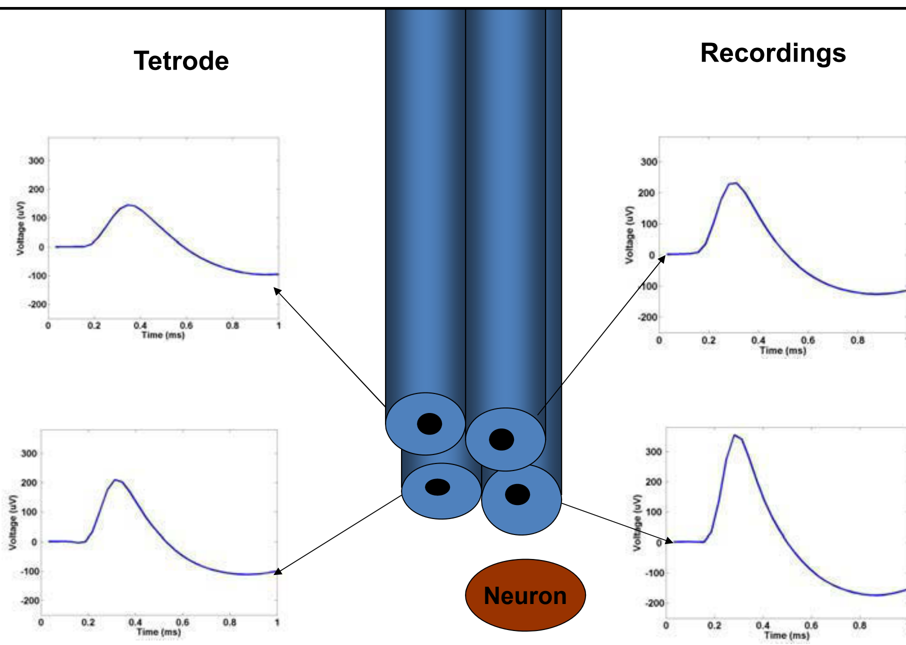
9.07 INTRODUCTION TO STATISTICS FOR BRAIN AND COGNITIVE SCIENCES

Emery N. Brown

Lecture 3: Examples of Probability Models Applied to Data

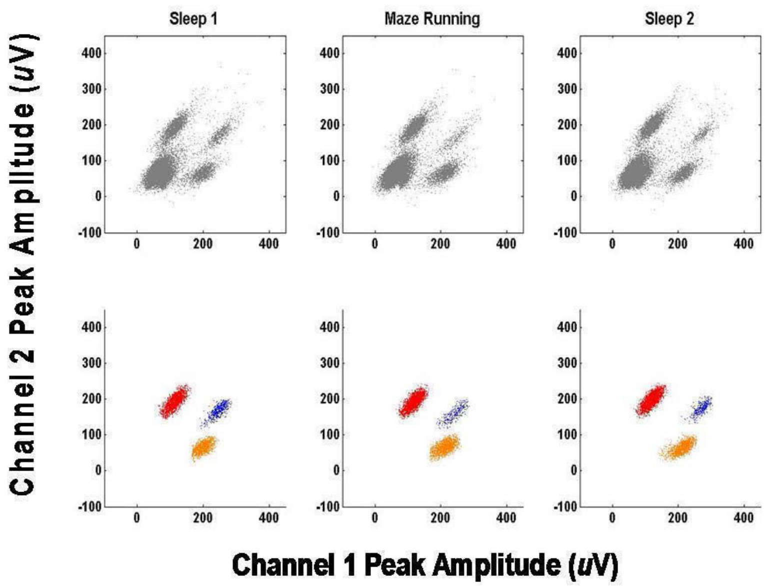
1. Gaussian Probability Model : Tetrode Recordings
2. Exponential Probability Model
   a. Channel Opening Times at the from NMJ
   b. Miniature Excitatory Post-Synaptic Currents
3. Gamma and Inverse Gaussian Probability Model: Interspike Interval Distributions
4. Beta Probability Model: Waking Up from General Anesthesia.

