Semantic Theory

Week 0: Introduction

Noortje Venhuizen & Harm Brouwer — Universität des Saarlandes — Summer 2022

Information about this course

- Course website: http://njvenhuizen.github.io/teaching/ST22/index.html
- Email: noortjev@coli.uni-saarland.de / brouwer@coli.uni-saarland.de
- Main communication platform: Microsoft Teams (slides, exercises, chat)
- Prerequisites: Familiarity with first-order predicate logic.
  - See: Logic in Action, Chapter 4 (Sec. 4.1 & 4.2): http://logicinaction.org/docs/ch4.pdf

Information about this course

Lectures, Exercises, Exam

- Lectures will take in person (starting 19.04.: room -1.05, C7.2; basement)
  - Standard university hygiene regulations apply: distancing & face masks
  - Tuesday and Wednesday will be flexibly used as lectures/exercise sessions
- Final exam date: 20.07.2022
  - Your grade for the final exam will be your grade for the course
- There will be 8 exercises throughout the semester; to be admitted to the exam, you may skip or fail at most one weekly exercise

Course Materials

Optional reading material

- The slides provide the main course material.
- For additional background reading, we use several online resources:
  - 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 (princial editor). https://plato.stanford.edu/

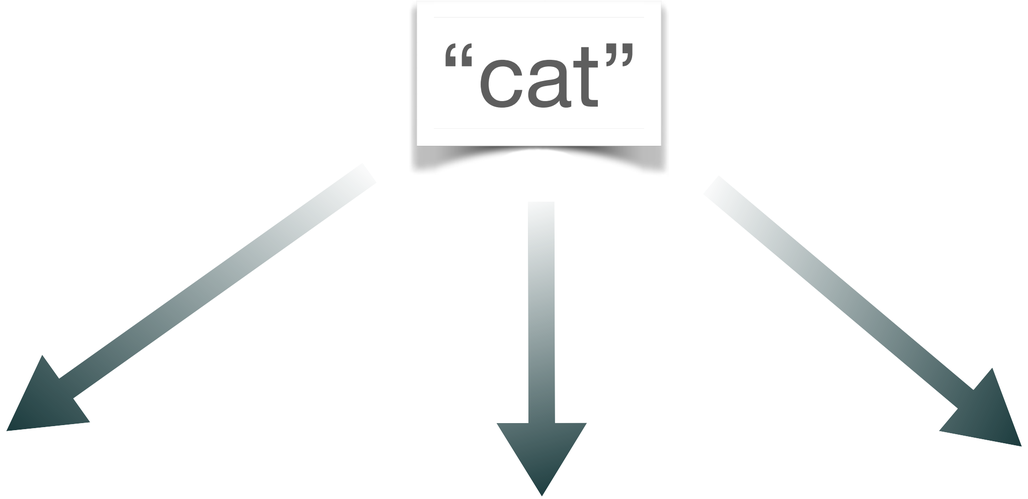
Semantic Theory

Semantic Theory is the study of (linguistic) meaning

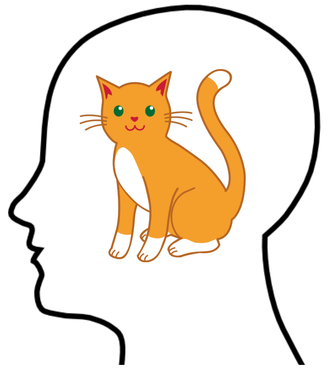
A philosophical question

What is ‘meaning’?

