Lecture 1: Grad Modeling

Todd M. Gureckis
Department of Psychology
New York University
http://gureckislab.org/courses/spring12/modeling
Bayesian Models
Decision making/Learning
Complex Systems
Neural Nets
Cog Neuro (analysis)
Category learning
Constructivism
Cog Neuro II (models as theories)
Memory
Advanced Topics
Developmental
Object recognition
Higher Cog
Causality
Architectures
Language

Topic Vote as of 11am
Why model?
**Figure 1.1** An example of data that defy easy description and explanation without a quantitative model.
Ptolemy
Copernicus
Kepler

**Figure 1.2** The geocentric model of the solar system developed by Ptolemy. It was the predominant model for some 1,300 years.
Why model?

- Data never speak for themselves but require a model to be understood and to be explained
Figure 1.3  Observed recognition scores as a function of observed classification confidence for the same stimuli (each number identifies a unique stimulus). See text for details. Figure reprinted from Nosofsky, R. M. (1991). Tests of an exemplar mode for relating perceptual classification and recognition memory. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 3–27. Published by the American Psychological Association; reprinted with permission.
Figure 1.4 Observed and predicted classification (left panel) and recognition (right panel). Predictions are provided by the GCM; see text for details. Perfect prediction is represented by the diagonal lines. Figure reprinted from Nosofsky, R. M. (1991). Tests of an exemplar mode for relating perceptual classification and recognition memory. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 3–27. Published by the American Psychological Association; reprinted with permission.
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• There are always several alternative models that vie for explanation of data, and we must select between them
Figure 1.5 Sample power law learning function (dashed line) and alternative exponential function (solid line) fitted to the same data. Data are represented by dots and are taken from Palmer's (1997) Experiment 3 (Subject 3, Pattern 13). To fit the data, the power and exponential functions were a bit more complex than described in Equations 1.1 and 1.2 because they also contained an asymptote \( A \) and a multiplier \( B \). Hence, the power function took the form \( RT = A_p + B_p \times (N + 1)^{-\beta} \), and the exponential function was \( RT = A_E + B_E \times e^{-\alpha N} \).
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- Verbal theorizing alone ultimately cannot substitute for quantitative analysis.
- There are always several alternative models that vie for explanation of data, and we must select between them.
- Model selection rests on both quantitative evaluation and intellectual and scholarly judgment.
Figure 1.10 Four possible hypothetical relationships between theory and data involving two measures of behavior (A and B). Each panel describes a hypothetical outcome space permitted by the two measures. The shaded areas represent the predictions of a theory that differs in predictive scope (narrow and broad in the top and bottom panels, respectively). The error bars represent the precision of the observed data (represented by the black dots). See text for details. Figure reprinted from Roberts, S., & Pashler, H. (2000). How persuasive is a good fit? A comment on theory testing. Psychological Review, 107, 358–367. Published by the American Psychological Association; reprinted with permission.
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- Model selection rests on both quantitative evaluation and intellectual and scholarly judgment.
- Even seemingly intuitive verbal theories can turn out to be incoherent or ill-specified.
“While adultery rates for men and women may be equalizing, men still have more partners than women do, and they are more likely to have one night stands; the roving male seeks sex, the female is looking for a better partner” (Leahey & Harris, 1989)
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- Model selection rests on both quantitative evaluation and intellectual and scholarly judgment.
- Even seemingly intuitive verbal theories can turn out to be incoherent or ill-specified.
- Only instantiation in a quantitative model ensures that all assumptions of a theory have been identified and tested.
“Verbally expressed statements are sometimes flawed by internal inconsistencies, logical contradictions, theoretical weaknesses and gaps. A running computational model, on the other hand, can be considered as a sufficiency proof of the internal coherence and completeness of the ideas it is based upon...” (Fum, Del Misser, Stocco, 2007)
Why model?

- Every researcher has a model, whether they like it or not. ex: somatic marker hypothesis, Craik and Lockhart (1972) “levels of processing”, recall versus recognition, remember/know, this bit of brain inhibits this bit of brain

- Advantages of a FORMAL model:
  - Make predictions explicit
  - Implications often **defy expectations**
  - Aid communication between scientists
  - Support **cumulative progress**
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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)

* thanks to Tom Palmeri for pointing these excellent quotes out
Why model?

