Data mining and neurocomputational modeling in the neurosciences

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- 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

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

841.005 1564.005 1650.005 2900.005 3684.005 3856.005 15409.005 19075.005 20331.005 2901.005 3666.005 3856.005 15409.005 19075.005 20331.005 21975.005 47126.006 47277.006 47391.006 47495.006 47598.006 55211.006 55268.006 59760.005 59951.010 60739.005 62070.005 62326.005 62377.005 62411.005 63589.005 64490.005 64883.005 65877.005 66511.005 66743.005 69950.020 69950.013 70056.023 70477.005 106429.005 108570.006 108705.006 109337.010 112883.005 113133.005 119337.020 119337.013 119387.023 120100.005

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

Figure window

Parameter Selection Toolbox

Status window
Approaches to modeling

- Traditional approach:
  - Independent variable $\rightarrow$ 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