Modeling: what is it, what is it good for, why DFT?

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road map

What is modeling good for?

- What is modeling/theoretical language
- Models and data
- Data and models
- Process models
- What does it mean to "understand" the mind?
- Why then model in DFT?

What is a model

- a construct that stands in a well-defined relationship with an aspect of the world/ nature

What is a model

- verbal models: discourse that maps onto a phenomenon, often using analogies from another domain (mechanisms etc)
  - e.g. the brain as a switchboard, the brain as a computer, motivation/drive as hydrostatic pressure

What is a model

- formal models: using mathematical concepts to express relationships between components that map onto phenomena
  - e.g. diffusion model of reaction time

Theoretical language and models

- Models use theoretical language, concepts
- Those may capture constraints, e.g. through mathematical theorems that establish links between concepts
- Theoretical frameworks: link different theoretical concepts used in modeling through logical constraints
- In physics, theory and model is often used interchangeable because all models are strongly constrained by theoretical frameworks

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Models and data

- Models "match" data, "predict" data, "account for" data
- What does that mean ?

Models and data: Quantitative fitting

- How powerful is the fit?
- => How much data vs how many parameters..
- BIC criteria meant to capture this abstractly
- But: what does "how much data" mean?
- … independent?
- … sampling different processes?

Models and data: laws/constraints

- But: are the data constrained by laws ?
- => does the model have the same constraints?
  - or could the model fit data that violate the constraint just as well?
  - example: diffusion model does constrain the shape of RT distributions
  - example: relaxation time and variance co-vary, a deep constraint
  - example: uncontrolled manifold structure of variance

Models and data: laws/constraints

- a model that has the same constraints as the data has uncovered a law of nature

Neural models and data: laws/constraints

- at which level of neural mechanism to model particular phenomena?
- if these phenomena are “laws”, the level of description is an empirical issue
- e.g. does a model at the level of spiking neurons have the same constraints at observed behaviorally
- or does a model at the population level?

Models and data: data compression

- Fits as a form of data compression …
- which means: the data is constrained: a subset predicts the rest
- although the model may not have the same constraints (could fit other data just as well)
- it may still extract=describe that constraint
- example: synergies/extracting lower-dimensional representations

Models and data: neural networks

- use many parameter to fit data (“back-propagation”)
- rigorously do not have any constraints: universal approximators
- by may describe constraints.. e.g. generalization

Models and data: neural dynamics

- if a model “captures” constraints (has the same ones as the data), what use is it to fit the data?
- existence proof: show that a fit is possible
- there is no additional constraint within the model that makes a fit impossible

Models and data: predictions vs assumptions

- what does it mean to "predict" an effect?
- is that the same as assuming the effect?
- are the assumptions tested?
- which "consumes" predictions
- predictions are strong if they cannot be "fixed"
- historical vs logical prediction

Models and data: predictions

- historical predictions: of as yet unknown effects
- “surprising” predictions… reveal more about the knowledge or prejudices of the researcher
- logical predictions: showing that given certain tested assumptions within a certain theoretical framework something else follows
- the direction of logical prediction does not be to unique .. physics is full of that

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Data and models: experiments that do "fitting"

- how generic or specific are the experimental conditions that lead to an effect
- role of pilot data: how much piloting is needed
- example: Bayesian estimation vs cue selection

Data and models: how much data

- does a model fit different data sets (from different experiments)?
- often the request is made that this fit uses the same set of parameter values
- but: it may be empirically incorrect to use the same parameter values as participants adapt to each task

Data and models: how much data

- the capacity to accommodate different tasks is itself a strength
- are the tasks truly different? probe different aspects?
- are the components that model the different data sets distinct ?

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Process models: what they are

- Models that are generative: could generate the behavior
- given a certain interface with sensors and with motors

Process models: what they are

- Example: a sensor provides image and model provides a classification decision …
- => that is more of a process account than a diffusion model that assumes the input is some value along a decision axis and the provides the RT to classify the input correctly

Process models: what they are

- the closer the sensory/motor interface to the neural/embodied system the more powerful the process description

Process models: interfaces

- sensor model
  - consistent with neural properties of sensor
  - does it make demands on normalization ?
- motor model
  - properties of human/biological actuator?
  - does it make demands on calibration

Process models: interfaces

- environmental model
  - does the model operate in closed loop with an environment?
  - does that environment minimize/eliminate problems?
  - e.g. variance in size, clutter, time-varying

Process models: and data

- example: a process model of upright stance must .. .stand upright
- is that data? is that a fit? it is a strong constraint
- process models are richly constrained that way.. .
- which is one reason they are powerful

Process models: does fitting them to data make sense?

- typically more difficult to fit.. because many other things must be true for the model to work
- fitting them to data shows that the data can be reached…
- failure to fit may lead to new insights into missing processes

Process models: sufficient/not necessary

- process models may reveal component process that are sufficient or are not necessary
- sufficient: generate the behavior/data from a set of assumptions, processes
- not necessary: if other commonly invoked processes/assumptions are not required, these are not necessary to explain the data
- which does not mean that those other processes do not contribute

Process models: necessary

- process models have a harder time with revealing what is necessary
- that requires theory: spanning a space of possible models and classifying within that space the models that may have certain properties

How to model in DFT

- characterize neural state space
- characterize interface to sensory and motor surfaces
- level of invariance of neural state
- characterizing neural function / dynamic regime
- parameter values based on that
- parameter values to fit data

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What does it mean to "understand" the mind/brain?

- laws of the mind
- links between laws of the mind
- possible minds

Understanding in the biology tradition

- Descriptions that are common, shared across species, contexts, etc provide "understanding"
- Ultimately an evolutionary perspective: shared/common traits of organisms
- But allowing for exotic, quirky special cases…

Understanding in the physics tradition

- laws
- of different relevance and certainty
- example: energy conservation
  - observed in many different contexts, levels, systems
- explanation: relations between laws
- a network of such relations is a theory

What does it mean to "understand" the mind/brain?

- the descriptive epistomological attitude of biology
- vs the law-oriented epistomological attitude of physics
- with neuroscience/psychology right at the boundary

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Why then model in DFT?

- to discover laws of the mind
- and their connections/inter-relations
- DFT models make explicit conceptual commitments .. which is where theory resides
- the mathematical formalization sharpens the scientific discourse and thinking
- DFT process models help uncover problems/overlooked processes through quantitative

Why then model in DFT?

- the mathematical formalization provided by DFT sharpens the scientific discourse and thinking
- DFT process models help uncover problems/ overlooked processes through quantitative comparison with data
- => DFT models also interesting when they fail

Discussion point

- “computation” is a metaphor that is not conceptually neutral…. emphasizes input-output relations and adopts an abstract level of description
- when neural principles uncover or explain laws of behavior… a neurally grounded model does not merely implement of abstract computational principles

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