Cognitive Modelling: Intro Lecture

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Sharon Goldwater
School of Informatics
University of Edinburgh
sgwater@inf.ed.ac.uk

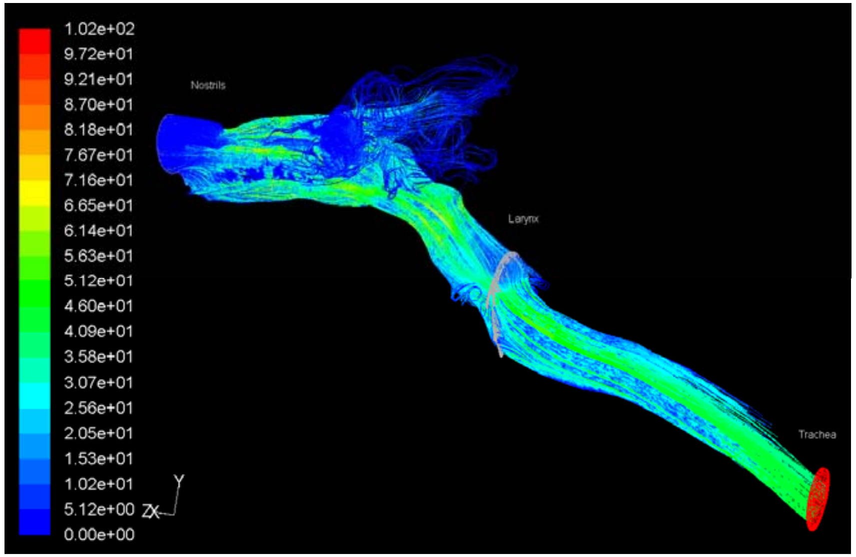
Reading: Chater & Oaksford (1999)

Outline

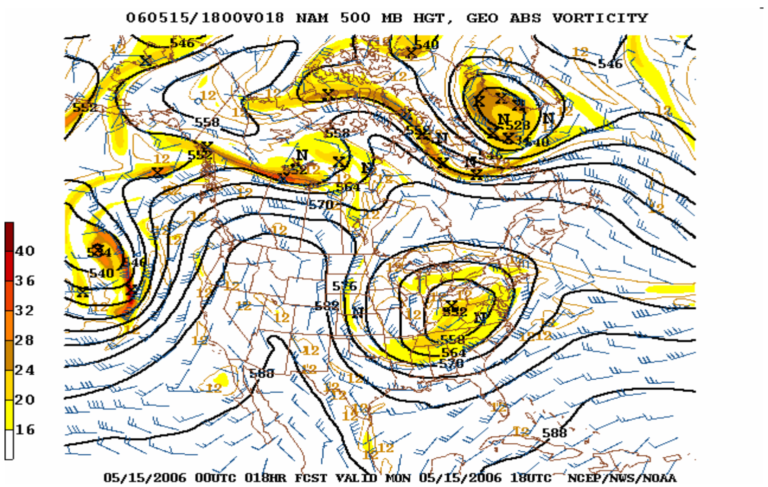
- Course introduction and overview
  - What the heck is cognitive modeling anyway?
- Approaches to cognitive modeling
  - Some examples of approaches we will cover.
- Course mechanics
  - The boring stuff you need to know.

What is a model?

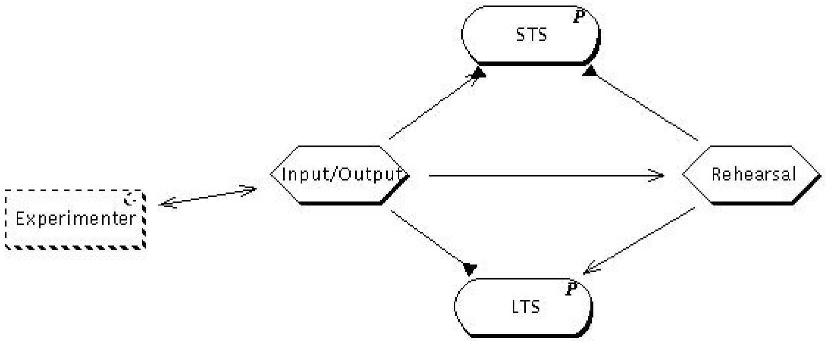
Source: Wikipedia



Source: Datta, Ashim (2005). Computational flow modeling of the equine upper airway.



