Statistical Models of the Brain: Topics and Readings
(some tentative)

NOTE: WHEN MORE THAN ONE READING IS REQUIRED, STUDENTS MAY CHOOSE TO COMMENT ON ONE OR ON ALL

Introduction

- Overview of course: Statistical models of neural coding and human behavior

- **Statistical Background 1:** probability; statistical models; and confidence intervals.

  *Required reading, with comment, for non-computational students:* KEB Sections 3.2.1-3.2.3, 7.3.1, 7.3.5, 7.3.8–7.3.10.

Stimulus-Response Instruments

- Power laws for stimulus intensity, learning time, and memory retention


• **Statistical Background 2:** sequences of random variables (and the Central Limit Theorem); log transformations; binomial, Poisson, and normal distributions; bivariate normal distribution and least squares regression.

  *Required, WITHOUT COMMENT, for non-computational students (recommended for all): KEB 2.21, 4.1, 4.2.1-4.2.2 and Example 4.3, 5.1-5.3, 5.4.1-5.4.3, 6.1.1, 6.2.1, 6.3.1.*

• **Statistical Background 3:** Maximum likelihood estimation.

  *Required, with comment, for non-computational students (recommended for all): KEB 7.1-7.2, 8.1-8.2, 8.3.1-8.3.3, 8.4.3 (Example 5.5 and Figure 8.9).*

• **Statistical Background 4:** Statistical tests.

  *Required, with comment, for non-computational students (recommended for all): KEB Selections from Chapter 10, starting with pp. 247-249 (up to Section 10.1.1), then Sections 10.2, 10.3.1, 10.3.4, 10.3.5, 10.4, especially Figure 10.3; also Section 11.2.1 through p. 298.*

• **Statistical Background 5:** Regression and generalized regression.

  *Required, with comment, for non-computational students (recommended for all): KEB 12.5 through 12.5.5 (in 12.5.2 only first paragraph and Example 12.4; in 12.5.3 only through p. 340), 12.5.8, 14.1 (can skip 14.1.2, 14.1.5), Example 14.5, pp. 410-411, 15.2 through 15.2.3, especially Figures 15.2 and 15.4.*

• **ROC curves in human discrimination tasks**

  *Required: KEB Section 10.4.4.*


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**Neurons as Leaky Integrators, Variable-Conductance Circuits, and Noisy Input-Output Devices**

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• **Integrate-and-fire neurons and the Hodgkin-Huxley model**

  *Required:* KEB, Section 5.4.6.

  *Required for computational students:* Gerstner on-line book  
  (icwww.epfl.ch/~gerstner/SPNM/node12.html) sections 2.1-2.2.

  *Recommended:*  
  Nicholls, Martin, Wallace, Fuchs, *From Neuron to Brain*, Chs 5-6.  
  Bean, B.P. (2007) The action potential in mammalian central neurons,  

  *Recommended for computational students:* Gerstner on-line book (node26).

• **Spike trains as point processes; firing rate and neural coding**

  *Required, with comment:* KEB Ch 19. Computational students should read all of KEB Ch 19. Non-computational students should focus on the Introduction, 19.1, Figures 19.2 and 19.3, Example 1.1 pp. 576-577, 19.3.1 though the middle of p. 580, and 19.3.4.

  *Required up to Section 2, p. 3877, and concluding remarks; rest recommended.*


• **Neural variability (Brent Doiron)**


**Spike count correlation**


**Communication Channels**

**Information theory in human discrimination**

Required, with comment: KEB, Section 4.3.2.


**Information theory in neural coding**


Optimal Observers

- **Optimal observers in perception and action**

  *Required (Background)* KEB, Sections 4.3.4; 7.3.9; 8.1.3; 16, through 16.1.4.


- **Rate coding versus temporal coding in the retina**


- **Bayesian neural computation and its implementation**


- **Hierarchical Bayesian computation (Tai-Sing Lee)**

• Decision-making in cognition (ACT-R; Christian Lebiere)


• Neural basis of decision making

Required: KEB, pp. 102-103.


Network Models

• Graph theory


• Dimensionality reduction (Byron Yu)

Required: KEB, Sec 17.3.1.


• Reinforcement Learning (Michael Halquist)


Oscillations in Neural Networks

- **Background**: Time series methods—autoregressive models and spectral analysis
  
  *Required, with comment*: KEB, 18, through section 18.3.

- **Oscillations and functional connectivity**
  
  *Required*: remainder of KEB, 18.
  
  *Required, with comment*:


  *Recommended*:


- **Oscillations and synchrony**
  


The Decoding Paradigm

• Population coding


• Whole-Brain Decoding (Ying Yang)


• Dynamical Systems and Movement Control (Will Bishop)