“cat”



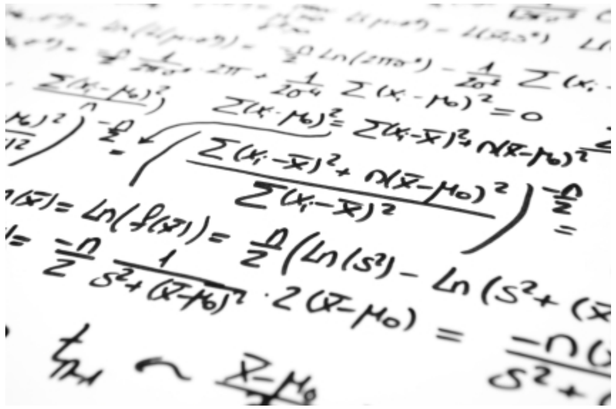
“a small domesticated carnivorous mammal with soft fur, a short snout, and retractile claws”



Formal semantics

Goal of Formal Semantics:

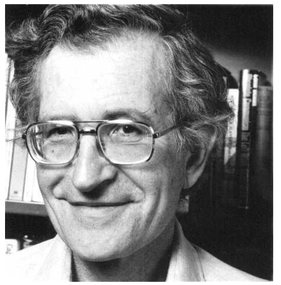
- To explain how meaning derives from linguistic form;
- Using formal mathematical principles.



The development of formal semantics

1933 — Bloomfield: “The statement of meanings is […] the weak point in language-study, and will remain so until human knowledge advances very far beyond its present state.”

1957 — Chomsky: “there is little evidence that ‘intuition about meaning’ is at all useful in the actual investigation of linguistic form”



1970 — Montague: “There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians”

Course Overview

Semantic Theory 2022

- **Part I:** Sentence semantics (Montague semantics)
- **Part II:** Lexical semantics
- **Part III:** Discourse semantics
- **Part IV:** Current issues in Semantic Theory

Part I:
Sentence semantics

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

Sentence meaning

- 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
- Sentence meaning = truth-conditions
- Indirect interpretation:

    1. Translate sentences into logical formulas:
       Every student works $\mapsto \forall x(\text{student}'(x) \rightarrow \text{work}'(x))$

    2. Interpret these formulas in a logical model:
       $[\![\forall x(\text{student}'(x) \rightarrow \text{work}'(x))]\!]^{M,g} = 1$ iff $V_M(\text{student}') \subseteq V_M(\text{work}')$

Step 1: from sentence to formula

Logical Languages

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 (∀x ϕ, ∃x ϕ), logical connectives (∧, ∨, ¬, →, ↔)
- Semantics: model structures and variable assignments

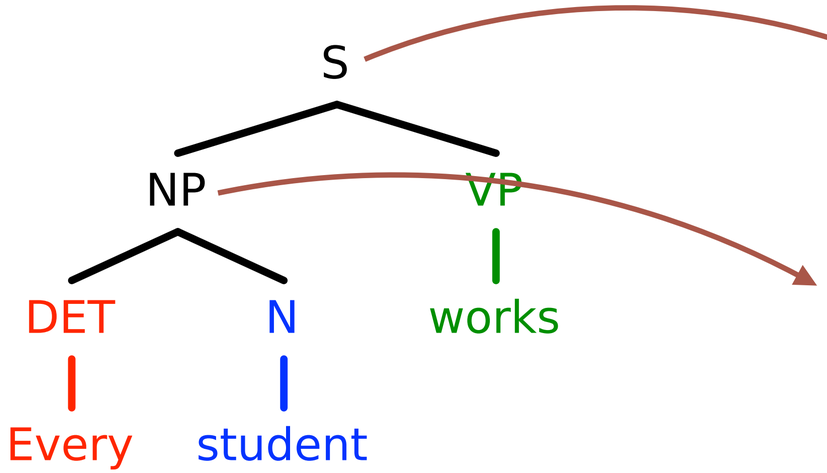
Type theory: Higher-order predicate logic with type-theoretic denotations

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"

(Barbara Partee, 1993)