Source: National Weather Service, http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/



Why build models?

- We build models in order to better understand a complex object or system.
  - Physical models: architecture, engineering.
  - Mathematical models: meteorology, engineering.
  - Computational models: cognition.
- All models capture certain important aspects of a system while abstracting away from others.
- So, cognitive models are computer programs
  - whose behavior is similar in some respect to human behavior.
  - from whose development and use we hope to gain insight into human cognition.

Questions we will address

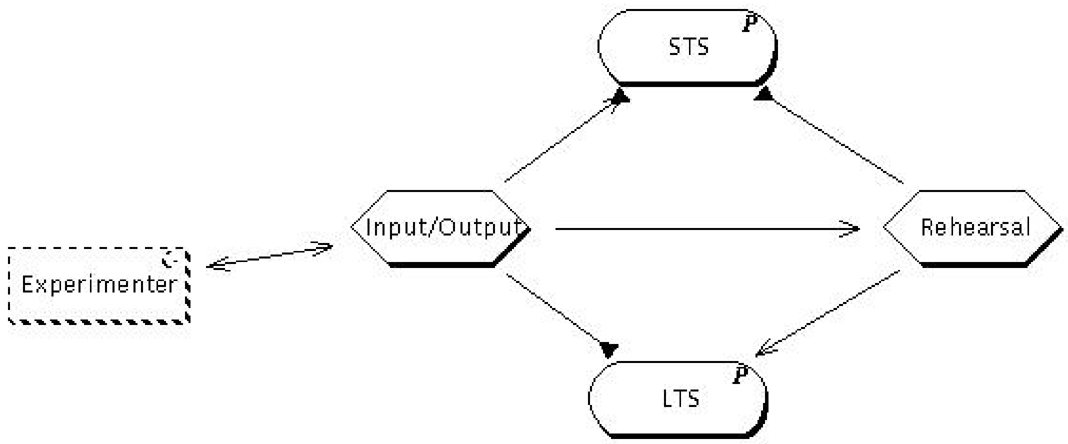
- What makes a good cognitive model?
  - Which aspects of cognition should we aim to capture?
    - External (measurable) behavior only.
    - Internal states and processes.
  - How can we evaluate models against human behavior (data from psychological experiments)?
    - Time course (relative, absolute).
    - Ultimate success or failure.
    - Relative task difficulty.

Course content

- Introduce concepts and methods from cognitive modeling.
- Focus on high-level cognition: arithmetic, problem solving, reasoning, language.
- Compare modeling methodologies: symbolic (cognitive architectures), subsymbolic (probabilistic models).
- Build models using Cogent cognitive modeling tool, and evaluate them against experimental data.
- Assessment: 3 practical assignments (10% each), final exam (70%) (more on this later).

Approaches to cognitive modeling

- Cognitive architectures:
  - Focus on mechanisms: causal structure and timing.
  - Models based on memory buffers, time cycles, production rules, information flow.
  - Examples: ACT-R, SOAR, Cogent.



Modal model of memory in Cogent

Approaches to cognitive modeling

- Rational analysis:
  - Focus on goals: Why does the system behave as it does? What is the problem the system is adapted to solve?
  - Models based on probability theory, often Bayesian.

$$p \propto P(A|H_A)P(Q|A)$$

Anderson’s (1990) rational model of memory

Approaches to cognitive modeling

- Connectionism
  - Focus on representation and low-level implementation: distributed, subsymbolic, (arguably) based on brain structure.
  - Implemented as artificial neural networks:

