Advanced cognitive modeling

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Course material: https://github.com/LegrandNico/CognitiveModeling

Introduction to cognitive and computational modeling

Why cognitive/computational models are interesting?

What is a cognitive/computational model?

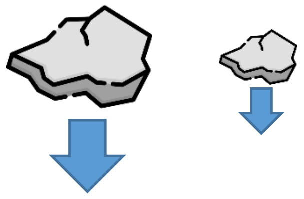
The example of cognitive computational neuroscience and computational psychiatry.

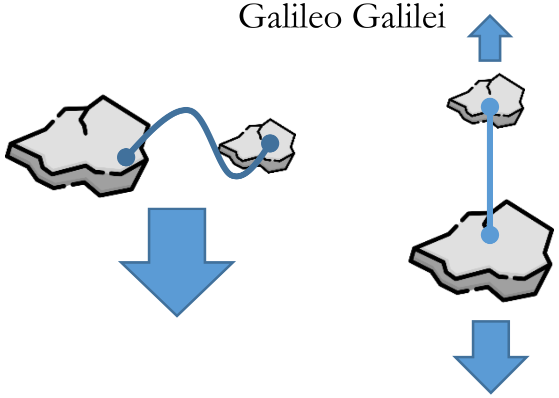
Introduction

Computational modeling is not something new.

Aristotle

Galileo Galilei



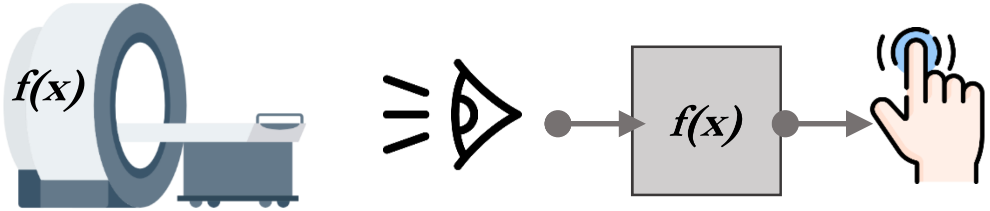


Actually, this is not computational, and this is not about cognition, BUT…

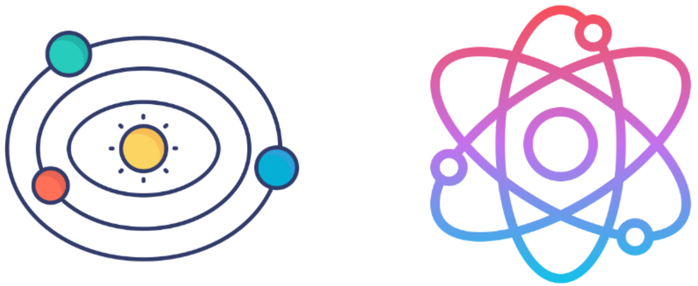
- *Data never speak for themselves*
- *A model instantiates algorithmic hypotheses*
- *The model explains the data*
- *The model is unobservable and exists only in the mind of people who use it*
- *There are many models for a single dataset*
- *We can compare models with each other*
- *Models can be checked for internal consistencies*
- *Model can make predictions and compare with experimental data*
- *Models can postulate the existence of hidden/latent phenomenon's*

"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 Missier, and Stocco (2007), p. 136

