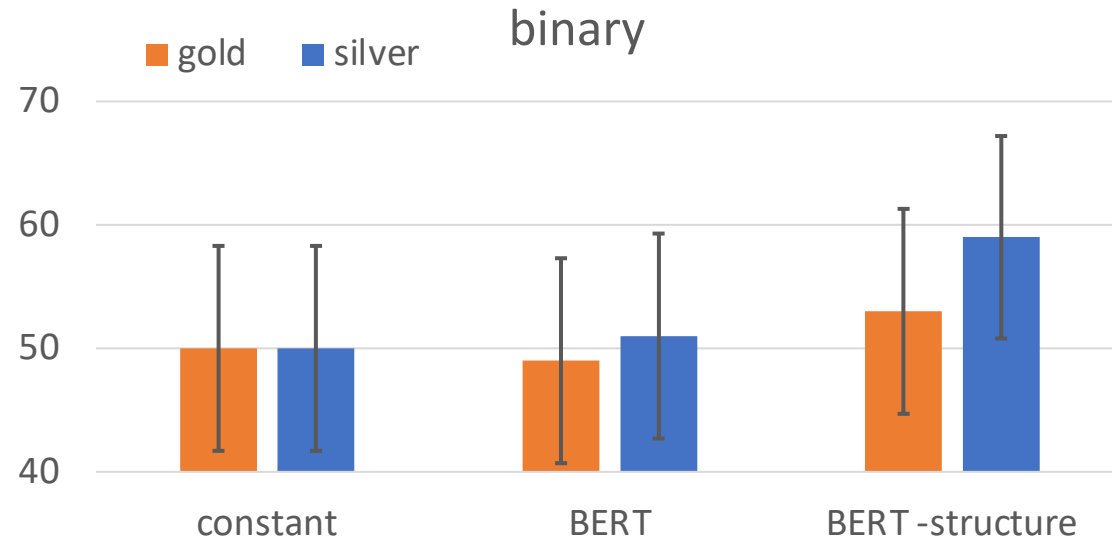
Prolog



# Argument instantiation baselines



# Argument instantiation baselines



# Argument instantiation baselines

- Additional structure + data helps
- Lack of a dedicated numerical solver and sparse data
- Approximate use of structure information
  - Arguments instantiated in order of appearance
  - Limited information and gradient flow between subsections

# Contributions

- Tasks that connect to established NLP tasks
- Annotations on SARA for each task
- Baselines as starting points for each task
- Finer-grained diagnostics
- Improvement in statutory reasoning performance

# Conclusions

- Statutory reasoning is a fundamental task for legal NLP
- Combines natural language understanding and logical reasoning
- SARA is a carefully crafted benchmark dataset
  - A closed set of statutes for tax law
  - Test cases covering the entirety of the statutes
- Statutory reasoning is a real-world few-shot learning problem
- Models for statutory reasoning could inform reasoning with prescriptive rules specified in natural language



# Statutory reasoning: next steps

- Dedicated solvers on subproblems
- Mapping statutes => reasoning modules through semantic parsing
- Better Legal IE for argument instantiation
- Engaging with others interested in this challenge!



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Benjamin Van Durme



Nils Holzenberger

Questions?

<https://nlp.jhu.edu/law/>



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