Tetrode Recordings



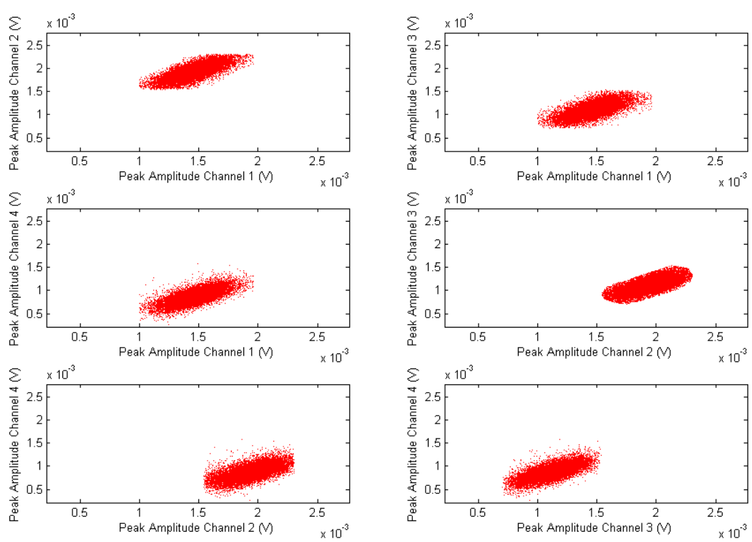
Data Courtesy of Sujith Vijayan

Bivariate Plots of Tetrode Recordings from Multiple Neurons

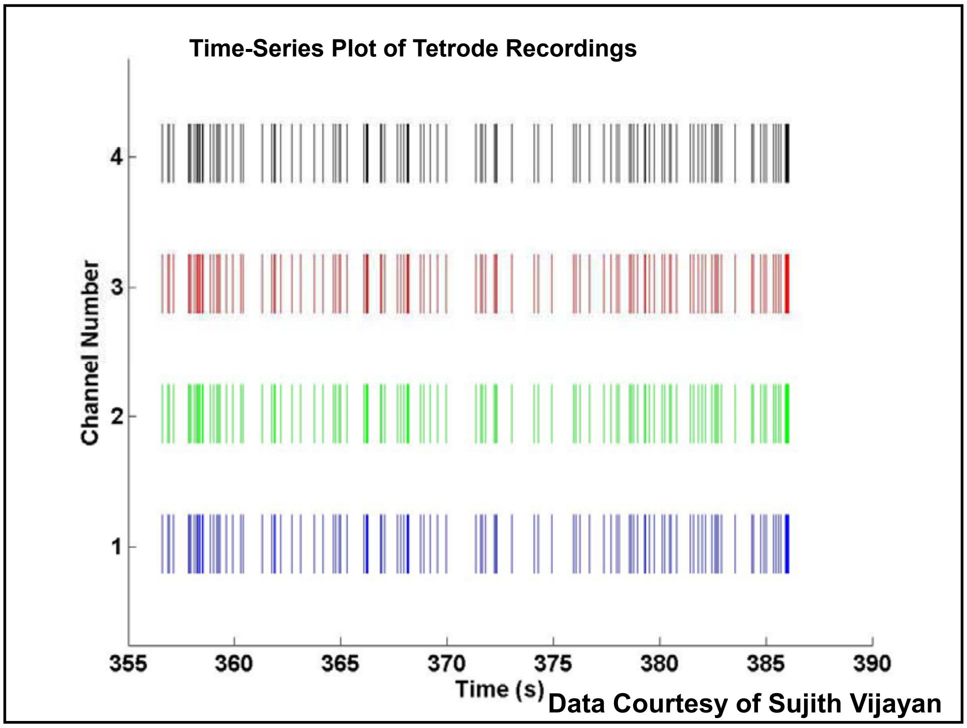


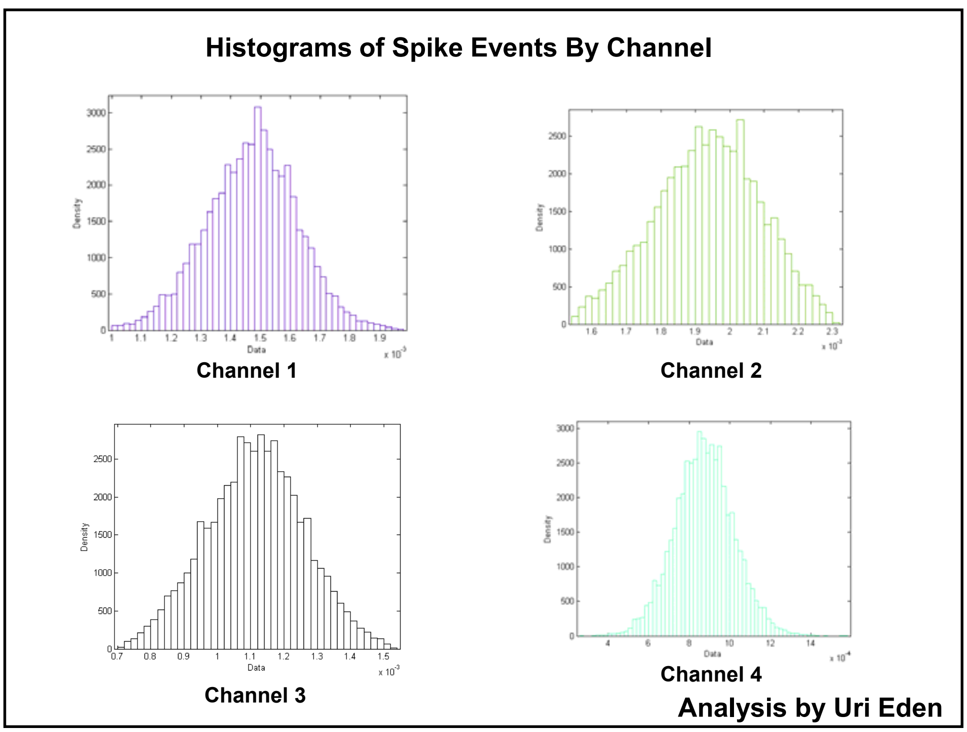
Data Courtesy of Sujith Vijayan

Six Bivariate Plots of Tetrode Channel Recordings



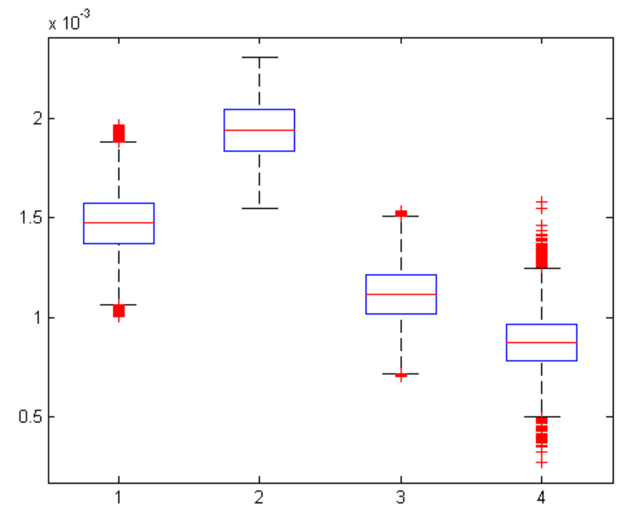
Data Courtesy of Sujith Vijayan


Time-Series Plot of Tetrode Recordings
Channel Number
4
3
2
1
355
360
365
370
375
380
385
390
Time (s)
Data Courtesy of Sujith Vijayan


Histograms of Spike Events By Channel
Channel 1
Channel 2
Channel 3
Channel 4
Analysis by Uri Eden

Box Plots of Spike Events By Channel

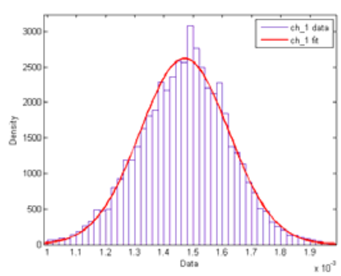
Voltage (V)