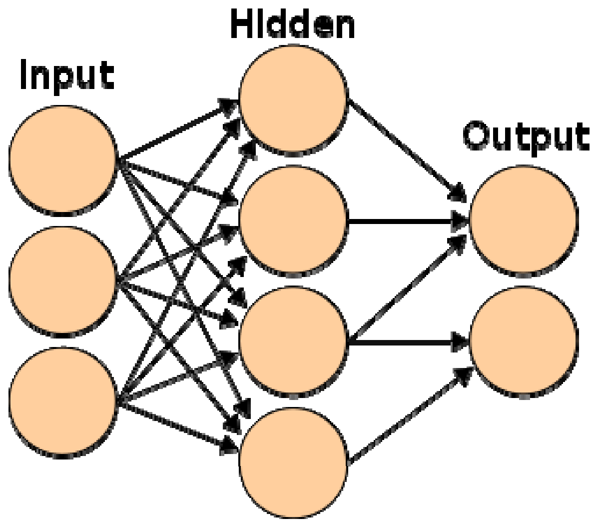


Figure: http://en.wikipedia.org/wiki/Artificial_neural_network

Approaches to cognitive modeling

- Connectionism
  - Focus on representation and low-l ... entation: distributed, subs ... brain structure.
  - Im

Not covered in this course!

If you want to learn about this, try
- Computational Cognitive Neuroscience
- Neural Information Processing
- Neural Computation

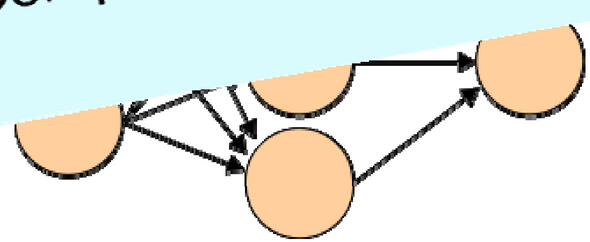


Figure: http://en.wikipedia.org/wiki/Artificial_neural_network

Cogent: a cognitive architecture

- Assignments will use the modeling tool Cogent.
  - Combines schematic (box-and-arrow) diagrams with more explicit implementation in a Prolog-like language.
  - Buffers: store information; e.g., model short term memory, long term memory;
  - Processes: move information from buffer to buffer and change its representation; e.g., model input/output, rehearsal;
  - Code and properties of buffers and processes determine the behavior of the model.