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

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

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

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

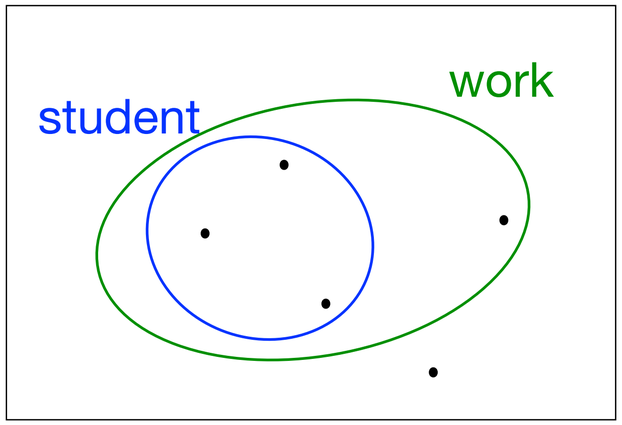
Step 2: from formula to model

Model-theoretic interpretation of first-order predicate logic

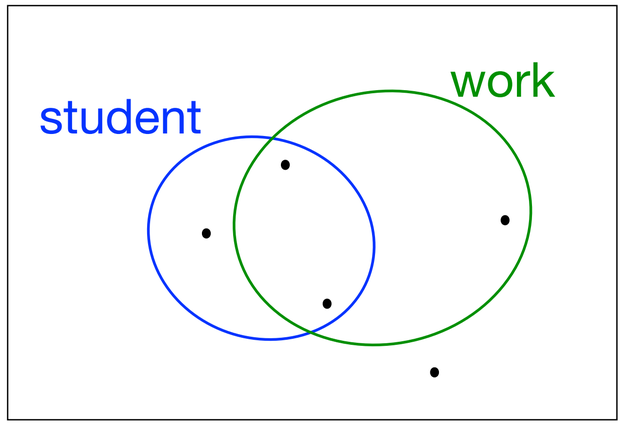
Every student works

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

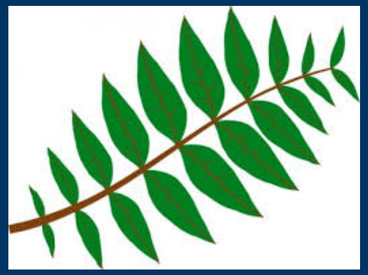
M1:



M2:



Part II:
Lexical semantics



Zooming in: the meaning of words

Lexical semantics revisited

- student ↦ 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

Event-denoting expressions

1. a. Bill saw an elephant.
   b. Bill saw an accident.
   c. Bill saw the children play.

Verb alternatives and semantic roles

2. a. The window broke.
   b. A rock broke the window.
   c. John broke the window with a rock.

Monotonicity and generalised quantifiers

3. All children came home late ↦ All children came home
4. No children came home late ↦̸ No children came home

Part III:
Discourse semantics

Beyond the sentence boundary

Limitations of sentence-level semantics

- **Anaphora**

  1. John hit Bill. He hit him back.

  2. If a farmer owns a donkey, he feeds it.

- **Presuppositions**

  3. a. Bill regrets that his cat has died.
     b. Bill doesn’t regret that his cat has died

- **Discourse relations**

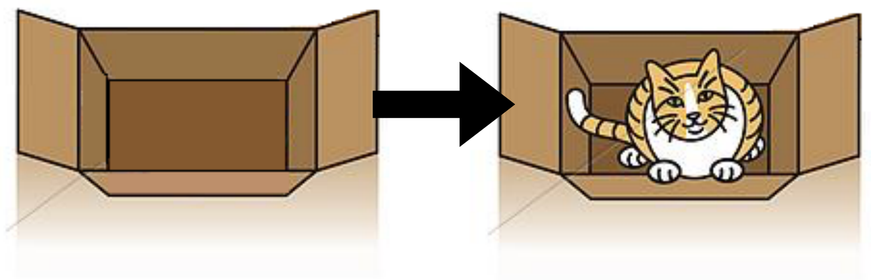
  4. John fell. Mary helped him up.