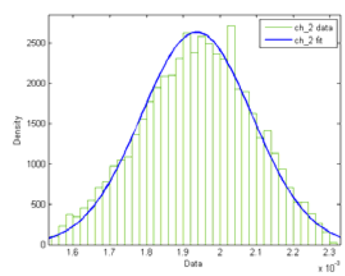
Channel 1 Channel 2 Channel 3 Channel 4

Analysis by Uri Eden

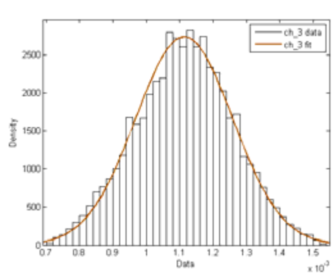
Histograms of Spike Events By Channel



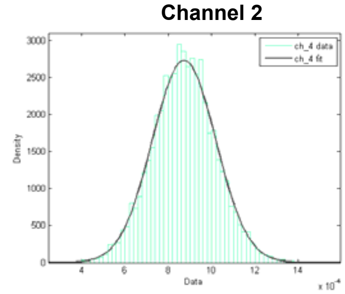
Channel 1



Channel 2



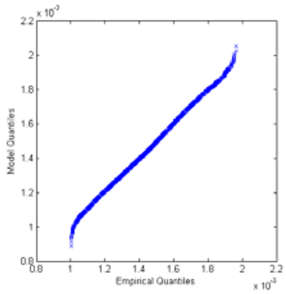
Channel 3



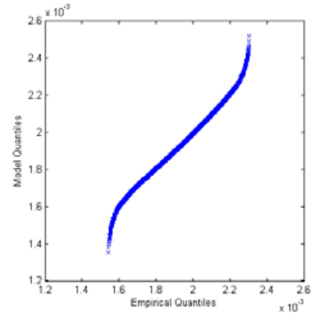
Channel 4

Analysis by Uri Eden

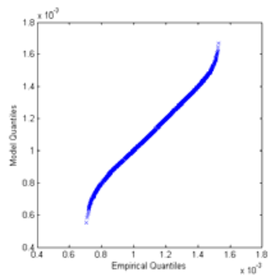
Q-Q Plots



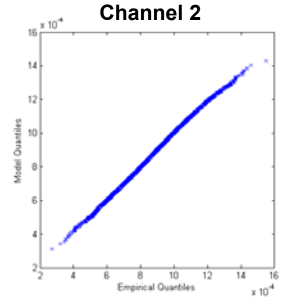
Channel 1



Channel 2



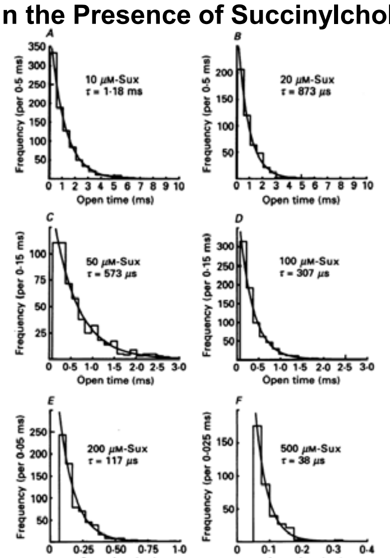
Channel 3



Channel 4

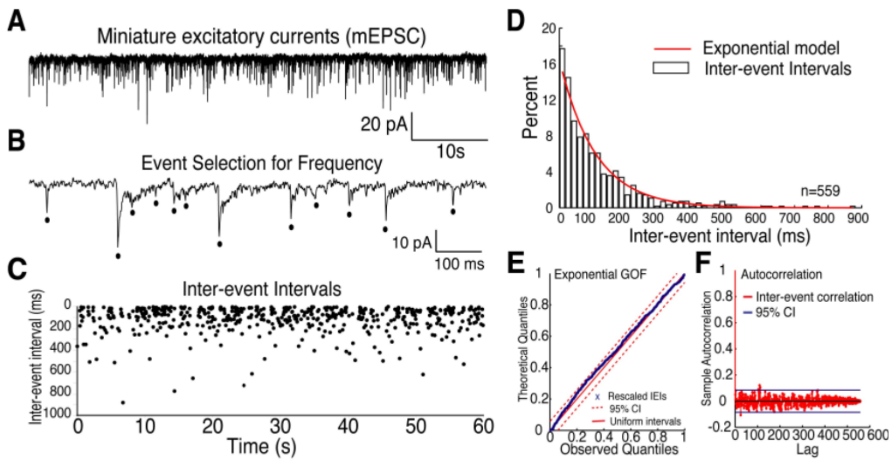
Analysis by Uri Eden

Channel Openings at the Frog Neuromuscular Junction in the Presence of Succinylcholine