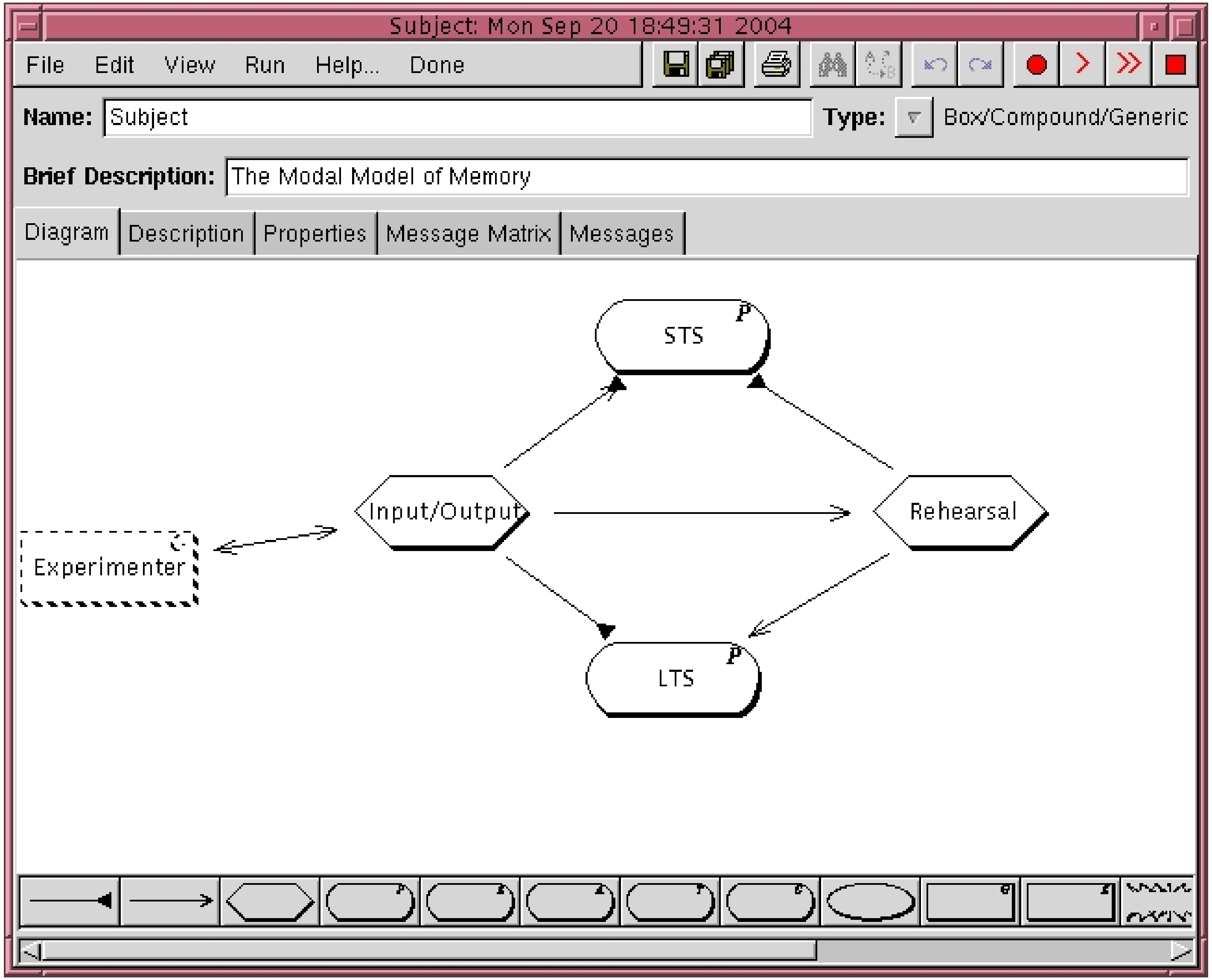
Example: Modal model of memory

- Experiment: subjects are asked to memorize a list of words presented briefly one at a time, then later to recall as many words as possible.

