Data mining and neurocomputational modeling in the neurosciences

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Behavioral/Cognitive Neuroscience

- Mission: Pinpoint the neurobiological mechanisms that underlie complex cognitive processes and resulting behaviors
- Growth areas
  - New techniques, refinements in techniques
    - Neuroimaging, optogenetics, cyclic voltammetry
  - Focus on systems and circuits
  - Interaction of complex processes
  - Molecular → Molar (different levels of analysis)
  - Computational modeling
- As a result…
  - Richer and larger data sets

Links with current funding trends

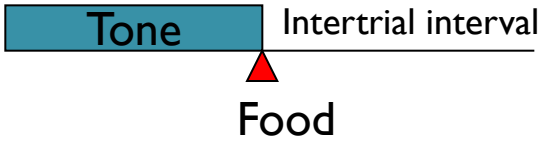
NIMH: Division of Neuroscience and Basic Behavioral Science (DNBBS)

- *Develop new and use existing physiological and computational models to understand the biological functions of genes, gene products, cells, and brain circuits in normal and abnormal mental function.*
- *Elucidate how cognitive, affect, stress, and motivational processes interact and their role(s) in mental disorders through functional studies spanning levels of analysis (genomic, molecular, cellular, circuits, behavior) during development and throughout the lifespan.*

Analytics, Data Mining, and Neurocomputational modeling

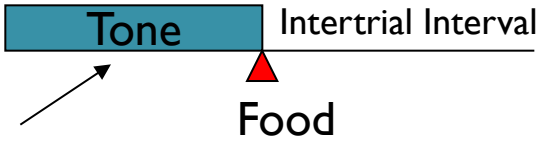
- Data mining
  - The process of knowledge discovery in databases
  - Data mining should be hypothesis driven
    - Surgical approach
    - Look for converging patterns
- Neurocomputational modeling
  - Understand computational processes that underlie complex behaviors
    - Deeper insight into mechanisms
  - Bridge between neurobiology and behavior
    - Brain-behavior translation

Three ways of collecting data

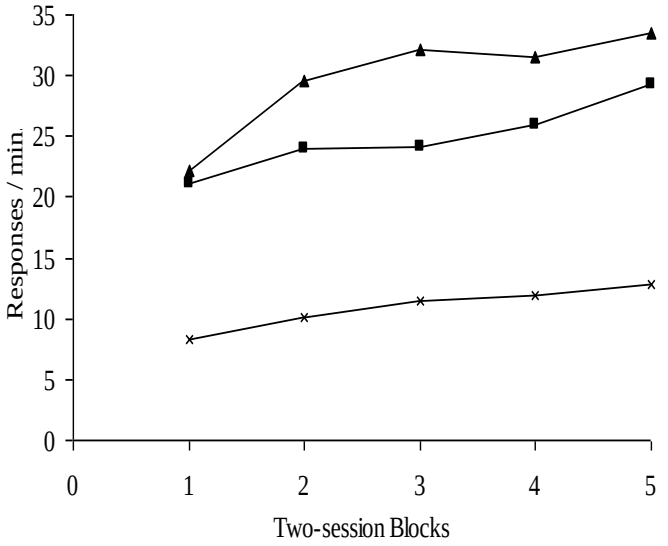


- Pavlovian conditioning
  - A tone is followed by food
  - A response (e.g., rat poking head in food cup) is measured
- Data collection method 1: Record the total number of responses during the tone.
- Data collection method 2: Record responses during time bins during the tone.
- Data collection method 3: Record every response with a time stamp (time-event code)

