– Seminar –
Cognitive Reasoning

Working Memory and Cognitive Reasoning

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October 21st, 2019

Cognitive Computation Lab
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Syllogistic Reasoning

No researchers are gods

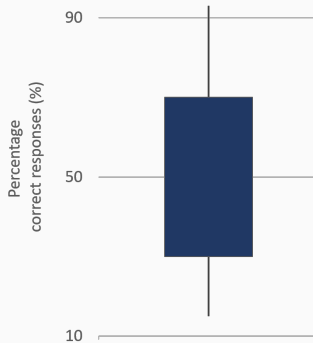Some gods are great reasoners

What (if anything) follows?

- Categorical quantified assertions (All, Some, Some ... not, No)
- Two premises, three terms (A, B, C)
- Goal is to infer relationship between A and C using one of the four quantifiers or "No Valid Conclusion" (NVC)

No A are B
Some B are C

What, if anything, follows?

1. Human conclusions differ substantially from classical first-order logic
2. Great inter-individuals differences (variance) in the human ability to reason logically (e.g., Frey et al., 2018; Galotti et al., 1986; Khemlani and Johnson-Laird, 2016;; Stanovich and West, 2000)
3. **Question:** Why are some individual able to draw a logically correct conclusion and others are not?

What is Working Memory (WM)?
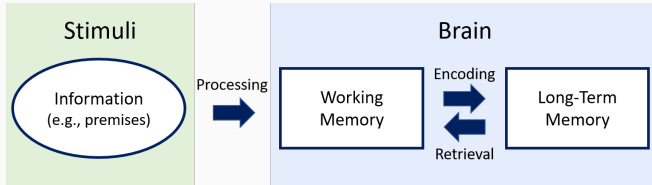
- **WM**: A system/ set of processes to hold mental representations temporarily available for use in thought and action (e.g., manipulation, Baddeley and Hitch; Oberauer et al., 2018)
- WM plays a central role in deliberative cognition (e.g., language comprehension, reasoning)
- **BUT**: Working memory capacity (WMC) is limited (often tested with complex-span tasks; e.g., Barrouillet et al.,2004)
- More information: Kick-Off Meeting!

There Are Many Models of Working Memory . . .

1. 3-component model of WM; replaced "short-term store" in earlier memory models (Baddeley and Hitch, 1974; and later: Baddeley, 2012)
   - Ongoing debate: Really multiple components?
     (Here: difference visual-spatial vs verbal WM)
2. Interference (e.g., Farrell and Lewandowsky, 2002) vs Fading:
   - Interference-based Connectionist Model SOB-CS (Oberauer, Lewandowsky, Farrell, Jarrold, and Greaves, 2012) or Feature Models (Nairne, 1988, 1990; Neath, 1999)
   - Decay-based models of working memory, such as TBRS (Barrouillet et al., 2007) or TBRS* (Oberauer and Lewandowsky, 2011)
3. Memory Measurement Models of WM (e.g., M3 Framework, Discrete State High-Threshold Models, MPT-Models, Continuous Strength Signal detection theory (SDT), Mixture Models, ...; for an overview see Oberauer and Lewandowsky, 2019)

- . . . But not all can be applied to explain differences in reasoning processes $\Rightarrow$ You will prepare and discuss this in the kick-off meeting

Objectives of the Seminar

Core Objective: Examine the impact of working memory on the performance of an individual reasoner.

- **Part I (everyone): Working Memory Models**
    1. Familiarize yourself with the three types of cognitive models in syllogistic reasoning, i.e., *heuristic*, *logical/rule-based*, and *model-based* (see, Khemlani & Johnson-Laird, 2012), specifically with Atmosphere, MMT, and PSYCOP
    2. Understand and present the WM aspect/model you were assigned to with respect to the word list remembering task
    3. Implement one aspect of your WM model to simulate human data on WM tasks
    4. Make a presentation:
        - Present all three theories on one example (3 slides); everyone needs to select a different running example
        - Answer (on each slide): What data structure/limitations do you think are relevant to perform the theories processes?
        - Present your WM model and how it performs on the word list remembering task
- After registration, we will send you an email with more information.

Core Objective: Examine the impact of working memory on the performance of an individual reasoner.