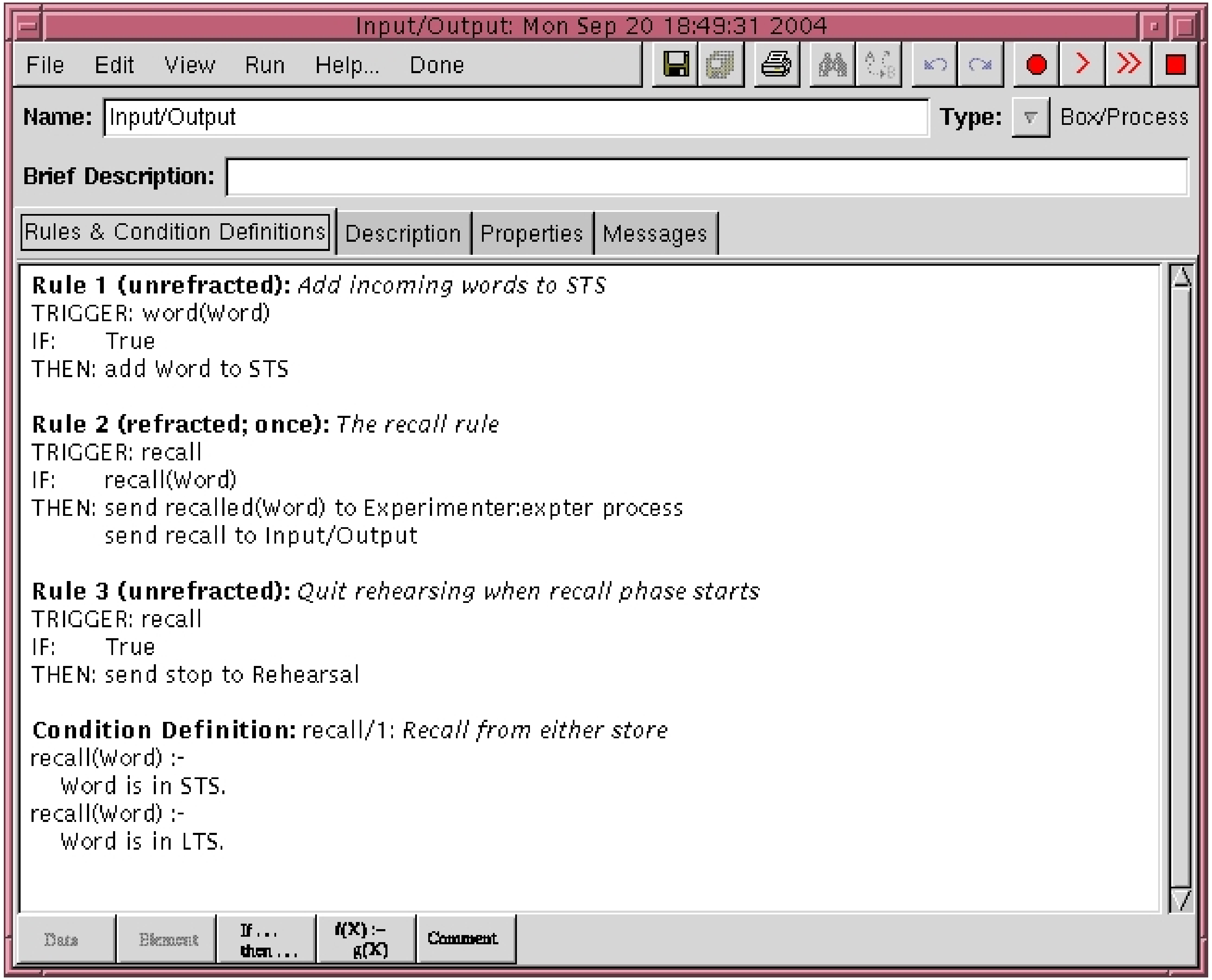
1. White	7. Cyan
2. Orange	8. Yellow
3. Black	9. Indigo
4. Magenta	10. Scarlet
5. Gray	11. Beige
6. Brown	12. Green

- Results: retention depends on the position of the word in the list. Words at the beginning and end of the list are remembered best.