Data Collection Method 1: Record the number of responses during the tone



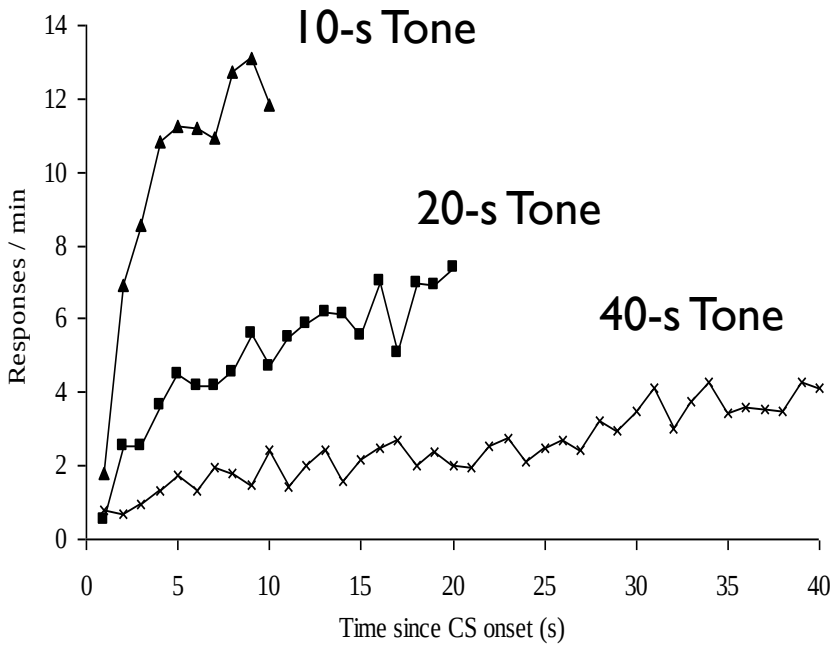
Run a counter

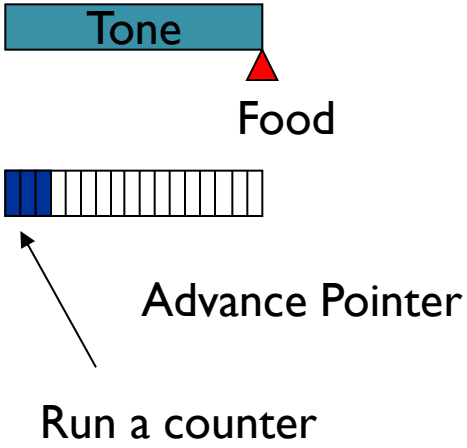


$$\frac{\text{Total number}}{\text{Total time}}$$

Jennings, Bonardi, & Kirkpatrick (2007)

Data Collection Method 2: Binned responses

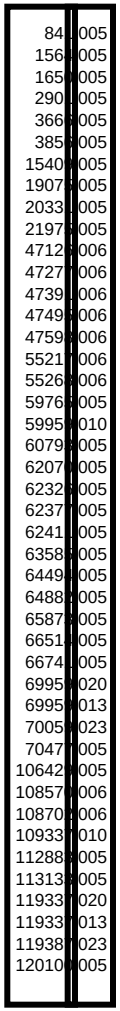




Jennings, Bonardi, & Kirkpatrick (2007)

Data Collection Method 3: Time-event codes

Time stamp in ms



Event codes

Head entry into food cup = 005

Drinking from water tube = 006

Tone on = 010
Tone off = 020

Food on = 013
Food off = 023

Why time-event codes?

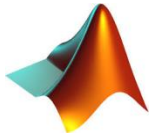
Advantages

- Flexibility in data analysis
- May be able to use one data set for many purposes
  - Grant applications
  - Computational modeling
  - Generate new research questions

Challenges

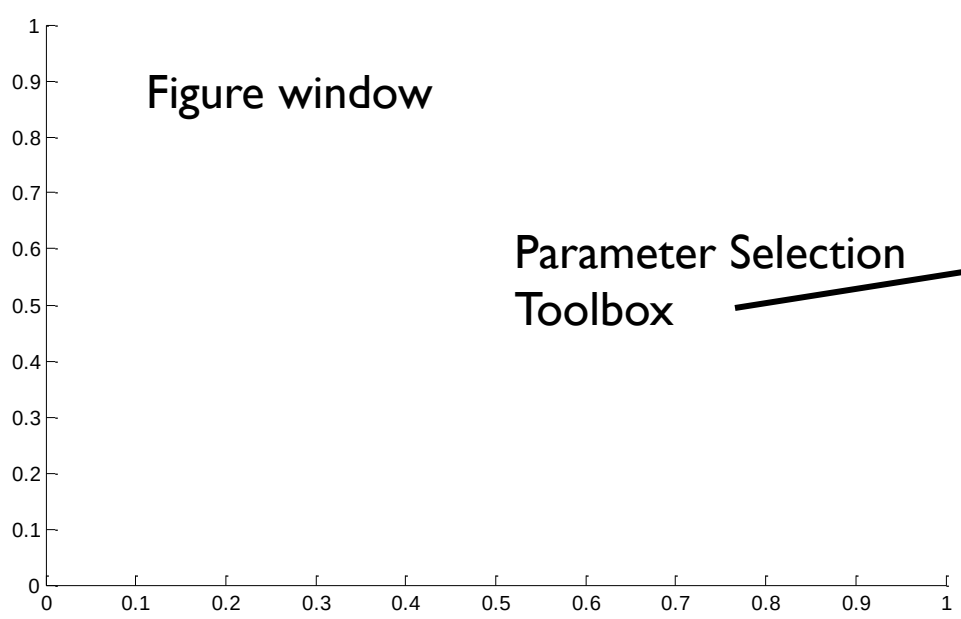
- Data management and archiving (500-3000 data files/study)
- Requires programming and data analysis skills
  - Data mining
- How involve students?