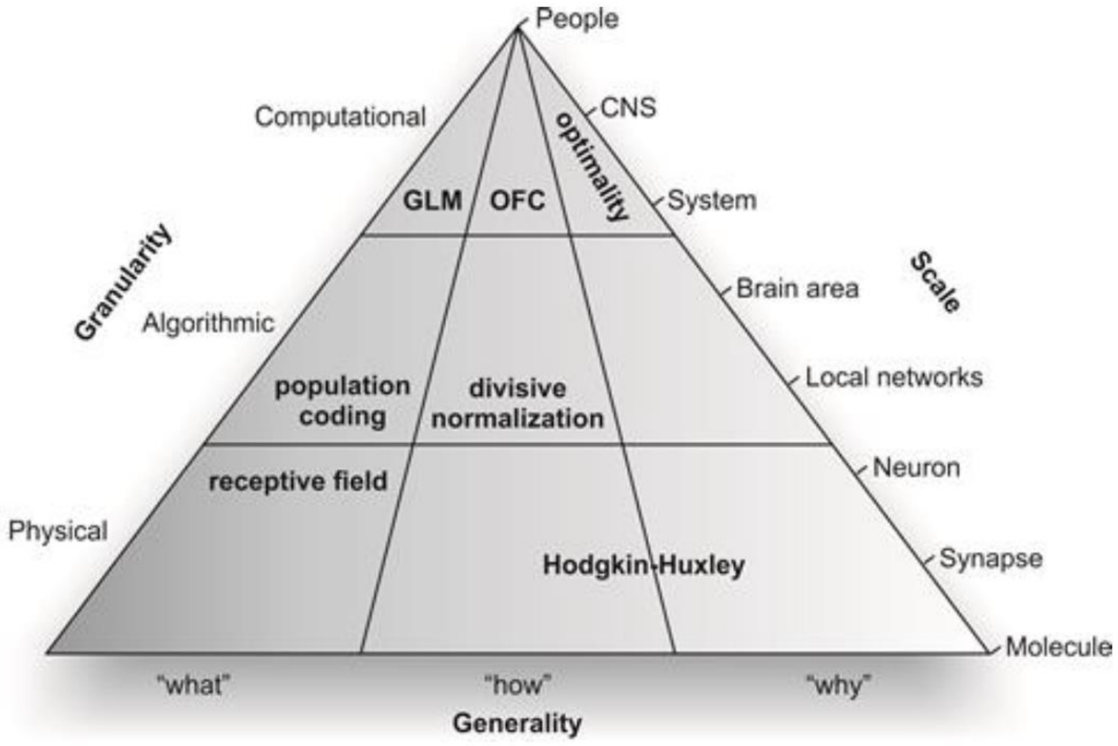
Introduction



Behaviors and neurocognitive processes are complex phenomenon's that cannot be fully understood just by looking at it.



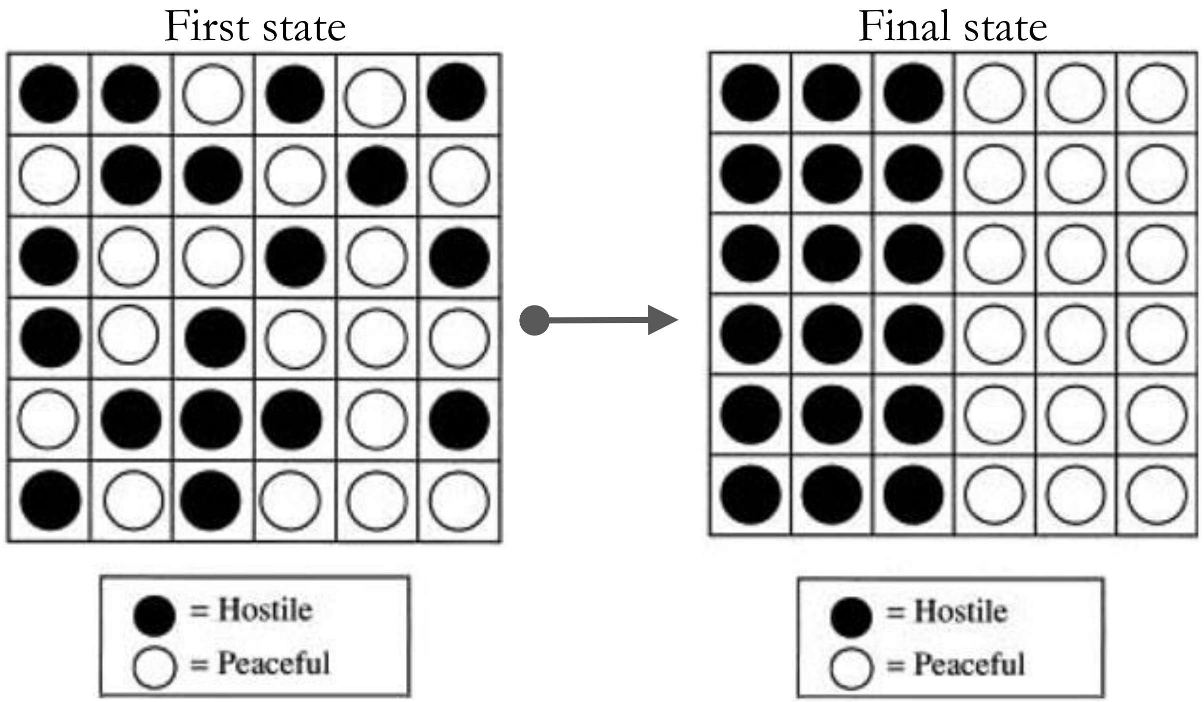
Models should be as simple as possible but as detailed as needed.



