Introduction

Week 1

Slides and materials based on the courses by
Noortje Venhuizen and Mareike Hartmann

Plan for today

- Introductions
- Course information
- Brief introduction to course topics

Course information

- Email: msullivan@lst.uni-saarland.de

- Main communication platforms: Microsoft Teams (chat, questions, etc.) and course website (schedule, assignments, etc.)
    - Please join the Team [155270] Semantic Theory SoSe 25 after this session
    - Course website: https://mjs227.github.io/courses/semantic-theory-25

Course information

- There will be 10 exercises throughout the semester
    - To be admitted to the exam, you need to hand in 7 of them

- Your grade for the final exam will be your grade for the course
    - Final exam date: 15.07.2025
    - Registration deadline: 08.07.2025

Schedule

Week	Reading	Tuesday	Wednesday
Week 1: April 15-16	None	Introduction	No lecture
Week 2: April 22-23	1. *Logic in Action*, Ch. 4 (Sec. 4.5-4.6) 2. *Elements of Formal Semantics*, Ch. 2	Predicate Logic	Overflow (*if necessary*)
Week 3: April 29-30	*Elements of Formal Semantics*, Ch. 3 (Parts 1-2)	Type Theory	Exercise 1: Predicate Logic
Week 4: May 6-7	*Elements of Formal Semantics*, Ch. 3 (Part 3)	Lambda Calculus	Exercise 2: Type Theory
Week 5: May 13-14	Generalized Quantifiers (Stanford Encyclopedia of Philosophy)	Generalized Quantifiers	Exercise 3: Lambda Calculus
Week 6: May 20-21	Event-Based Semantics (Lasersohn, 2012)	Event Semantics	Exercise 4: Generalized Quantifiers
Week 7: May 27-28	None	Lexical Semantics	Exercise 5: Event Semantics
Week 8: June 3-4	Dynamic Semantics (Stanford Encyclopedia of Philosophy)	Dynamic Semantics	Exercise 6: Lexical Semantics
Week 9: June 10-11	Discourse Representation Theory (Stanford Encyclopedia of Philosophy)	DRT	Exercise 7: Dynamic Semantics
Week 10: June 17-18	None	Presuppositions in DRT	Exercise 8: DRT
Week 11: June 24-25	None	Implicature	Exercise 9: Presuppositions in DRT
Week 12: July 1-2	None	Current Issues and Applications	Exercise 10: Implicature
Week 13: July 8-9	None	Exam Review	Take-home Practice Exam
Week 14: July 15-16	None	**Exam**	No lecture

https://mjs227.github.io/courses/semantic-theory-25/schedule/

Course Materials

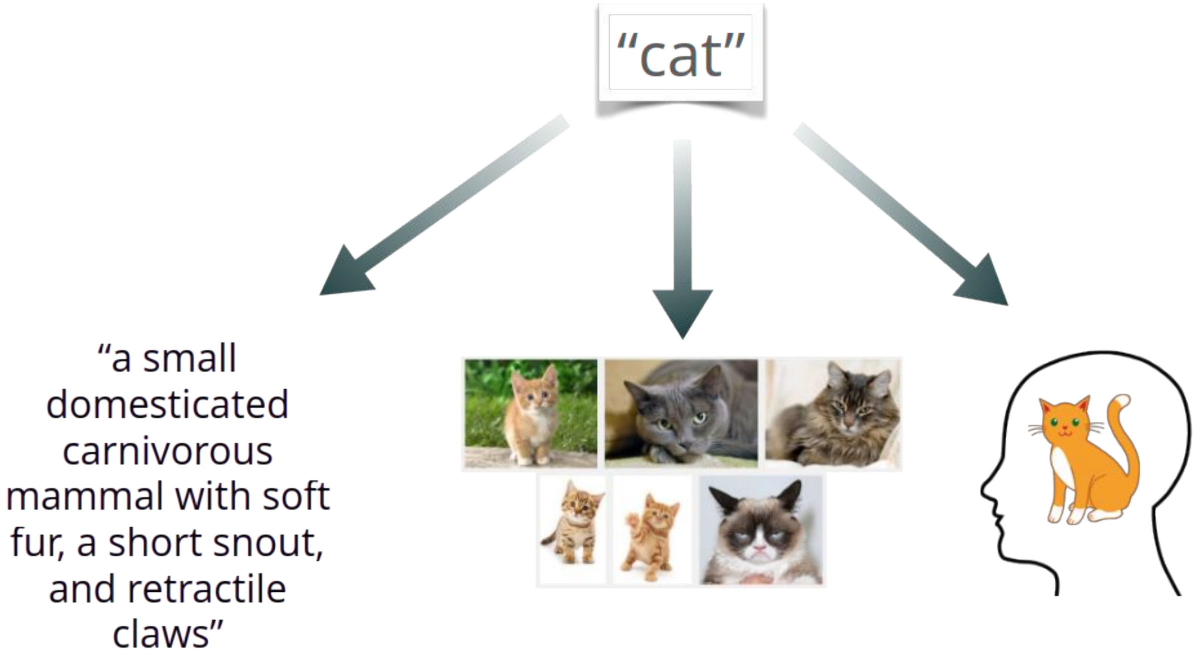
- The slides provide the main course material.

