– Seminar –
Cross-Domain Modeling of Human Cognition

apl. Prof. Dr. Dr. Marco Ragni
Nicolas Riesterer, Daniel Brand

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Cognitive Computation Lab,
Department of Computer Science,
University of Freiburg

Human Reasoning

Syllogistic Reasoning

No researchers are gods
Some gods are great reasoners

What (if anything) follows?

Conditional Reasoning

If it rains, the road is wet
The road is wet

What (if anything) follows?

Human Reasoning

Syllogistic Reasoning

No researchers are gods
Some gods are great reasoners

Some great reasoners are not researchers

Conditional Reasoning

If it rains, the road is wet
The road is wet

Nothing follows

Syllogistic Reasoning

- Categorical assertions
- Quantifiers (All, Some, Some ... not, None)
- Syllogisms combine two premises
- Nine possible responses
- Total of 64 syllogisms

No A are B
Some B are C

Some C are not A

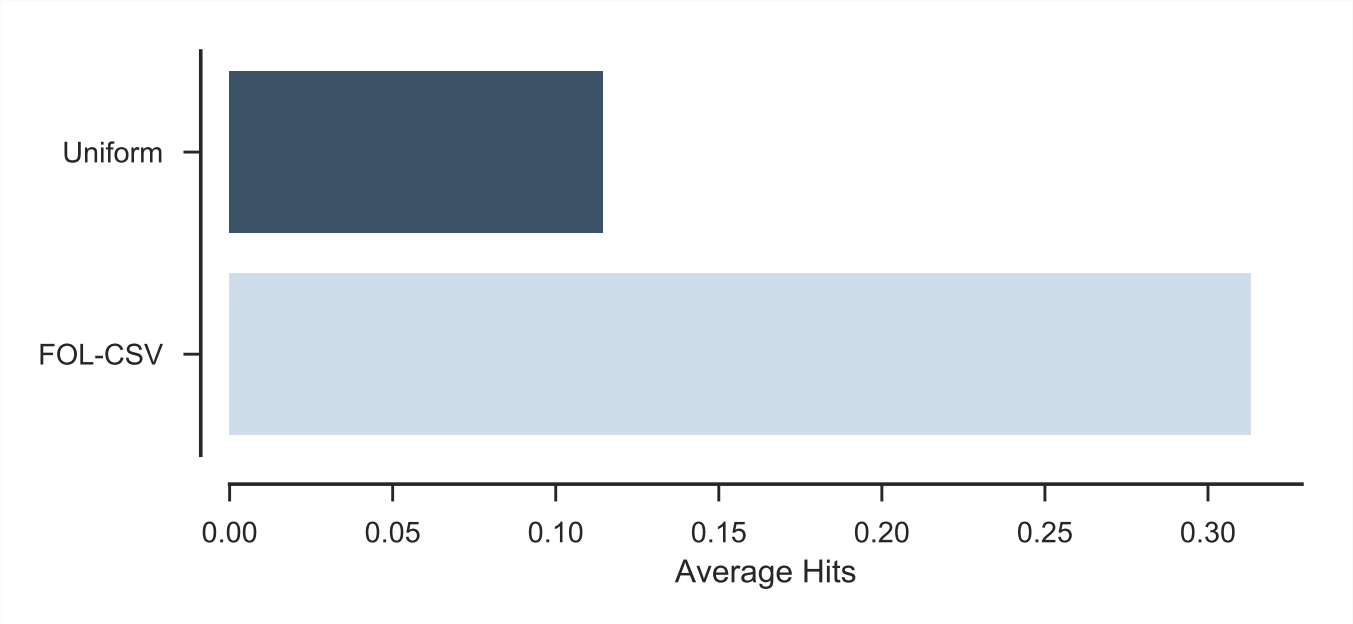
Conditional Reasoning

- Statements of the form
  "If A then C" (A$\rightarrow$C)
- Antecedent A, Consequent C
- Four conclusion types:
  1. Modus Ponens (MP)
     From $A \rightarrow C$, A follows C
  2. Modus Tollens (MT)
     From $A \rightarrow C$, $\neg C$ follows $\neg A$
  3. Affirmation of Consequent (AC)
     From $A \rightarrow C$, C follows A
  4. Denial of Antecedent (DA)
     From $A \rightarrow C$, $\neg A$ follows $\neg C$

