Identifying and Classifying Ambiguity for Regulatory Requirements

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Legal Domain: Healthcare

- Health Insurance Portability and Accountability Act (HIPAA) passed in 1996
  - Regulates security and privacy for healthcare organizations
  - $25,000 fines per violation per year for non-criminal violations
  - Amended by the **HITECH Act** in 2009 to address data breaches and increase enforcement actions
- Recent Settlement Actions:
  - Concentra Health Services – **$1.7 Million** (April 2014)
  - New York and Presbyterian Hosptial – **$3.3 Million** (May 2014)
  - Columbia University Hospital – **$1.5 Million** (May 2014)

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Legal Ambiguity: a Critical Challenge for Requirements

- Legal texts are often **intentionally ambiguous**.
  - Example:
    - "make ***reasonable*** efforts to limit protected health information to the minimum necessary to accomplish the intended purpose of the use" – HIPAA §164.502(b)
  - The word **"reasonable" appears 61 times** in HIPAA!

- Traditional approaches, such as disambiguation or removal, do not work for legal ambiguities.
  - Legal texts cannot easily be re-written
  - Legal stakeholders cannot easily be sought out for definitive clarification.
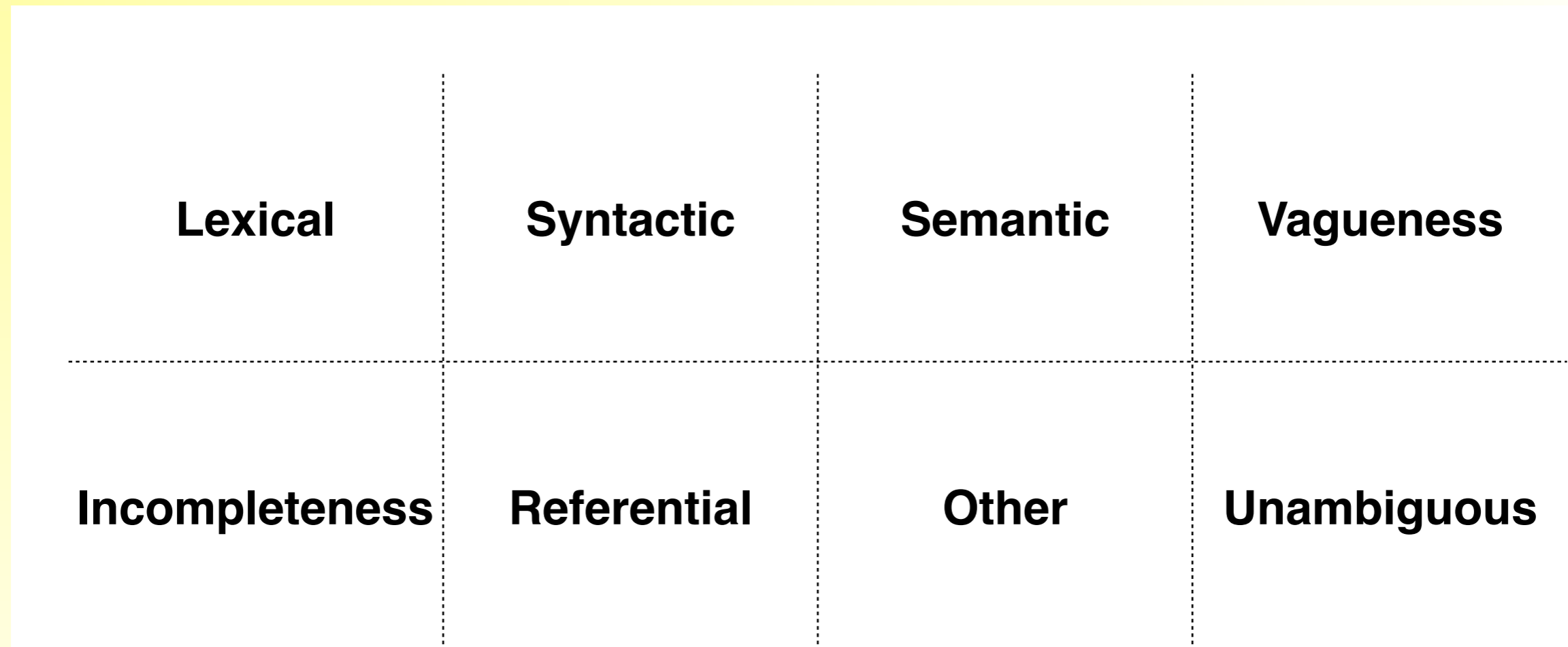 - Requirements engineers must interpret ambiguities in legal texts!

