Intro. to Computational Modeling
Todd Gureckis
Environment

Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior
Environments

Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior

Theory
Stimuli that are perceived by the body and nervous system lead to the Cognitive Mechanism (representations, processes), which in turn predicts behavior. Theory predicts these processes.
Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior

Theory

describes

predicts
Stimuli that are perceived by the body and nervous system → Cognitive Mechanism (representations, processes) → Behavior

Model:

\[ P(\alpha_i) = \frac{x_i}{\sum_j x_j} \]
Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior

Model

\[ P(\alpha_i) = \frac{x_i}{\sum_j x_j} \]
Environment

Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior

Model

\[ P(a_i) = \frac{x_i}{\sum_j x_j} \]
Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Environment

Behavior

Experiment

Model

\[ P(a_i) = \frac{x_i}{\sum_j x_j} \]

Generates

Implements

Observe

Manipulates

Refines/tests
Why models?

- Every researcher has a model, whether they like it or not. ex: somatic markers, recall/recognition, remember/know, etc...

- Advantages: **make predictions explicit**, implications often **defy expectations**, aid **communication** between scientists, support **cumulative progress**
“Formal (i.e., mathematical or computation) theories have a number of advantages that psychologist often overlook. They force the theorist to be explicit, so that assumptions are publically accessible and reliability of derivations can be confirmed...” (Hintzman, 1990)

* thanks to tom palmeri for pointing these excellent quotes out
“To have one’s hunches about how a simple combination of processes will behave is a humbling experience that no experimental psychologist should miss. Surprises are likely when the model has properties that are inherently difficult to understand such as variability, parallelism, and non-linearity - all undoubtedly, properties of the brain” (Hintzman, 1990)

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How are categories represented by the mind?
The graph illustrates the percent endorsed among controls and amnesics across different conditions: Prototype, Low, High, and Random. The data shows a decrease in percent endorsed as the complexity of the condition increases.
How do we acquire language?
Many arguments for innate grammar: the poverty of the stimulus (Chomsky, etc...) 

However, exactly how sparse is the stimulus? Can we learn (at least) some aspects of language from experience alone?

A Solution to Plato’s Problem: The Latent Semantic Analysis Theory of Acquisition, Induction, and Representation of Knowledge

Thomas K. Landauer  
University of Colorado at Boulder

Susan T. Dumais  
Bellcore

How do people know as much as they do with as little information as they get? The problem takes many forms; learning vocabulary from text is an especially dramatic and convenient case for research. A new general theory of acquired similarity and knowledge representation, latent semantic analysis (LSA), is presented and used to successfully simulate such learning and several other psycholinguistic phenomena. By inducing global knowledge indirectly from local co-occurrence data in a large body of representative text, LSA acquired knowledge about the full vocabulary of English at a comparable rate to schoolchildren. LSA uses no prior linguistic or perceptual similarity knowledge; it is based solely on a general mathematical learning method that achieves tracting the right number of dimensions (e.g., 300) to represent other theories, phenomena, and problems are sketched.  


Finding Structure in Time

Jeffrey L. Elman  
University of California, San Diego
Model/theories often drive empirical research

- Multiple systems hypotheses in the brain can in some sense be linked to early single system models (i.e., perhaps most interesting to the degree that it rules out these other models)

- Can lead to unique insights for education, design, etc... (processing/representational assumptions often lead to surprising predictions)
Rational/Computational level analysis

- Why does the system do this?
- How optimal is the performance of the system relative to the available constraints?
- Focus less on mechanism, and more on characterizing what is to be computed, why, and efficiency compared to a appropriately specified ideal-observer.
- Ex: Anderson & Schooler paper
Where do models come from?

- “My ass” - David Gliden

- **Interest**: We think X is the process people use to solve this task. We just ran an experiment, does our idea account for this data?

- **Challenge**: I just got some data which proves your theory wrong. NO! I can model that!

- **Falsification/elimination**: We think people do X, however one might argue they actually use the [simpler/more complex] strategy of X. However, this model fails.
What data can we model?

- **Short answer**: Almost anything
- Confidence judgements
- Fluency judgements
- Reaction Time
- Choices
- Errors
- fMRI Bold signal
- EEG data, MEG data
- Single cell recordings
- Eye movements/body movements
- “Real world” data sets (web surfing, purchasing decisions, social networks)
Can I/You Model My Data?

- What kind of data do you have?
- What existing models are out there in your area?
- What kinds of things are you looking for your model to do? ex: predict RT, model fMRI data, degrade following a lesion like mice do, learn like an amnesics?
Should I make a new model?

- Chances are no.
- What!? No, really.
- What other things are out there? What could be required to “adapt” these to your paradigm. (ex: exemplar-based random walk model)
- How would a new model go beyond what has been done?
- Do existing models fail in a fundamental way?
- The “why”: progress accumulates when new models build on successful ones (unless they are fundamentally wrong)
Types of models

- “Mathematical” Models: akin to equations you learn in an intro chemistry or physics class. Relate a set of variables together without direct reference to processes, representations, etc… (ex: the first half of the Anderson & Schooler paper)

- “Computational” Models: theories of a mechanisms or process. Assumption about stages of processing, representations, input/output. Usually take the form of computer simulations (Griffiths, et al. paper goes in that direction).
Computational Modeling Techniques

- Symbolic systems
- Neural Networks
- Bayesian Networks
- Reinforcement Learning
- Machine Learning/AI approaches
- Heuristics
- Agent-based models
- Statistical Learning algorithms (i.e., LSA, BEAGLE, etc...)
People don’t know how to take derivatives! How could the visual system compute edges!
Lesson 1: Models with many interacting parts are (often) difficult to derive intuition for.
“To have one’s hunches about how a simple combination of processes will behave is a humbling experience that no experimental psychologist should miss. Surprises are likely when the model has properties that are inherently difficult to understand such as variability, parallelism, and non-linearity - all undoubtedly, properties of the brain” (Hintzman, 1990)
http://www.exploratorium.edu/complexity/java/lorenz.html
Readings?