- **Part II (group-specific, 2-3 people): Reasoning and WM**
    1. Data science and machine learning e.g., classifying reasoners (e.g., cluster analysis) or patterns (e.g., neural networks, decision trees)
    2. Cognitive computational modeling (up to 3 groups): Extend existing reasoning models using WM limitation rules to improve their predictive performances

Topics for Part II

Please send us your two most preferred topics from the list below. We will try to find an assignment for anyone according to their preferences (if not possible, we will randomly assign topics):

- Data dimension: Analysis and machine learning
  1. Data analysis methods (e.g., cluster analysis, LCA, etc.)
  2. Machine learning I: Predict individual reasoning responses
  3. Machine learning II: Predict individual WMC

- Model dimension: Cognitive computational modeling
  1. Parameter analysis of an existing model implementation (mReasoner)
  2. Comparison of cognitive model predictions (PHM and MMT) on the basis of individual WM characteristics
  3. Extend and improve predictive performance of existing cognitive models
  4. Augmenting cognitive models with working memory: Change of response patterns

- Supervisor: Nicolas Riesterer and Hannah Dames
- Task: Identify different groups of reasoners/ response patterns based on their WM capacities
  1. Methods: E.g., Hierarchical Cluster Analysis/ Latent Class/Profile Analysis
  2. Task 1: Collect predictions for typical psychological effects (e.g., figural bias)
  3. Task 2: Exploratory cluster analysis to discover similarities in participants' response patterns
  4. Task 3: Clusters on syllogism data only: Predict identified classes using WM

- Supervisor: Nicolas Riesterer and Hannah Dames
- Task: Predict individual reasoning responses using WM data
    1. Feature extraction & input encoding
    2. Model conception (e.g., network topology)
    3. Evaluation of training & test performance
    4. Use of the CCobra Evaluation Framework
- Topics:
    1. (Deep) Neural Networks
    2. Recommender Systems
    3. Decision Trees

- Supervisor: Nicolas Riesterer and Hannah Dames
- Task: Predict an individual's working memory capacity using reasoning data
  1. Feature extraction & input encoding
  2. Model conception (e.g., network topology)
  3. Evaluation of training & test performance
  4. Use of the CCobra Evaluation Framework
- Topics:
  1. (Deep) Neural Networks
  2. Recommender Systems
  3. Decision Trees

Cognitive Modeling: Parameter Analysis of mReasoner

- **Supervisor**: Nicolas Riesterer and Hannah Dames
- **Task**: Analyze how individuals' WM constraints impact reasoning according to the Mental Model Theory (MMT) for its implementation mReasoner

  1. Task 1: Familiarize yourself with the program *mReasoner* that generates conclusions by building and scanning a mental model
  2. Task 2 (Simulation): Simulate data based on your own ideas how WM limitations may affect certain parameters; compare with actual data
  3. Task 3 (Fitting): Identify optimal parameter settings for different WM capacities
  4. Task 4 (Interpretation): Interpret the identified parameters for different WM capacities

Cognitive Modeling: Compare Two Cognitive Models on WM

- Supervisor: Nicolas Riesterer and Hannah Dames
- Task: Fit and compare two cognitive models (PHM and MMT) on the basis of individual WM characteristics
    1. Task 1: Familiarize yourself with the program *mReasoner* and the PHM model implementation which generate conclusions by using either mental models or heuristics
    2. Task 2.1: Fit the models to different groups of individuals (low, middle, high WM capacities, verbal vs. spatial)
    3. Task 2.2: Analyze whether some individuals respond according to the MMT or the PHM model and then analyze whether the likelihood to fit either theory depends on an individual's WM capacity
    4. Task 3 (Interpretation): Interpret the identified model parameters for different WM capacities

Cognitive Modeling: Extend Reasoning Models with WM

- **Supervisor**: Nicolas Riesterer and Hannah Dames (Group 1) and Marco Ragni (Group 2)
- **Task**: Extend existing reasoning models using WM limitation rules to improve their predictive performances
  - Task 1: Familiarize yourself with the predictions made from various existing cognitive theories
    - Task 2 (Group 1): Formalize simple rules and heuristics that people with different WM capacities may use
    - Task 2 (Group 2): Apply working memory models from Part I
    - Task 3 (Group 1): Extend existing reasoning models using these rules (change predictions)
    - Task 3 (Group 2): Extend existing reasoning models using these working memory models (change predictions)
  - Task 4: Compare new model predictions with previous predictions for different groups of people (e.g., low, middle, high WM capacity) using the CCobra evaluation framework

Requirements for Successful Participation in the Seminar

1. Presentation of your insights gained from implementation on your assigned WM model in our kick-off meeting
2. Presentation of your preliminary results in our midterm meeting
3. Presentation of your final results in our blockseminary meeting
4. Written report of your work (6 pages, CogSci-Proceedings-Style)

Important Dates

- October 21st: Introductory meeting
- October 30th: HisInOne registration deadline
- November 11th: Kick-off meeting
- December 3rd: Midterm presentation
- January 2nd 2020: Deadline for final models & written report
- January 10th-11th: Blockseminary

For additional information, check our website

`https://www.cc.uni-freiburg.de/teaching`

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

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