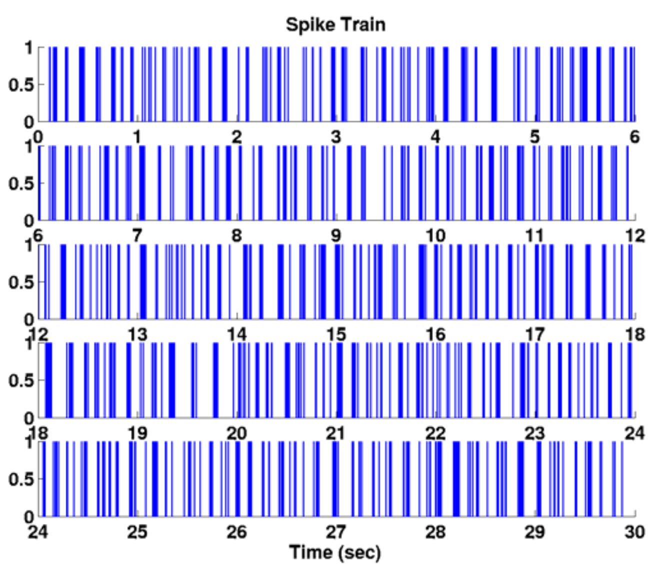
Marshall et al. Journal of Physiology, 1990

Minature Excitatory Post Synaptic Currents



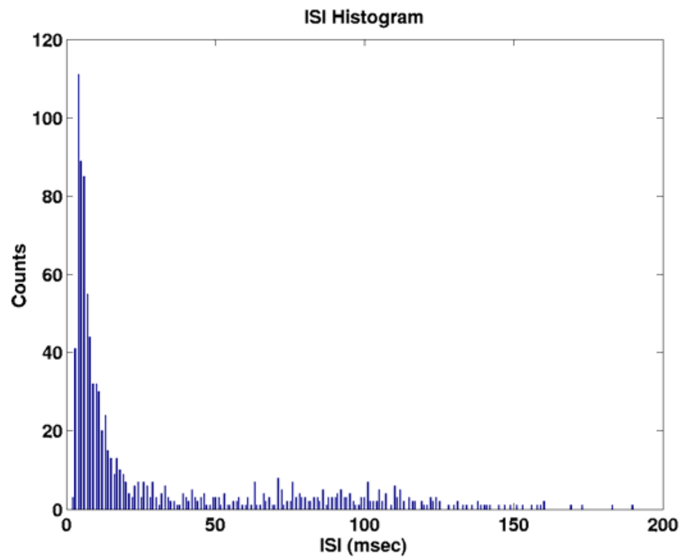
Data Courtesy of Marnie Phillips and Martha Constantine-Paton; Analysis by Laura Lewis