Techniques and tools

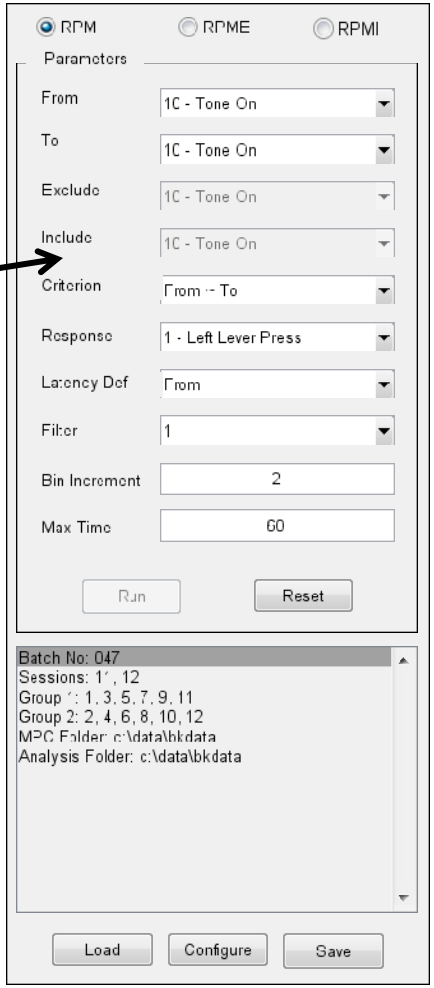


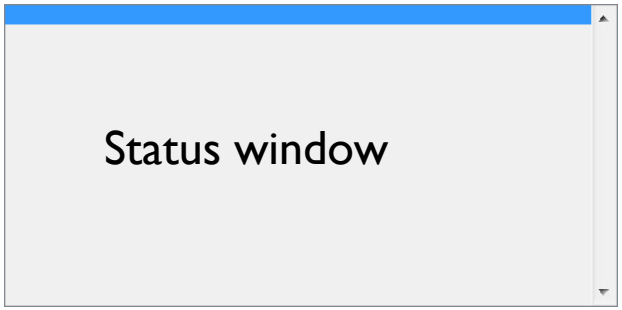
- Using MATLAB ("matrix laboratory" developed by The Mathworks) for data mining
  - Custom functions and scripts for data extraction and data reduction
  - Statistical analysis
- Graphical user interface (GUI) using GUIDE in MATLAB

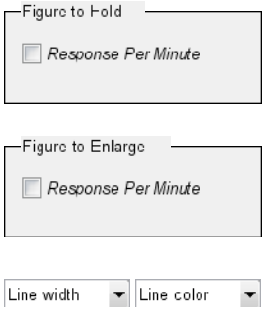
Techniques and tools



Parameter Selection Toolbox





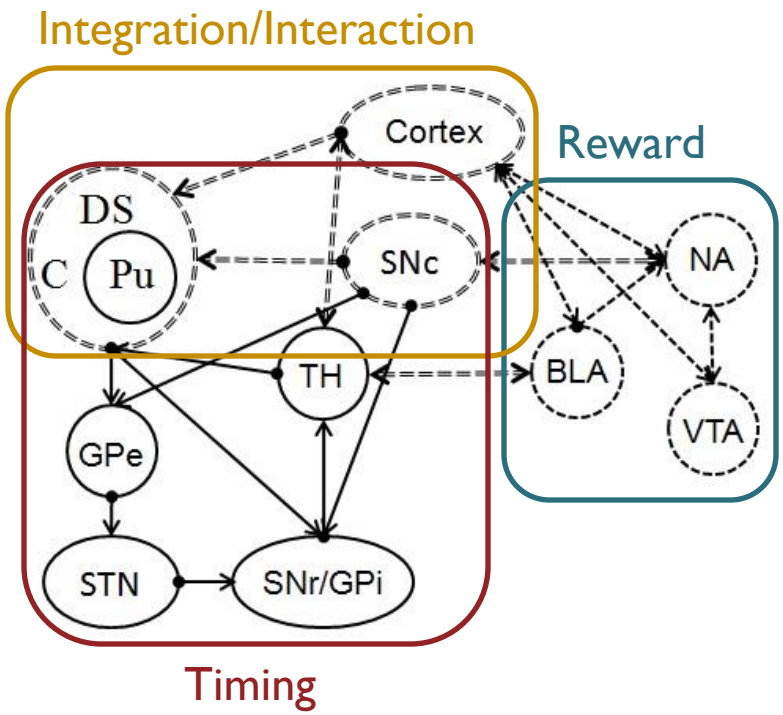


Approaches to modeling

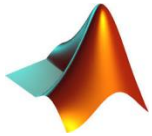
- Traditional approach:
  - Independent variable → Behavior relationships
  - Use metaphors for modeling intervening processes
  - E.g., scalar timing theory uses the metaphor of a stop watch to explain timing behavior
- Neural plausibility

Neurocomputational modeling

- Develop computational models that are guided and constrained by the properties of the relevant neural circuitry
  - Neural circuitry
  - Firing dynamics
  - Neurotransmitter dynamics
- Map onto quantitative aspects of behavior



Techniques and tools



- Develop model simulations in MatLab for specific tasks and behaviors
- Obtain output and compare with behavior
- Vary parameters of the model to improve prediction of data from individuals
- Can create GUIs for model simulations in GUIDE

Summary and Conclusions

- Develop stronger training programs for students
- Sharing data
- Sharing tools for analysis and modeling