If it rains, then the road is wet
The road is wet

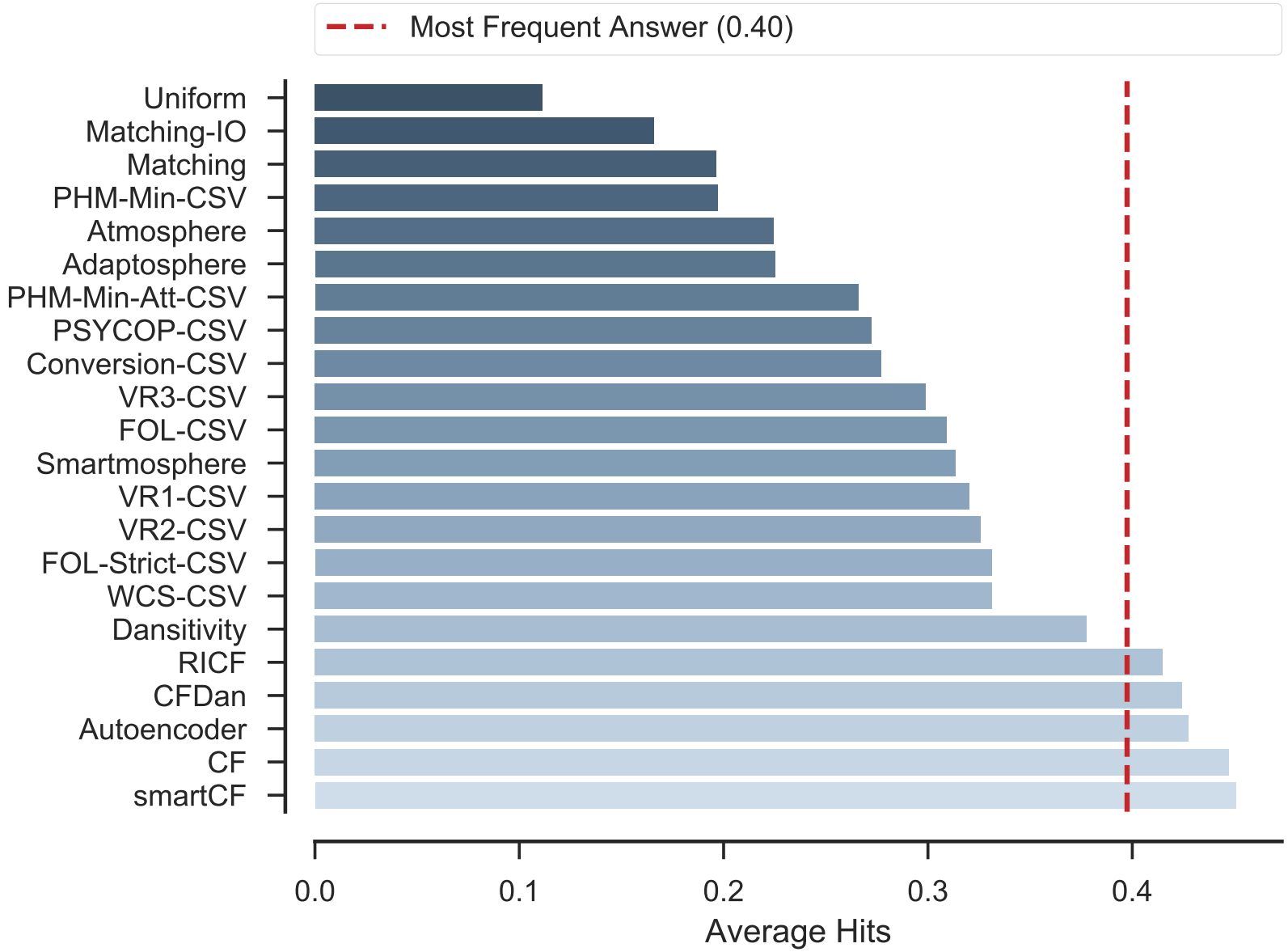
Nothing follows

Humans are Illogical



- Psychology has identified numerous effects and phenomena surrounding reasoning
- Surely the problem can be considered solved at this point
  ... or can it?

Modeling Syllogistic Reasoning



Objective of the Seminar

1. Familiarize yourself with the literature on cognitive modeling of human syllogistic reasoning
2. Implement a model
   - Phenomena/Effects identified by psychology or cognitive science
   - Probability calculus (e.g., Bayes)
   - Logic systems (e.g., nonmonotonic logics, answer set programming)
   - Machine learning (e.g., neural networks, recommender systems)
   - ...
3. Competition between different modeling approaches
4. Give a presentation on your findings
5. Write a technical report about your results

Approaches To Modeling

You decide on one topic from each of the following high-level approaches to modeling. We will assign you to one of your choices.

1. Cognitive Modeling
2. Computational Modeling
3. Machine Learning

Cognitive Modeling

- Supervisor: Marco Ragni
- Task:
  1. Implement the conditional cognitive theory,
  2. Generalize it to syllogistic reasoning based on identified theory,
  3. Improve the theories
- Topics:
  1. Supposition:
     - Evans, J. S. B., Handley, S. J., Neilens, H., & Over, D. E. (2007). Thinking about conditionals: A study of individual differences. Memory & Cognition, 35(7), 1772-1784.
  2. Bayesian approach:
     - Oaksford, M., Chater, N., & Larkin, J. (2000). Probabilities and polarity biases in conditional inference. Journal of Experimental Psychology: Learning, Memory, and Cognition, 26(4), 883.
  3. Mental Models
     - Johnson-Laird,P.N., Khemlani, S. & Goodwin, G. Logic, probability, and human reasoning, Trends in Cognitive Sciences, Volume 19, Issue 4, 2015, 201-214.