  5. 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

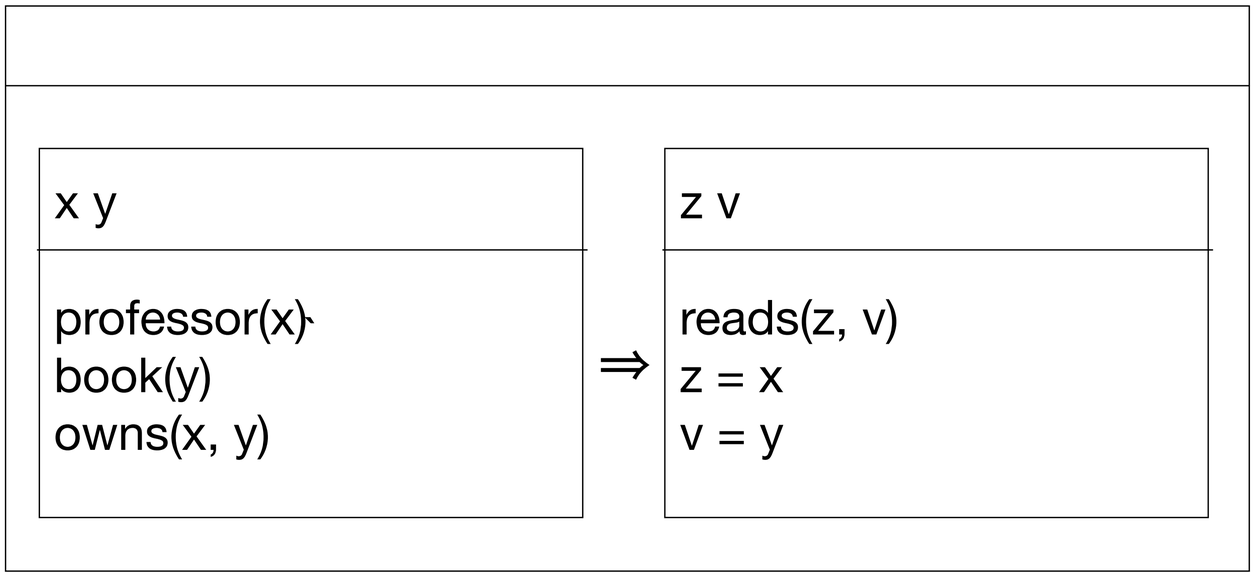


Discourse Representation Theory

Representational, mentalist approach to semantics

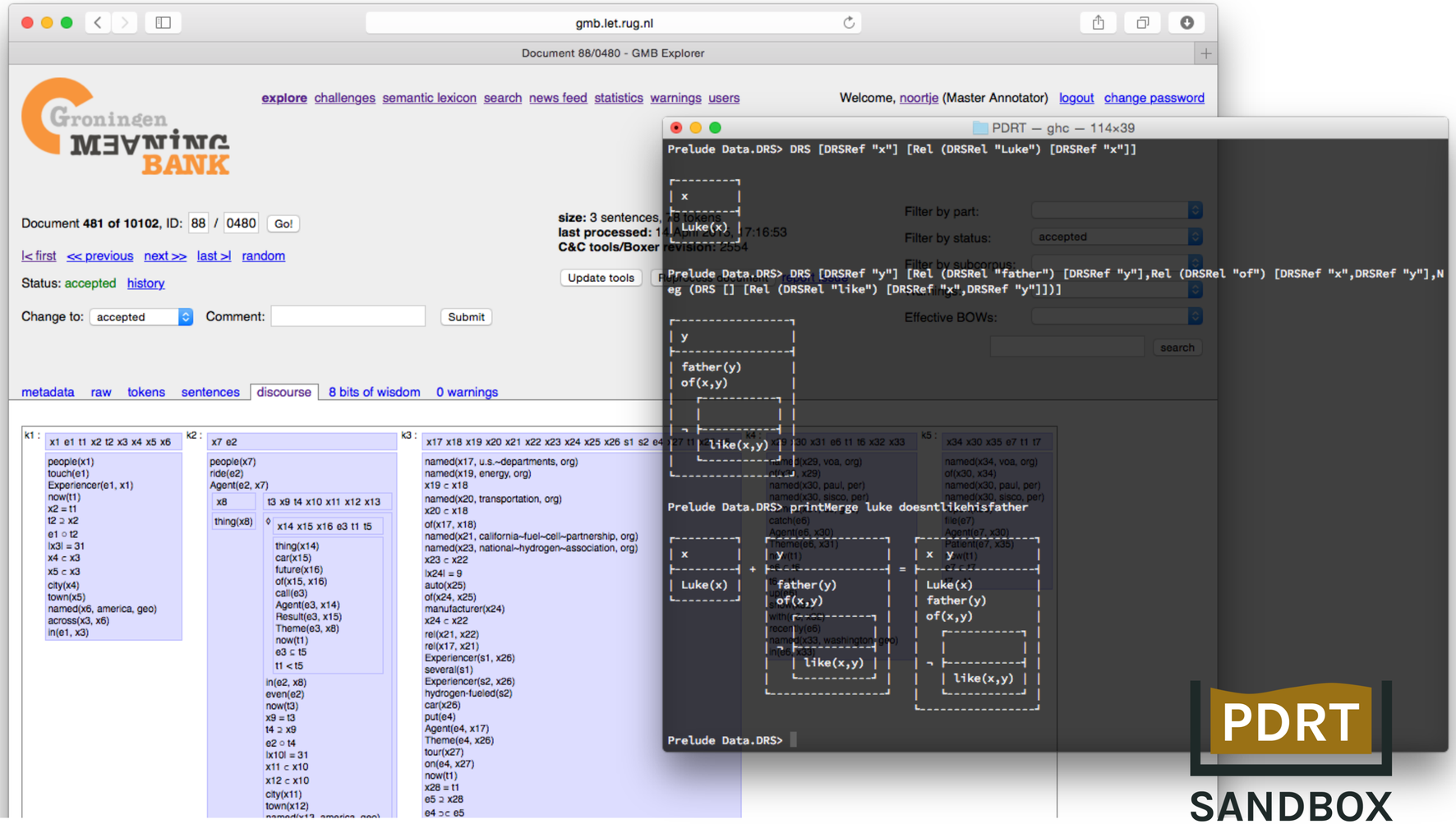
If a professor owns a book, he reads it.

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

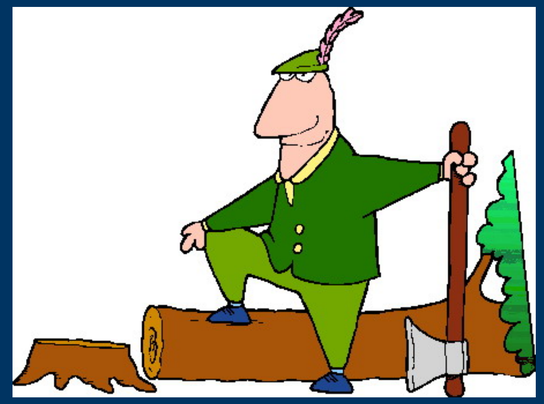


Discourse Representation Theory

Applications



Part IV:
Current Issues in Semantic Theory



The Next Big Thing in Semantic Theory…

Formal semantics for deep learning?