- For additional background reading, we will use several online resources (readings listed on the course website):
  - Logic in Action, J. van Benthem, H. van Ditmarsch, J. van Eijck and J. Jaspars, 2016. http://logicinaction.org/
  - Elements of Formal Semantics (Ch. 1-3), Yoad Winter, Edinburgh University Press, 2016.
  - https://www.phil.uu.nl/~yoad/efs/main.html
  - Stanford Encyclopedia of Philosophy, Edward N. Zalta (principal editor).
  - https://plato.stanford.edu/

Semantic Theory

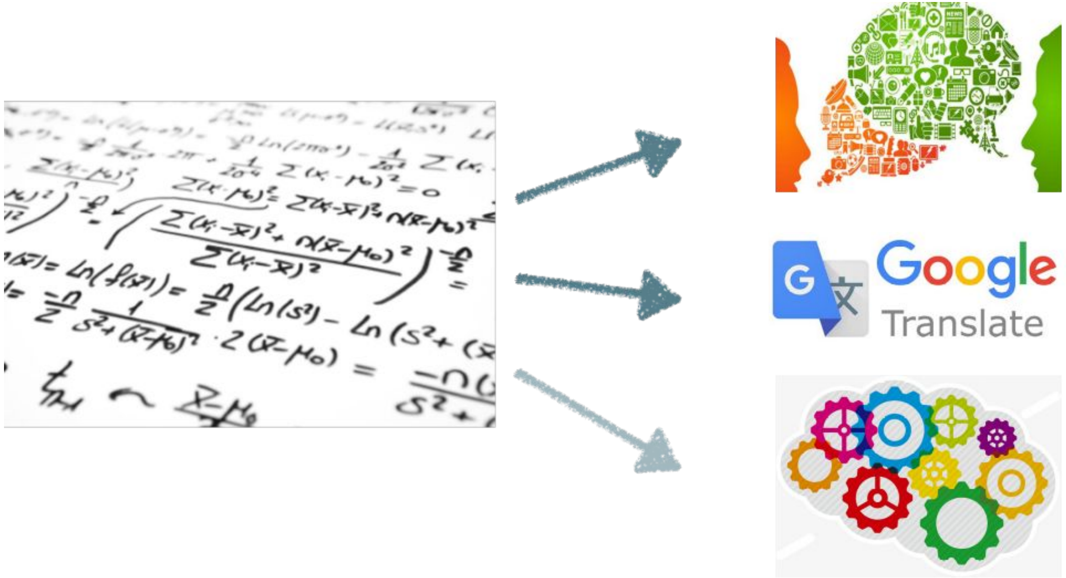
Semantic Theory: the study of (linguistic) meaning

What does “meaning” mean?



Formal semantics

- Goal of Formal Semantics:
  - To explain how meaning derives from linguistic **form**
  - … using **formal** mathematical principles



Course Overview

- **Part I** (Weeks 2-6): Sentence semantics (Montague semantics)
- **Part II** (Week 7): Lexical semantics
- **Part III** (Weeks 8-11): Discourse semantics
- **Part IV** (Week 12): Current issues in Semantic Theory

Sentence Semantics

Part I

Truth-conditional semantics

- A basic semantic principle:

  “For two sentences A and B, if in some possible situation A is true and B is false, A and B must have different meanings.”

  (M. Cresswell, 1975)

- Applied to logical representations:
  - For a logical formula α and a sentence A:
    If in some possible situation corresponding to a model structure M, sentence A is true, and α is not, or vice versa, then α is not an appropriate meaning representation for A.