What is ambiguity?

- ANSI/IEEE Standard 830-1993: a requirements specification is **unambiguous only when each requirement has a single interpretation.**

- Definitional Concerns:
  - Should a statement with no clear interpretation be considered ambiguous?
  - What constitutes a valid interpretation? Who decides?

- **No objective standard exists.**
  - There is no "correct" identification or classification of ambiguity.
  - We do have relative standards: Does a group agree as a whole on an interpretation?

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Research Overview

- **Case study of 18 students** identifying and classifying ambiguity
  - technologists
  - policy analysts
- Using a **taxonomy** based on linguistics, software engineering, and legal understandings of ambiguity.
- Legal text: **§170.302 of the HITECH Act**.
  - 23 paragraphs (104 lines)
  - Meaningful Use Stage 1 Criteria for a certified EHR
- **Tutorial introducing the taxonomy** and study procedure
- 5 Research Questions

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A Taxonomy of Ambiguity

Lexical	Syntactic	Semantic	Vagueness
Incompleteness	Referential	Other	Unambiguous

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Lexical Ambiguity

- Lexical ambiguity occurs when a word or phrase has **multiple valid meanings**.

- Examples:
  - **Conversational:** Melissa walked to the bank.
  - **§170.302(d):** Enable a user to electronically record, modify, and retrieve a patient's active medication list as well as medication history for longitudinal care.

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Syntactic Ambiguity

- Syntactic ambiguity occurs when a sequence of words has **multiple valid grammatical parsings**.
- Examples:
  - **Conversational:** I saw the man with the binoculars.
  - **§170.302(f):** Enable a user to electronically record, modify, and retrieve a patient's vital signs…

Semantic Ambiguity

- Semantic ambiguity occurs when a sentence has more than one interpretation **based entirely on the surrounding context**.

- Examples:
  - **Conversational:** Fred and Ethel are married.
  - **§170.302(j):** Enable a user to electronically compare two or more medication lists.

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Vagueness

- Vagueness occurs when a term or statement admits **borderline cases or relative interpretation.**

- Examples:
  - **Conversational:** George is tall.
  - **§170.302(h)(3):** Electronically attribute, associate, or link a laboratory test result to a laboratory order or patient record.

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Incompleteness

- Incompleteness occurs **when a statement fails to provide enough information** to have a single clear interpretation.

- Examples:
  - **Conversational:** Combine flour, eggs, and salt to make fresh pasta.
  - **§170.302(a)(2):** Provide certain users with the ability to adjust notifications provided for d̶ ̶ ̶ ̶d̶ drug-allergy interaction

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Referential Ambiguity

- Referential ambiguity occurs when a word or phrase in a sentence **cannot be said to have a clear reference**.

- Examples:

  - **Conversational:** The boy told his father about the damage. He was very upset.

  - **§170.302(n):** For each meaningful use objective with a percentage-based measure, electronically record the numerator and denominator…

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Per-paragraph Response Block

Please complete the table below using the procedure detailed in the tutorial.

Ambiguities Found in 45 CFR Subtitle A, § 170.302(a)(1)–(2)

Lexical	Syntactic	Semantic	Vagueness
Incompleteness	**Referential**	**Other**	**None**

Software engineers should be able to build software that complies with this legal text.