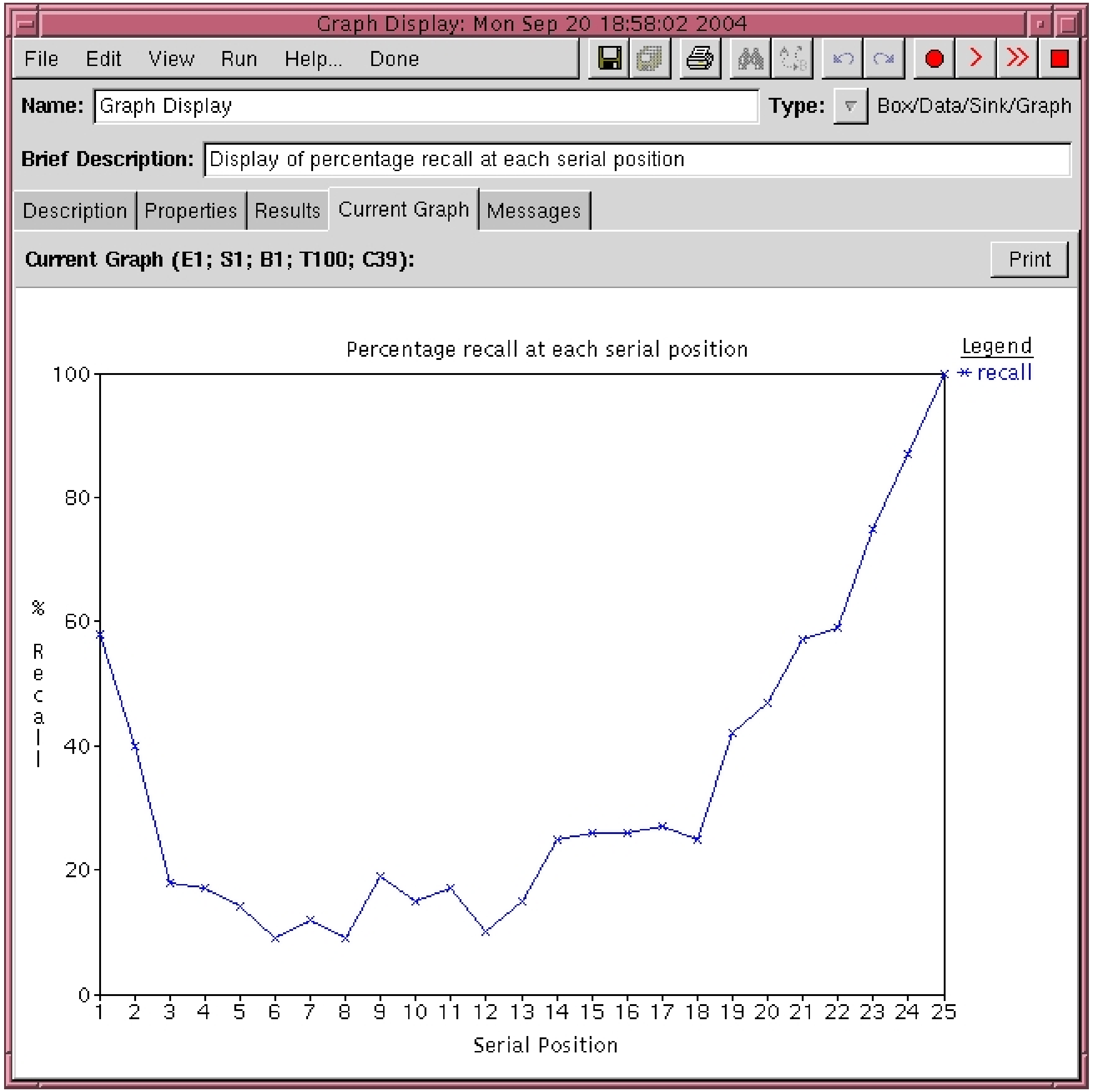
Example: Modal model of memory



Example: Modal model of memory



Example: Modal model of memory



Rational analysis

- Methodology (Anderson 1990):
  1. **Goals**: specify the goals of the cognitive system.
  2. **Environment**: develop a formal model of the environment to which the system is adapted.
  3. **Computational limitations**: make minimal assumptions regarding the cognitive limitations of the system.
  4. **Optimization**: derive an optimal behavioral function using 1-3.
  5. **Data**: evaluate the behavioral function against empirical data.
  6. **Iteration**: refine the model by repeating 1-5.

Example: Wason selection task

- Every card has a letter on one side and a number on the other.

A K 2 7

- Which cards do you need to turn over to test the following rule?

If there is an A on one side,
then there is a 2 on the other.

Example: Wason selection task

- Logical formulation:
  - $p \rightarrow q \;\; <=> \neg q \rightarrow \neg p$

p = If there is an A on one side,
q = then there is a 2 on the other.

A	K	2	7

  - $A \rightarrow 2 \;\; => \neg 2 \rightarrow \neg A => 7 \rightarrow \neg A$

- Subjects' responses:

A only: 33%	A and 2 and 7: 7%
A and 2: 46%	A and 7: 4%

Rational analysis: logical ≠ optimal

- Explanation for seemingly irrational behavior:
  - Logical principles are not very helpful for day to day reasoning, because most events are rare.
  - Ex: if the button is pressed (p), the light goes on (q).
  - For rare events, direct evidence ($p \rightarrow q$) is more informative than indirect evidence ($\neg q \rightarrow \neg p$).
  - Obtaining evidence is often costly, so more informative evidence is preferred.