Schrater et al. - Modeling in neuroscience as a decision process

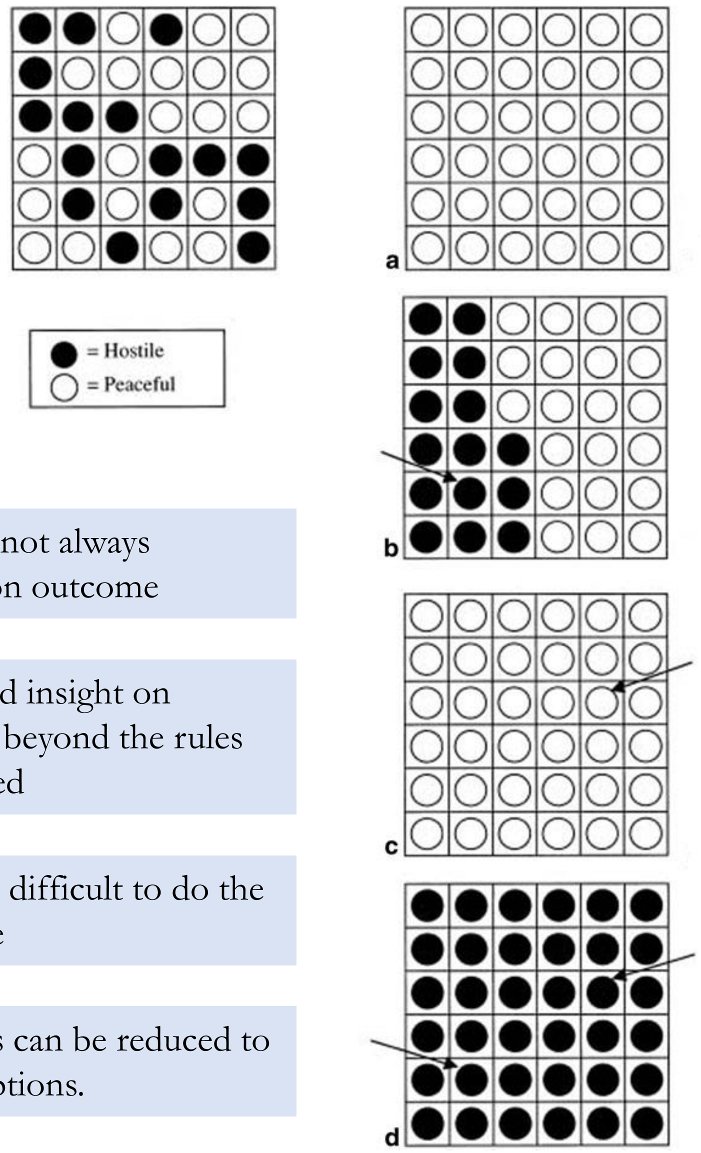
Introduction

The emergence of social structure from simple individual behaviors.



If $n_{Neighbors} = \text{Hostile} > n_{Neighbors} / 2$
 $State_{t+1}$=Hostile
Else
 $State_{t+1}$=Peaceful

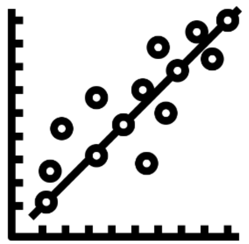
- Verbal theories cannot always anticipate simulation outcome
- The simulation yield insight on emergent behavior beyond the rules initially programmed
- It would have been difficult to do the backward inference
- Complex behaviors can be reduced to very simple assumptions.



Kenrick DT, Li NP, Butner J (2003) Dynamical evolutionary psychology: individual decision rules and emergent social norms. *Psychol Rev 110:3–28.*

Models of cognition

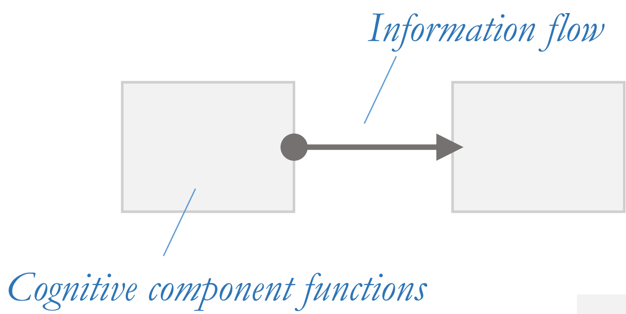
Data analysis models



Help establish relationships between measured variables

They are not models of brain information processing.