Truth-conditional semantics

- To know the meaning of a (declarative) sentence is to know what the world would have to be like for the sentence to be true
  - i.e. sentence meaning = truth-conditions

- Interpretation:
  - Translate sentences into logical formulas:

    "every student works" $\mapsto \forall x[\mathit{student'}(x) \rightarrow \mathit{work'}(x)]$

  - Interpret these formulas in a logical model:

    $[\![\forall x(\mathit{student'}(x) \rightarrow \mathit{work'}(x))]\!]^{M,g} = 1$ iff $V_M(\mathit{student'}) \subseteq V_M(\mathit{work'})$

Step 1: from sentence to formula

- **Propositional logic**: Propositions as basic atoms
  - Syntax: propositions (*p*, *q*, ...), logical connectives (¬, ∧, ∨, →, ↔)
  - Semantics: truth tables, truth conditions

p	q	$p \& q$	$p \vee q$	$p \rightarrow q$	$p \leftrightarrow q$
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

- **Predicate logic**: Predicates and arguments
  - Syntax:
    - predicates & terms (*love'*(*j'*, *m'*), *mortal'*(x), …)
    - quantifiers (∀xφ, ∃xφ)
    - logical connectives (∧, ∨, ¬, →, ↔)
  - Semantics: model structures and variable assignments

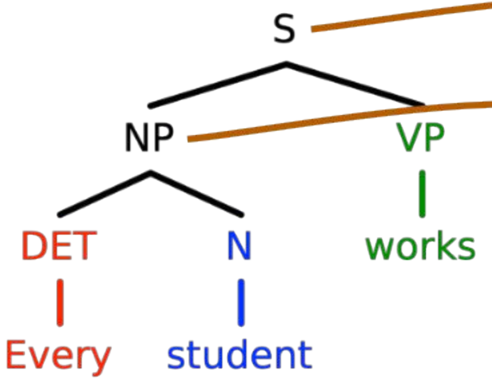
- **Type theory**: Higher-order predicate logic with type-theoretic denotations

Step 1’: from words to sentence meaning

- **The principle of compositionality**:

  “The meaning of a complex expression is a function of the meanings of its parts and of the syntactic rules by which they are combined”

  (Partee, 1993)



$$[\![\text{Every student works}]\!]^{M,g} = f_1([\![\text{Every student}]\!]^{M,g}, [\![\text{works}]\!]^{M,g})$$

$$[\![\text{Every student}]\!]^{M,g} = f_2([\![\text{Every}]\!]^{M,g}, [\![\text{student}]\!]^{M,g})$$

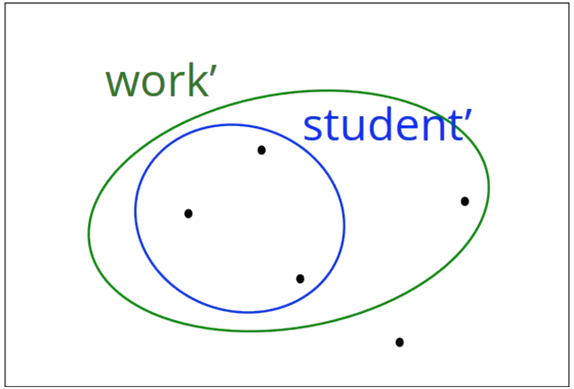
Step 2: from formula to model

- Model-theoretic interpretation of first-order predicate logic:

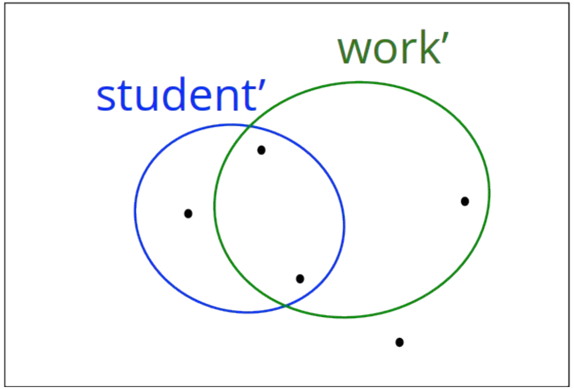
  “every student works”

  $[\![\forall x(\mathit{student}'(x) \rightarrow \mathit{work}'(x))]\!]^{M,g} = 1$ iff $V_M(\mathit{student}') \subseteq V_M(\mathit{work}')$

M$_1$



M$_2$



Lexical Semantics

Part II

Zooming in: the meaning of words

- *“student”* $\mapsto$ *student’* … what does the *’* stand for?