Retinal Ganglion Cell Recorded In Constant Light Conditions

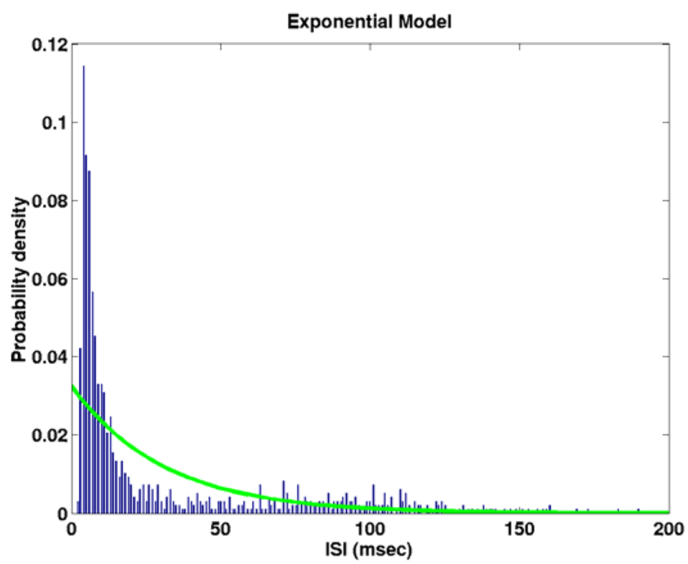


Data: Courtesy of Satish Iyengar

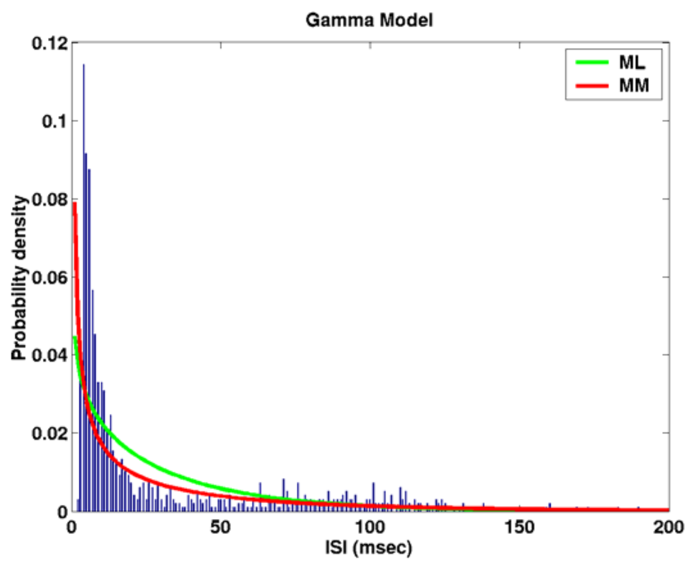
Retinal Ganglion Cell Recorded In Constant Light Conditions