Box-and-arrow models

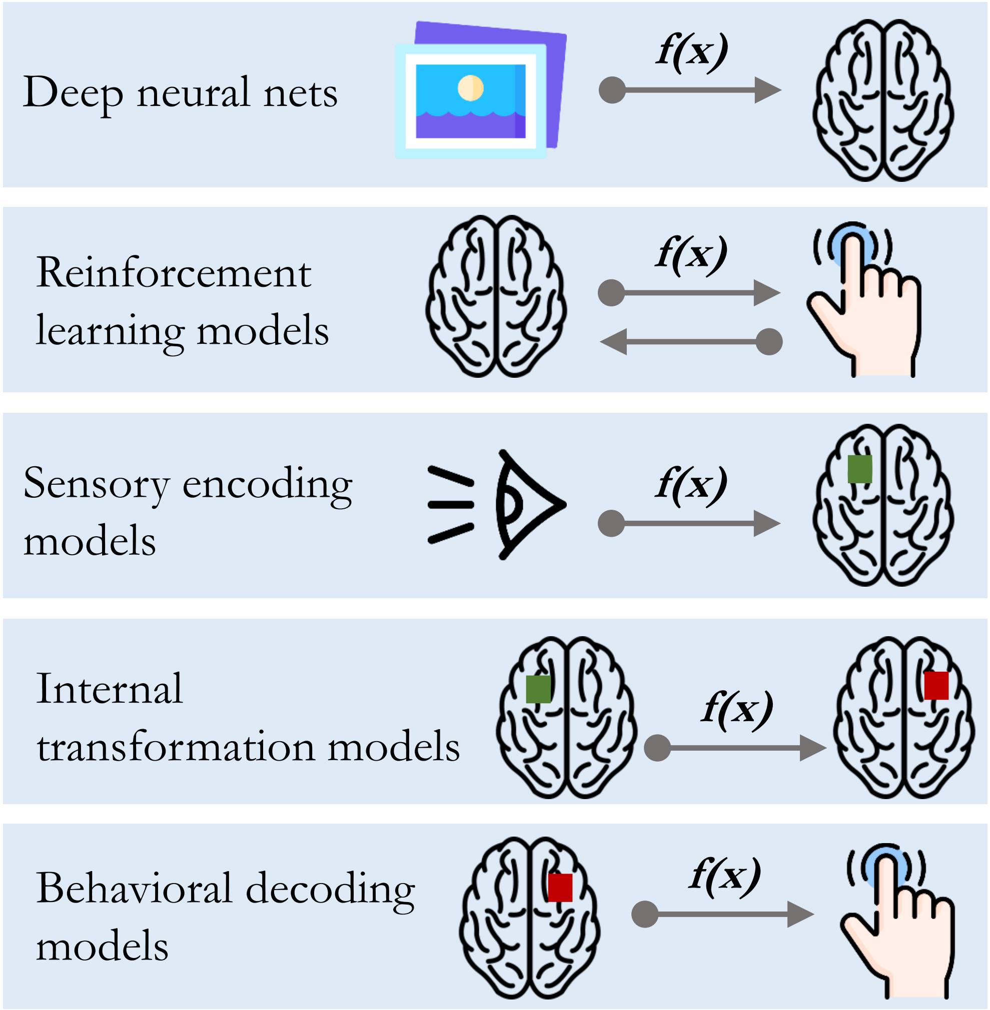


Models of the world

- Model-based reinforcement learning
- Model-based cognition

Brain-computational model (BCM)