Circle one: Agree   Disagree

Research Questions 1 to 3

1. Does the taxonomy provide **adequate coverage** of the ambiguities found in § 170.302?

2. **Do participants agree** on the number and types of ambiguities they identify in § 170.302?

3. Do participants agree on the number and types of **intentional** ambiguities they identify in § 170.302?

Research Questions 4 and 5

4. **Do participants agree** on whether software engineers should be able to build software that complies with each paragraph of § 170.302?

5. Does an **identified ambiguity affect** whether participants believe that software engineers should be able to build software that complies with each paragraph of § 170.302?

Research Question Measures

- **Q1 Measures:** (1) Use of each of the first six ambiguity types and (2) minimal use of the "Other" type.

- **Q2 Measures:** ICC for both number and type of ambiguities identified

- **Q3 Measures:** ICC for both number and type of **intentional** ambiguities identified

- **Q4 Measures:** Fleiss Kappa agreement on implementability of the paragraph.

- **Q5 Measures:** The percentage of paragraphs deemed unimplementable that contain identified ambiguities

Q1: Taxonomy Coverage

- Participants identified on average 33.47 ambiguities for the 23 paragraphs examined.
  - 50 minutes provided for the study
  - All participants finished before time was up
- Every ambiguity type was used.
  - Least frequent: Semantic (1.59 on average)
  - Most frequent: Vagueness (9.82 on average)
- The "Other" type was less common than the least common ambiguity classification we defined (0.82 on average).
- **Result: Yes, the taxonomy provides adequate coverage.**

Ambiguities per Paragraph
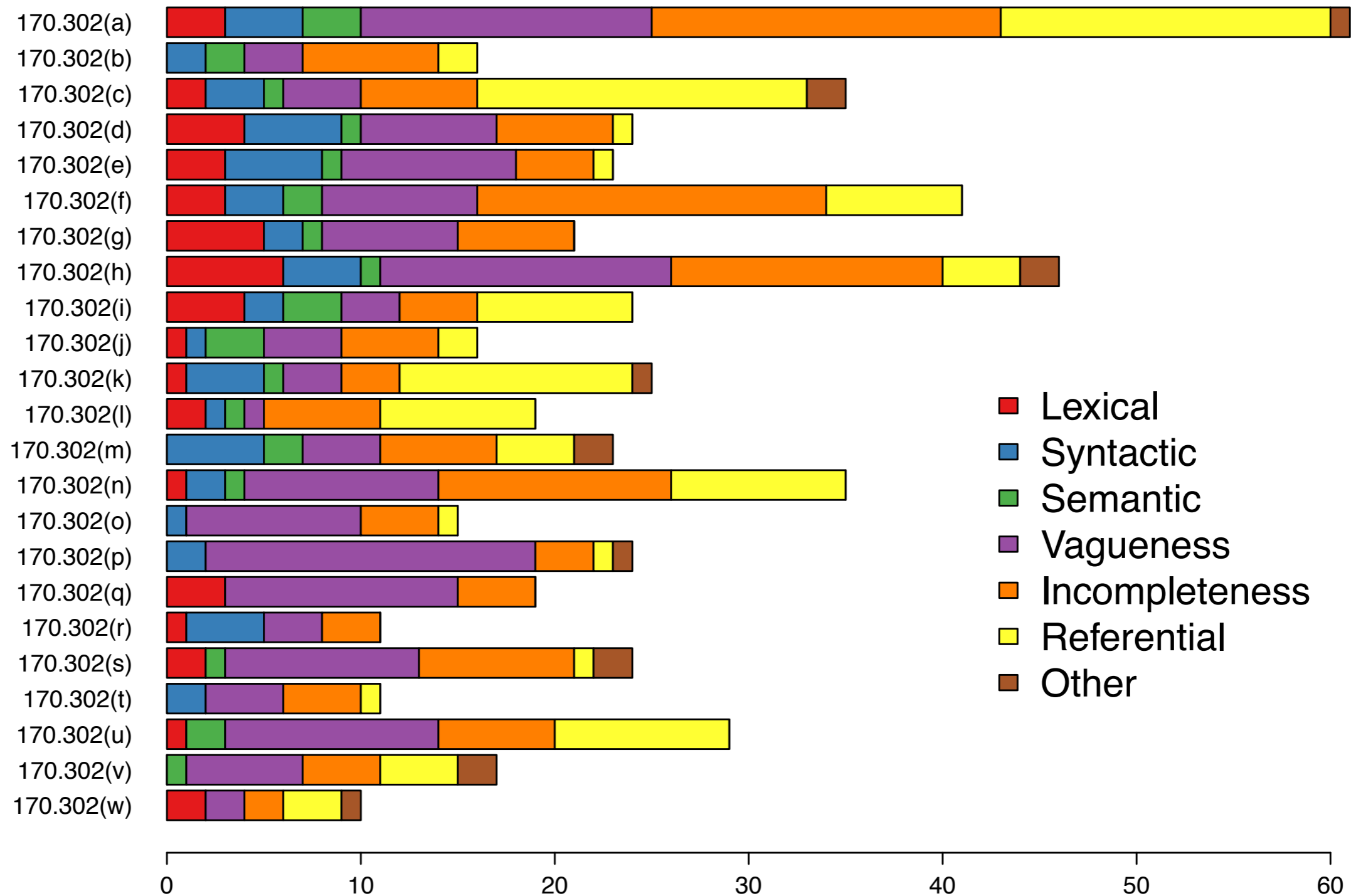
Q2: Number and Type agreement