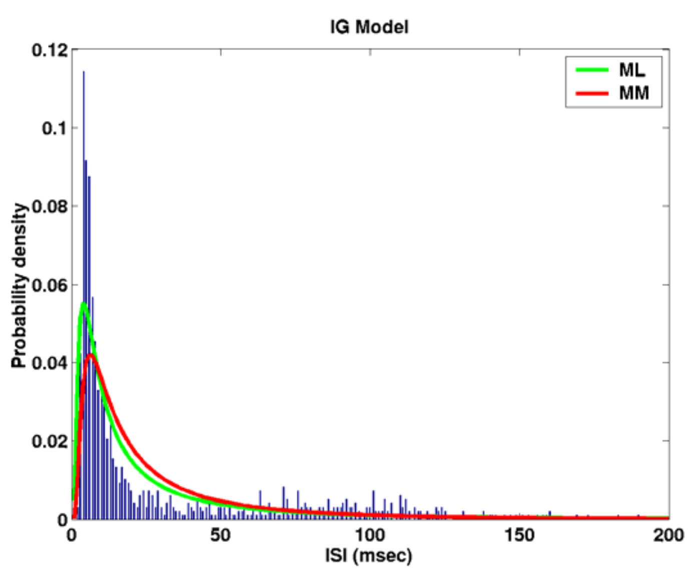
Analysis by Uri Eden



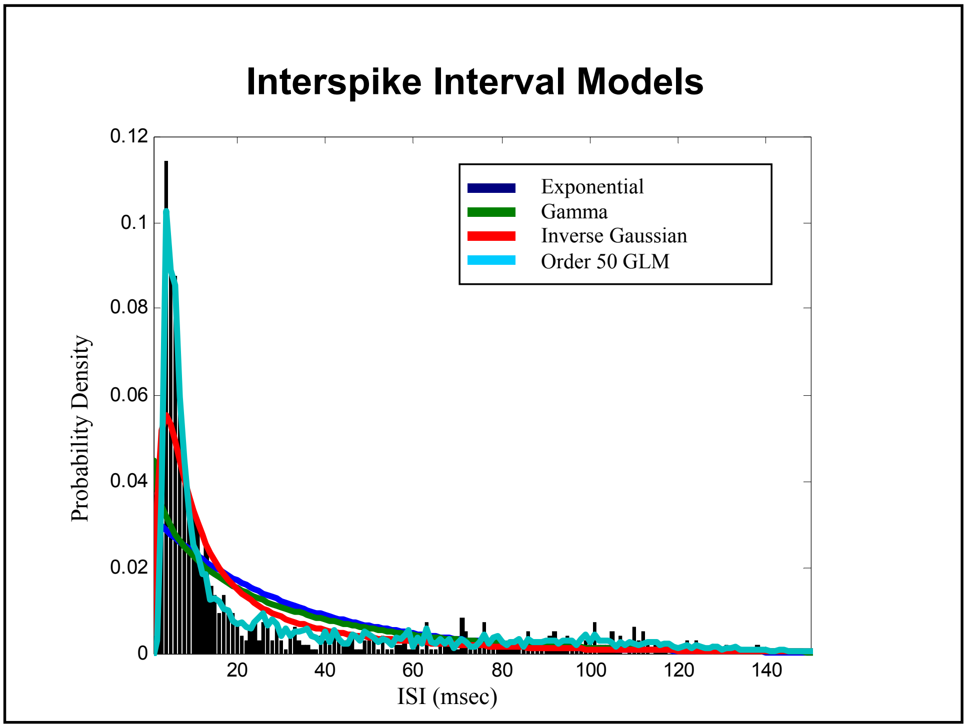
Analysis by Uri Eden

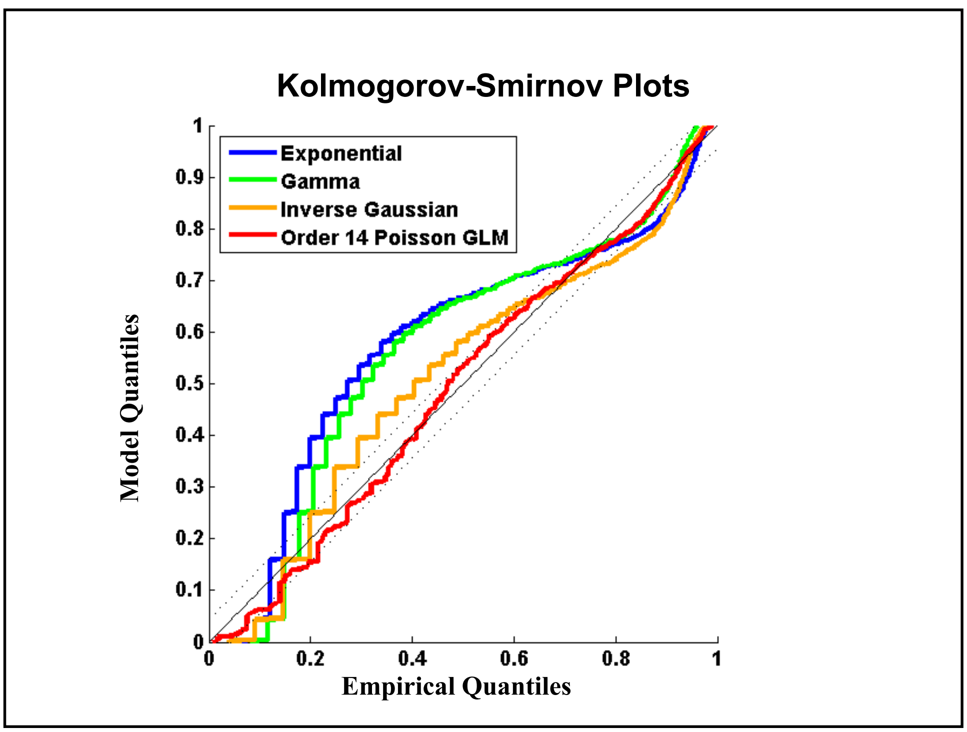


Analysis by Uri Eden



Analysis by Uri Eden


Interspike Interval Models
Exponential
Gamma
Inverse Gaussian
Order 50 GLM
Probability Density
ISI (msec)
0
0.02
0.04
0.06
0.08
0.1
0.12
20
40
60
80
100
120
140


Kolmogorov-Smirnov Plots
Exponential
Gamma
Inverse Gaussian
Order 14 Poisson GLM
Model Quantiles
Empirical Quantiles
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

Reanimation from General Anesthesia by Administering Ritalin

Animals are anesthetized with propofol.