Mimics the brain information processing

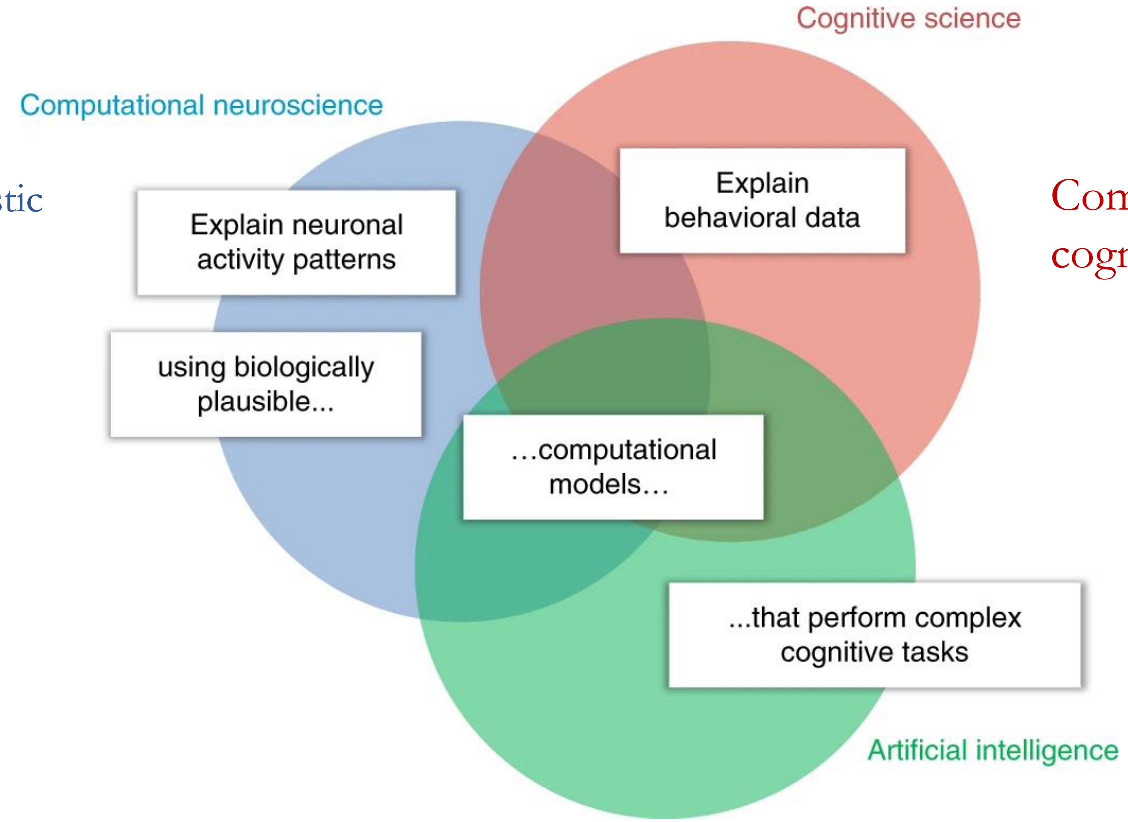


Kriegeskorte and Douglas (2018). *Nature neuroscience*

Cognitive computational neuroscience

Create biologically plausible computational models that perform cognitive tasks and explain brain information processing and behavior.

Neurobiologically plausible mechanistic models that explain brain activity



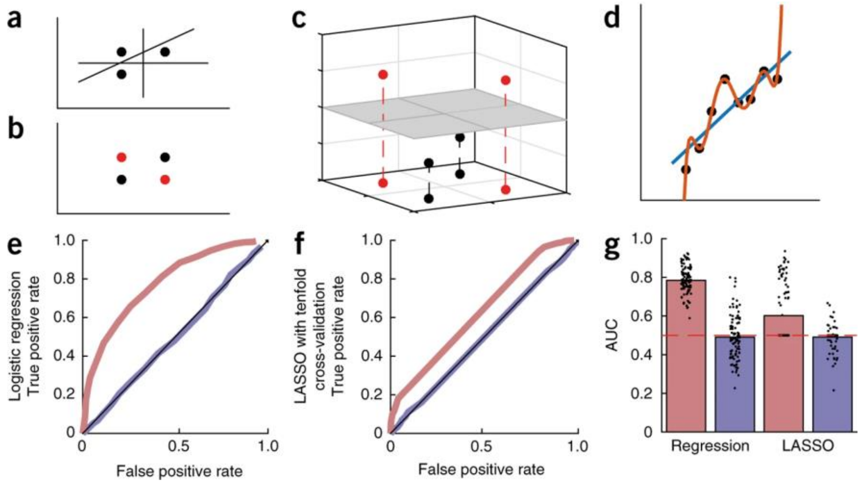
Computational models that perform cognitive tasks and explain behavior