- Number agreement: ICC: 0.316, indicating **fair agreement on number** ($p < 0.001$)

- Type agreement:
  - For 2 of the 23 paragraphs, the participants demonstrated near-universal agreement.
  - For the remaining 21, the participants demonstrated only slight agreement.
  - Overall Fleiss Kappa for type agreement: 0.0446, indicating **slight agreement on type** ($p < 0.0029$)

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Q3: Intentional Number and Type

- **Number:** ICC 0.141, ($p < 0.0001$)
- **Type:** ICC 0.201 ($p < 0.001$)
- The Incompleteness category was a primary driver of type disagreement.
  - Technologists identified significantly more ambiguities of this type.
  - Removing Incompleteness, Type agreement ICC becomes 0.39, indicating fair agreement ($p < 0.0001$)
- **Result: Participants agreed less on intentional ambiguities than on total ambiguities.**

Ambiguities by Type and Intent
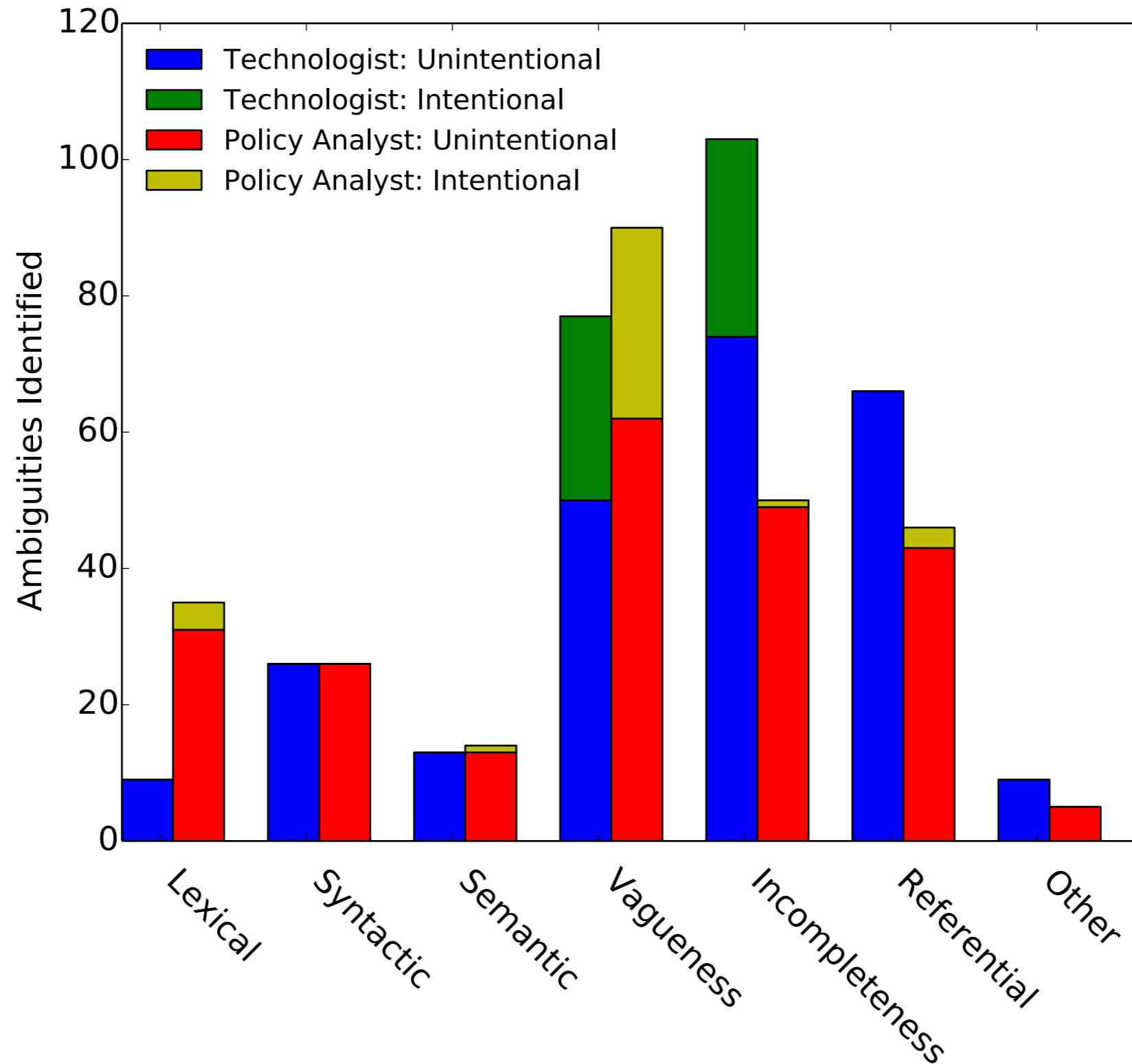
Q4: Implementability

- **All participants:** Fleiss Kappa value of 0.0052, **p < 0.788** — not statistically significant.

- **Technologists:** Fleiss Kappa value of 0.0455, **p < 0.116** —— not statistically significant.

- **Result: Participants agreement on implementability was not statistically significant.**

Q5: Ambiguity and Implementability

- 89% of unimplementable paragraphs contained an ambiguity

- 48% of implementable paragraphs contained an ambiguity

- **Result: Yes, ambiguity is more commonly identified in paragraphs deemed unimplementable.**

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Summary

- In 50 minutes over 104 lines of legal text our participants identified **33.47 ambiguities on average**

- **The taxonomy provided reasonable coverage: 97.5%** of all ambiguities identified were classified as one of the six defined types

- Participants accepted paragraphs with unintentional ambiguity as implementable!

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Future Work

- Participants did not exhibit strong agreement on the number and type of ambiguity.
  - 50 minute limit?
  - Better guidelines for the taxonomy?
- Additional case studies
  - More partipants
  - Different legal domains
  - Does identifying and classifying ambiguity prior to other legal requirements activities improve performance?

Thank You! Questions?

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