Group 1: Saline Group
0 of 6 animals have return of righting

Group 2: Ritalin Group
11 of 12 animals have return of righting

Are animals more likely to have return of the righting reflex after Ritalin than after saline?

Probability Model: Binomial

Is p in one group different from p in the other group?

Group 1: Binomial (n = 6, k = 0)

p = 0/6 = 0

Group 2: Binomial (n = 12, k = 11)

p = 11/12 = 0.92

Chemali et al. Anesthesiology 2012

Bayes' Theory
What is the best estimate of p given the observed data?

$$f(p\,|\,k) = \frac{f(p)f(k\,|\,p)}{f(k)}$$

Probability Model for the Data

$$f(k_i|p_i) = \binom{n}{k_i} p_i^{k_i}(1 - p_i)^{n-k}$$

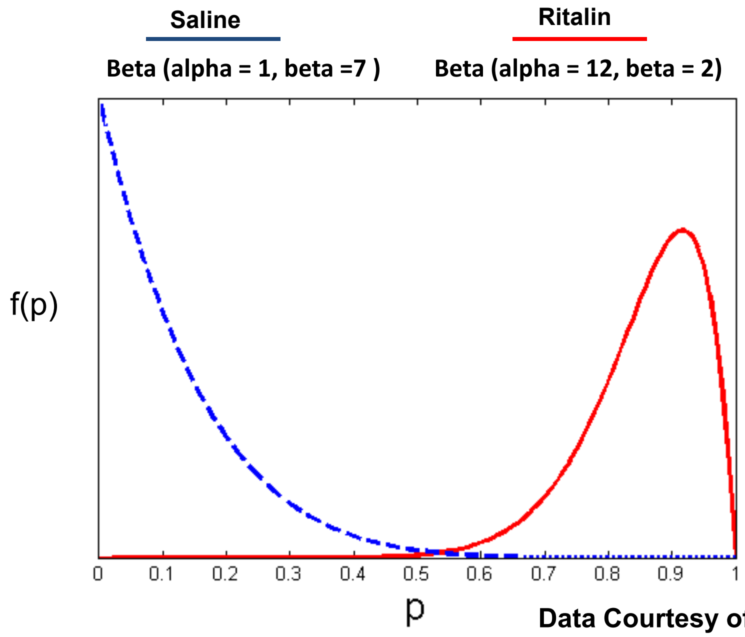
Prior Probability Model

$$f(p_i) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} p_i^{\alpha-1}(1 - p_i)^{\beta-1},$$

Posterior Probability Model

$$f(p_i|k_i) = \frac{\Gamma(n + \alpha + \beta)}{\Gamma(k_i + \alpha)\Gamma(n - k_i + \beta)} \times p_i^{k_i+\alpha-1}(1 - p_i)^{n-k_i+\beta-1}.$$

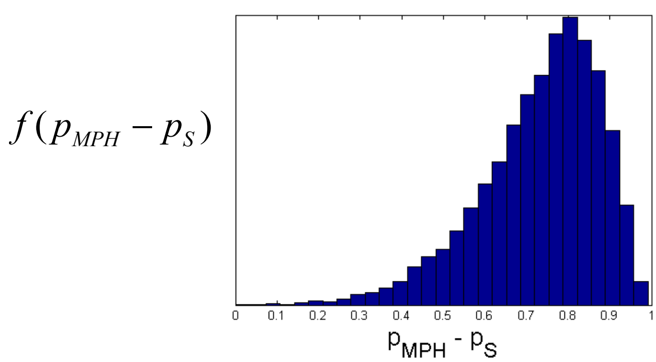
Two Beta Posterior Densities



Chemali et al Anesthesiology 2012

Data Courtesy of Ken Solt
Analysis by Jessica Chemali

Probability Density of the Difference in the Probabilities



$$\Pr(p_{MPH} > p_S) = \Pr(p_{MPH} - p_S > 0) > 0.95$$