"What I cannot create, I do not understand"
Richard Feynman

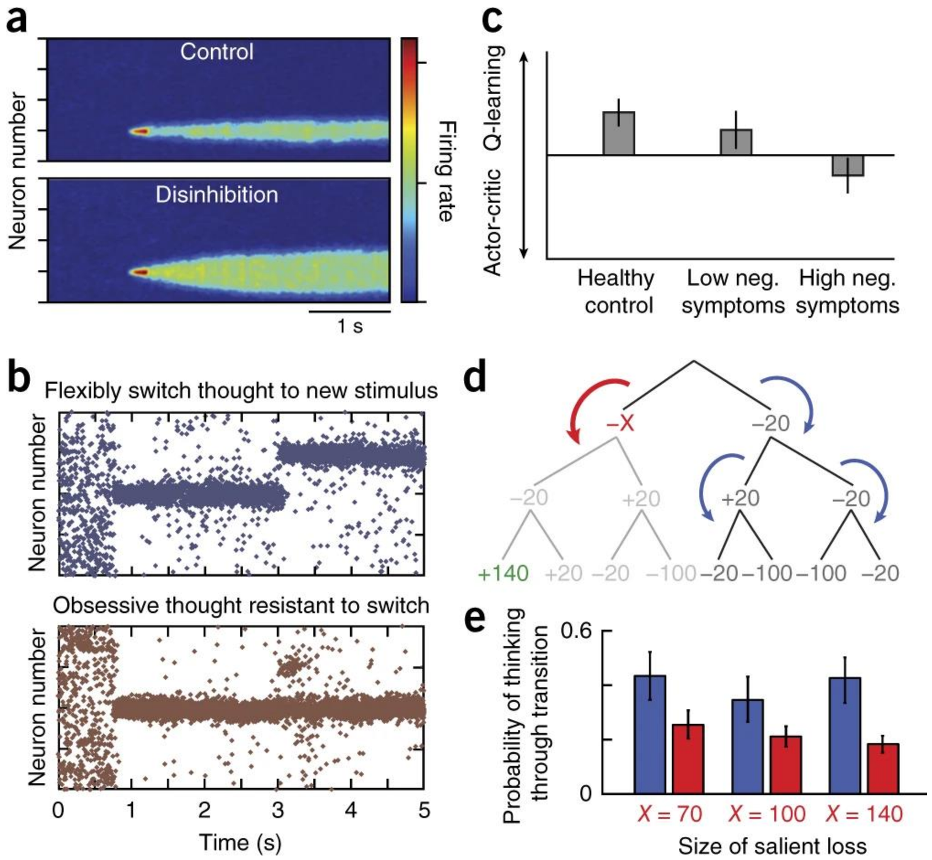
Kriegeskorte and Douglas (2018). Nature neuroscience

Computational psychiatry

Data-driven



Theory-driven



Huys et al. (2016) Nat. Neurosci.

Bayesian decision theory broadly provides three routes to psychopathology:

- solving the wrong problem correctly (e.g. consistently prioritizing alcohol intake over health)
- solving the correct problem wrongly (e.g. using alcohol to 'treat' emotional problems),
- solving the correct problem correctly, but in an unfortunate environment or after unfortunate prior experiences (e.g. having persecutive worries after persecutory experiences).

Course goals

1. (Hierarchical) Bayesian modeling.

PyMC3

2. (Deep) Reinforcement learning.

TensorFlow

OpenAI

Model goals

- Descriptive

WHAT

Describe the data

- Mechanistic

HOW

Describe the data in term of mechanisms

- Explanatory

WHY

Describe the data in term of mechanisms following optimal solutions to (constrained) problems in the real world

Resources

Huys, Q. J. M., Maia, T. V., & Frank, M. J. (2016). Computational psychiatry as a bridge from neuroscience to clinical applications. Nature Neuroscience, 19(3), 404–413. https://doi.org/10.1038/nn.4238

Kriegeskorte, N., & Douglas, P. K. (2018). Cognitive computational neuroscience. Nature Neuroscience, 21(9), 1148–1160. https://doi.org/10.1038/s41593-018-0210-5

Lewandowsky, S. & Farrell, S. (2011). *Computational modeling in cognition : principles and practice*. Thousand Oaks: Sage Publications.

Forstmann, B. & Wagenmakers. (2015). *An introduction to model-based cognitive neuroscience*. New York, NY: Springer. Ch. 1: An Introduction to Cognitive Modeling.

BayesCog Summer 2020 (Lei Zhang)

- https://www.youtube.com/watch?v=8RpLF7ufZs4&list=PLfRTb2z8k2x9gNBypgMIj3oNLF8lqM44-

Neuromatch Academy (W1D1)

- https://www.youtube.com/watch?v=KxldhMR5PxA
- https://www.youtube.com/watch?v=KZQXfQL1SH4