Computational Modeling

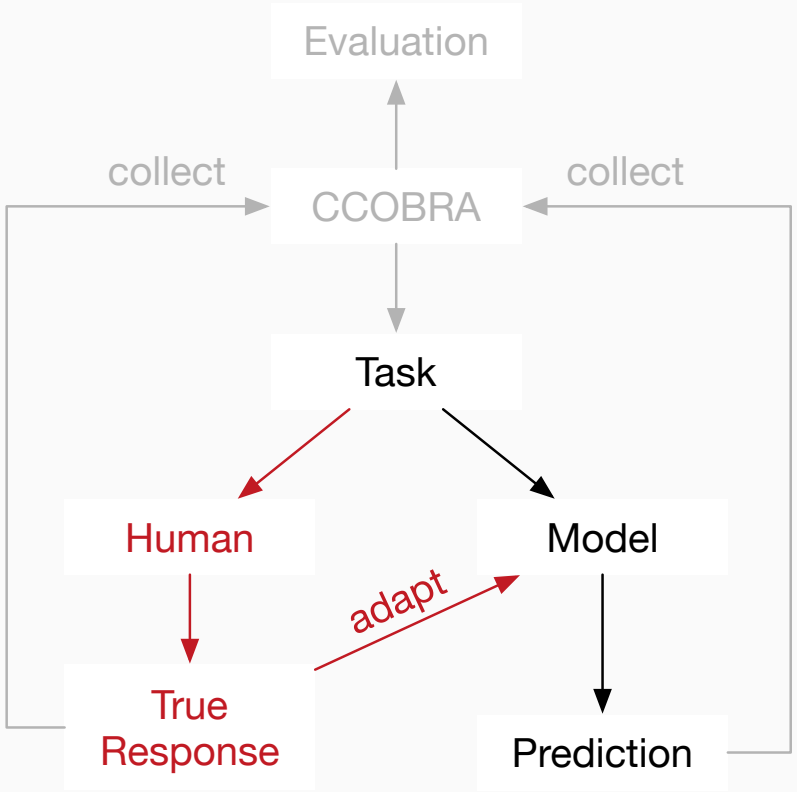
- Supervisor: Daniel Brand
- Task:
  1. Get inspiration from literature (psychological effects) and custom data analysis
  2. Develop computational process models
  3. Evaluate both, predictive performance and interpretability
- Topics/Directions:
  1. Portfolio approaches
  2. Graph-based models (e.g., multinomial process trees, petri nets)
  3. Deduction systems (e.g., distorted logics)

Machine Learning

- Supervisor: Nicolas Riesterer
- Task:
  1. Feature extraction & input encoding
  2. Model conception (e.g., network topology)
  3. Evaluation of training & test performance
- Topics:
  1. (Deep) Neural Networks
  2. Recommender Systems
  3. Decision Trees

The CCOBRA Modeling Problem

1. Model is initialized for predicting an individual reasoner (general training)
2. Framework presents task
3. Model generates prediction
4. Prediction is compared with true human response
5. Model adapts to the human response (online learning)
6. Framework presents next task



Modeling Syllogistic Reasoning Using CCOBRA

```
import ccobra

class MyModel(ccobra.CCobraModel):
    def __init__(self, name='MyModel'):
        """ Initializes the model. """
        supported_domains = ['syllogistic', 'conditional']
        supported_response_types = ['single-choice']
        super(MyModel, self).__init__(
            name, supported_domains, supported_response_types)

    def pre_train(self, dataset):
        """ Pre-trains the model. """

    def predict(self, item):
        """ Predicts a response to a syllogism. """

    def adapt(self, task, target):
        """ Adapt to the last response. """
```

CognitiveComputationLab/ccobra

Benchmarking Models Using CCOBRA

```
$> cd .../ccobra/benchmarks/syllogistic
$> ccobra baseline.json -m mymodel.py
```

CognitiveComputationLab/ccobra

Evaluation Datasets

- Datasets recorded from individuals responding to both conditional and syllogistic problems
- After registration, you will participate in such an experiment to provide the training data
- We will perform the final evaluation on hidden test data

Important Dates

- April 25th: Introductory Meeting
- April 23rd - May 1st: Registration HisInOne
- May 29th: Midterm presentation of preliminary results
- July 7th: Deadline for final models & written report
- July 12th - 13th: Blockseminary

Workload & Expectations

- Use your time wisely (4 ECTS - 120h of work):
  - 10h Literature review
  - 40h First model (midterm)
  - 40h Model optimization (final)
  - 10h Presentation
  - 20h Written Report
- We expect you to have uploaded your models/files to the repositories we will provide you with until 11:59 PM on the respective dates
- Missing deadlines results in failing the seminar

For additional information, check our website

cc.uni-freiburg.de/teaching/seminar-ss-2019

In case of questions, ask now or send a mail later

ragni@cs.uni-freiburg.de
riestern@cs.uni-freiburg.de
daniel.brand@cognition.uni-freiburg.de