- Structured approaches to the lexicon: lexical meaning defined as relations between concepts in a model
  - a “student” is someone who studies
  - a “bachelor” is a man who is not married

Topics in lexical semantics

- Verb alternatives and semantic roles
  - *"the window broke"*
  - *"a rock broke the window."*
  - *"John broke the window with a rock"*

- Monotonicity and generalised quantifiers
  - *"<u>all</u> children came home late"* ⇒ *"<u>all</u> children came home"*
  - *"<u>no</u> children came home late"* ⇏ *"<u>no</u> children came home"*

Discourse Semantics

Part III

Beyond the sentence boundary: limitations of sentence-level semantics

- **Anaphora**
  - *“John hit Bill. He hit him back.”*
  - *“If a farmer owns a donkey, he feeds it.”*
- **Presuppositions**
  - *“Bill regrets that his cat has died.”*
  - *“Bill doesn’t regret that his cat has died.”*
- **Discourse relations**
  - *“John fell. Mary helped him up.”*
  - *“John fell. Mary pushed him.”*

Dynamic Semantics

- Revisiting the idea of meaning as truth-conditions
  - There is more to meaning than truth-conditions

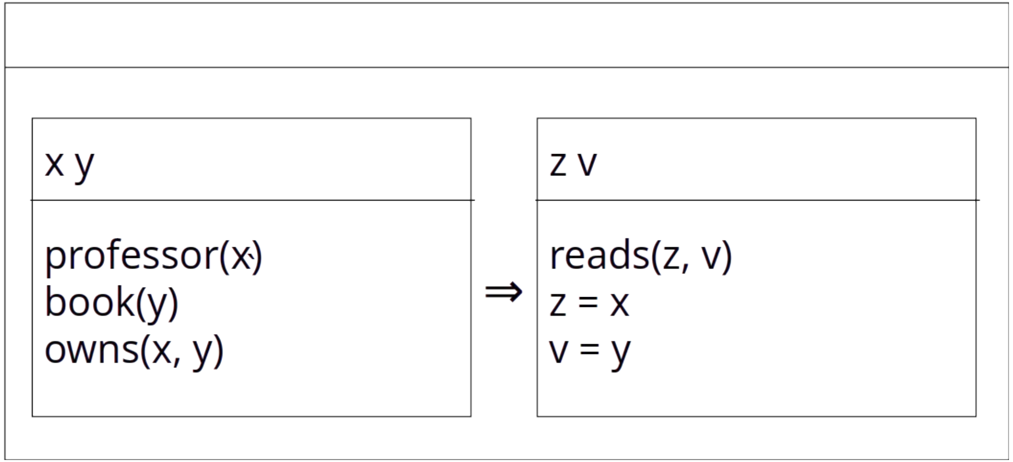
- Meaning is context-dependent
  - Meaning is dynamic: it keeps changing
  - Solution: meaning = context-change potential

Discourse Representation Theory

- Representational, mentalist approach to semantics

“if a professor owns a book, he reads it”

$\mapsto \forall x \forall y[\text{professor}(x) \wedge \text{book}(y) \wedge \text{own}(x,y) \rightarrow \text{read}(x,y)]$



Current Issues in Semantic Theory

Part IV

Current issues in Semantic Theory

- Where is the border between semantics and pragmatics?
- What do (or: can) formal semantic theories say about the way meaning is stored and created in the human brain?
- How can we use formal semantics for practical purposes?

Why does this matter?

- Semantic representations for LLMs: e.g. Zhou et al. (2020), Zhang et al. (2020), Wu, Peng, and Smith (2021), and Prange, Schneider, and Kong (2022), etc.
  - Semantically-augmented LMs improve over baseline models, *without* using additional training data

- *Semantic-theoretic correctness ensures representational consistency*:
  - Semantic Theory allows us to verify that our representational framework is accurately modeling meaning

Why does this matter?

- We need semantic concepts to evaluate LLMs:
    - e.g. NLI, code (?)

- … and to determine what they're doing *wrong*
    - If our goal is human-like LMs, we need to understand human-like language use