Rational analysis of Wason task

1. **Goals**: select data with highest expected information gain.
2. **Environment**: events *q, p* are rare.
3. **Computational limitations**: obtaining evidence is costly, so minimize the amount required.
4. **Optimization**: Optimal Data Selection (ODS) model: subjects select the most informative evidence given (1) and (2).
5. **Data**: predictions match subjects' behavior:
   - One card: A selected most often
   - Two cards: A and 2 selected most often
   - Three cards: A, 2, 7 selected most often
6. **Iteration**: new prediction: performance should change if rarity (2) is violated.

Summary

- Cognitive model: an artificial system that behaves similarly to natural cognitive system.
- Cognitive architectures (e.g., Cogent):
  - Emphasis on the mechanisms of the cognitive system.
  - Buffers store information, processes manipulate information.
  - Symbolic representations.
- Rational analysis:
  - Emphasis on the purpose of the cognitive system.
  - Assume the system is adapted to its environment.
  - Often implemented using Bayesian reasoning/probability theory.

Course mechanics

- 20 slots: mostly lectures, 2 tutorials, others TBD.
- website: http://www.inf.ed.ac.uk/teaching/courses/cm/
  - contains contact details, time/place of lectures, software, schedule of assessments, and reading list. All slides and assignments will appear on the web site.
- course mailing lists:
  - cm-4-students@inf.ed.ac.uk, cm-5-students@inf.ed.ac.uk.
  - Will be used for important information. You will be added automatically upon registering.
- You need a DICE account! If you don't have one, apply for one through the ITO as soon as possible.

Reading

- Textbook (multiple copies available in library):

  Cooper, Richard P. 2002. *Modelling High-Level Cognitive Processes*. Lawrence Erlbaum Associates, Mahwah, NJ.

- Additional papers as readings for individual lectures (see website for a reading list and links to online copies).

Assessment

- 3 assessed assignments, worth 10% each (i.e., 30% in total), and a final exam (120 minutes), worth 70%.
  - A combination of implementation using Cogent, testing/analysis, and discussion of implementations and readings.
  - One un-assessed "pre-assignment" to familiarize you with Cogent.
- Warning: assignments differ for 4th year (level 10) and MSc (level 11) version of this course. Make sure to answer the right set of questions!
- Assignments are due at 16:00 on the due date.
  - Typed hard copies handed in to the ITO.
  - Deadlines are listed on the course web page.

Assessment

- 70%: final exam (120 minutes).
  - Questions and solutions from previous years on website.
- 30%: three assessed assignments, worth 10% each.
  - A combination of implementation in Cogent, testing/analysis, and discussion of implementations and readings.
  - Assignments should be typed, and are due in hardcopy at the ITO at 16:00 on the due date.
  - Deadlines are listed on the course web page.
  - Warning: assignments differ for 4th year (level 10) and MSc (level 11) version of this course. Make sure to answer the right set of questions!

Assessment

- Unless clearly stated in the assignment, all assessed work should be completed individually.
- One un-assessed “pre-assignment” to familiarize you with Cogent.

Plagiarism

- Definition: Plagiarism is the act of copying or including in one's own work, without adequate acknowledgment, intentionally or unintentionally, the work of another. It is academically fraudulent and an offence against University discipline.
- Details:

  http://www.inf.ed.ac.uk/teaching/plagiarism.html

Plagiarism

- Examples of plagiarism:
  - Including extracts from another person’s work without using quotation marks and acknowledgment of source.
  - Summarizing others’ work without acknowledgment.
  - Using others’ ideas or help without acknowledgment.
  - Copying another student’s work, with or without their knowledge or agreement.
  - Collaborating with students or others on work that should be completed individually.
  - Cutting and pasting text, illustrations, diagrams, etc. from electronic sources without acknowledging the URL.

References

Anderson, John R. 1990. *The Adaptive Character of Thought*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Chater, Nicholas and Mike Oaksford. 1999. Ten years of the rational analysis of cognition. *Trends in Cognitive Sciences* 3(2):57–65.

Cooper, Richard P. 2002. *Modelling High-Level Cognitive Processes*. Lawrence Erlbaum Associates, Mahwah, NJ.