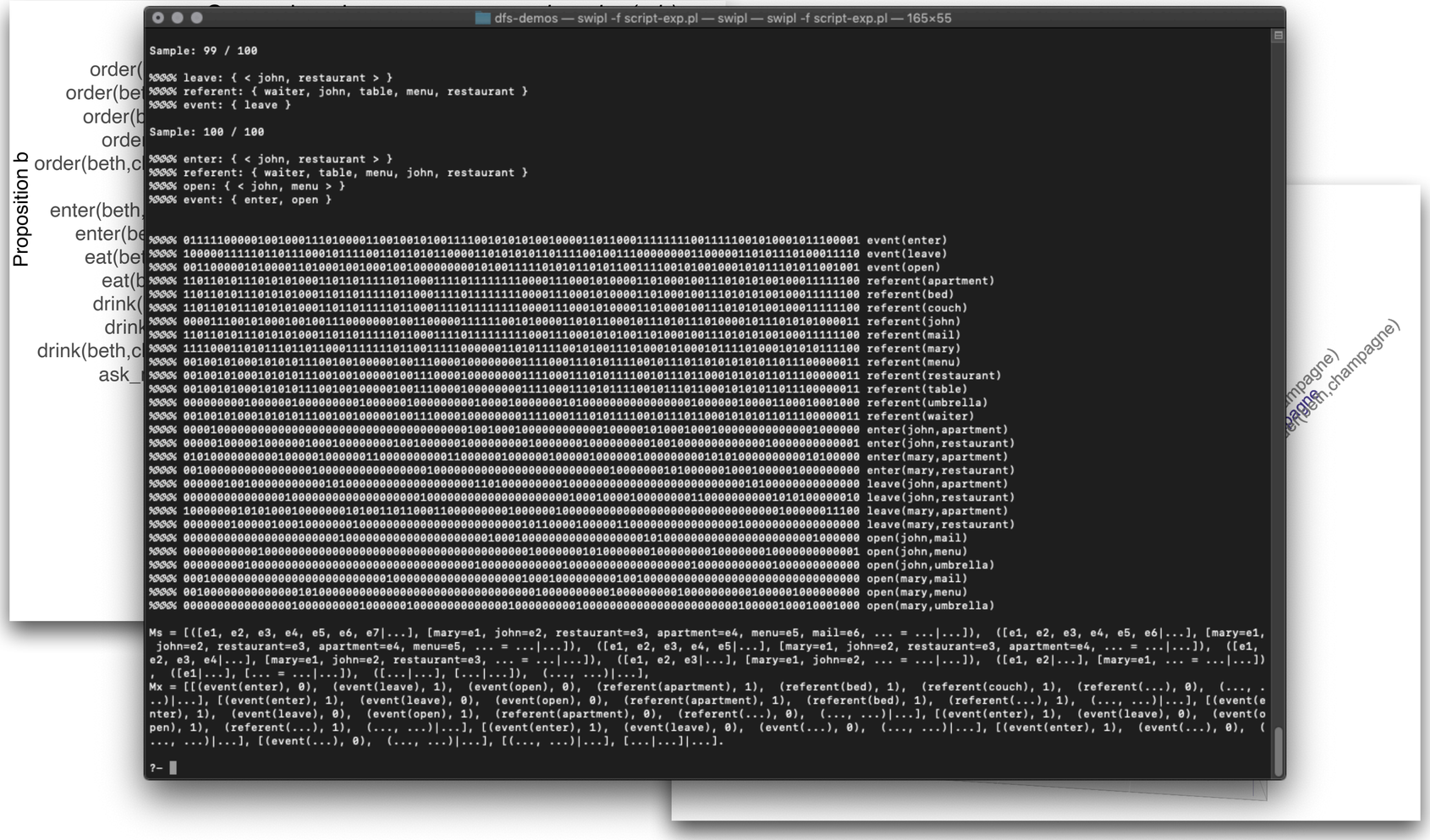
Distributional Semantics *"You shall know a word by the company it keeps"* (J. R. Firth, 1957)

- lexical meaning: high dimensional vectors derived from corpora (*big data!*)
- semantic similarity ~ vector similarity
- … but what about formal semantic principles such as compositionality?

Distributional Formal Semantics

- Meaning vectors defined over propositions in a world
- Expressive, compositional, probabilistic, inferential and neurally plausible
- … but how does it relate to formal semantic models?

Distributional Formal Semantics



Current issues in Semantic Theory

Open questions

- 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 (for example to improve machine translation)?

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See you on Tuesday (in person!) 😀