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- Advantages of a model:
  - Make predictions explicit
  - Implications often **defy expectations**
  - Aid **communication** between scientists
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“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 publicly accessible and reliability of derivations can be confirmed...” (Hintzman, 1990)

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but creeping outward...
Principles of Neural Science (Kandel, Schwartz and Jessel)

OUR TASK is to make this book shorter! Describing ≠ Understanding
don’t forget...

psychological models can help make computers better...
What is the role of modeling in behavioral science?
Environment

Stimuli that are perceived by the body and nervous system

Behavior
Environment

Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior
Environment

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 → Cognitive Mechanism (representations, processes) → Behavior → Theory predicts
Environment

Stimuli that are perceived by the body and nervous system

Cognitive Mechanism (representations, processes)

Behavior

Theory

describes

predicts
Environment
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

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Debated for thousands of years. If you don’t have an immediate answer, don’t feel bad. Various proposals have been thrown around from by Plato, Buddha, Aristotle, Zoroaster, ancient Greek, Indian, and Islamic philosophers, and even a few folks at NYU.
What makes a mind?

What do they do?

Minds encompass our thoughts, which are the mental processes which allow us to deal with the world. These include not only explicit wishes, desires or intentions but unconscious processes as well.
What makes a mind?

Does MIND = BRAIN?

We know that we can’t have a mind or thoughts without a brain, but does that mean that minds and brain are synonymous?
A common philosophical approach is the “slippery slope” argument to try to convince us that minds are not literally brains, but encompass anything that is organized as a set of represented mind states that accurately reflect aspect of the world.
Figure 1.1 — The BRAIN/MIND RIDDLE. What is common to the minds of various sentient creatures that look at the scene in the center of this picture and see three objects? This question can be elaborated (by asking it about two cylinders and a sphere rather than "three objects"), or extended to other cognitive processes such as thought or discourse that need not involve vision or any other particular perceptual modality.
Edelman’s argument

- What is common to all sober observers viewing the same scene and who are in agreement about what is viewed?

- Can’t literally be neurons. My neurons are my own, and you can’t borrow them to solve your own problems.

- Well maybe is the literal organization of the human nervous system (up to the limit of correspondence). However, we know (or at least believe) that cats have a very similar visual system and view the world much like we do. Is it the mammalian visual system? What about other animals?

- What about artificial systems formed of computers and video cameras that can accurately recognize the scene as well?

- The key to minds may be not the physical substrate in which they are embodied but the relations that various states of the system have to one another and to the environment/world.
The “organizational” view of the mind

- Minds aren’t human neurons or cat neurons or robot parts, but the organization of dynamic, continually evolving systems that relate ongoing internal (i.e., mind) states and external (i.e., world) states.

- Correspondences can be made between the evolution of two systems to describe what they are doing independent of the exact things they operate on.

- Such correspondences are particularly well described in the language of computation, simply because the THEORY OF COMPUTATION offers use formal insight into how ostensibly dissimilar systems can be formally identical.

- Everything that can be expressed in one system can be expressed in a different, but functionally identical system.
thus...

Computational Modeling maybe the only way toward a scientific theory of mind
People don’t know how to take derivatives! How could the visual system compute edges!

(true question from grad student)
Where do models come from?

- “My ass” - A tenured prof.

- **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/model complex] strategy of Y. However, this model fails.
Modeling techniques

- Always evolving/being developed
  - Symbolic systems
  - Neural networks
  - Bayesian networks
  - Reinforcement Learning
  - Machine learning/AI techniques
  - Heuristics
  - Agent-based models
  - Statistical learning algorithms (e.g., topics models, LSA)
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/action
  • Real world data (web surfing pattern, purchasing decisions, social networks)
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. Think in terms of PATTERN LANGUAGES (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

- **Descriptive model:** 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...

- **Process model:** Assumption about stages of processing, input/output. Usually take the form of computer simulations (example was multinomial process trees).

- **Explanatory process model:** Theories of a mechanisms or process. Assumption about stages of processing, representations, input/output. Usually take the form of computer simulations (examples like Generalized Context Model... claims about memory traces, how they interact with experience to make decisions).

- **Rational model:** Why does the system this? How optimal is the performance of the system relative to the available constraints? Focus less on mechanism, more on what is being computed and why.
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Why not?
For next time....

- Check out readings (not from book this time).
- Emphasis: types of models, “thinking in levels” of explanation
- Shelling T. (1978) Micromotives and macrobehavior: Ch. 4 Sorting and mixing, Race and Sex
- Wolfram, S. (2005) A new kind of science (ch. 2)