Listen! Do you smell something? Signal Detection Theory in Biology
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1. Abstract
This is for faculty, not students.

a. Biological Question

How does a photoreceptor detect the presence of a photon?
How does a doctor detect the presence of a tumor?
How does a cell detect the presence of a chemical, such as a morphogen, a chemoattractant, or a nutrient.

b. Statistical Content

Basic signal detection: True positive, True Negative, False Positive, False Negative
Senstivity vs specificity and tradeoffs
D'?
Receiver Operating Characteristic curves
Signal+noise

c. What students do

In the current Bio 230 class (approx. 290 students), there are likely to be three groups; a) those who don't do either assignment, who are likely to be the weakest students b) those who only do the online background and look at the slides, who will be a mix of strong and weak students c) those who do both the online and in-class activities. B and C together should form a natural comparison group for statistics, but are not likely comparable to A.

Attempt to detect something, such as a sound or AM modulation in quiet and in noise
Draw signal distributions in those cases
Construct table of 4 outcomes
Calculate sensitivity, specificity, and d'
Make and evaluate decision under different cost scenarios

d. Skills (those developed and practiced in the exercise, including things like writing, computer skills, etc.)

e. Student-active approaches (used in the exercise)

f. Assessable outcomes

2. Background
This section is written for faculty who can modify the background material as appropriate for their students.

3. Student Instructions
These are detailed step-by-step instructions for the students to do the exercise.
a. Follow the tutorial on signal detection theory found at http://wise.cgu.edu/sdtmod/index.asp up through the summary
b. Complete the simple follow up questions through Blackboard or Qualtrics (1 pt. EC)

c. Complete the FM detection using Matlab and send data to Blackboard to be compiled.

4. Faculty Notes

a. Objectives and audience

The audience is intended to be sophomore biology students or biomedical and chemical engineering students at sophomore level or above. AP statistics or familiarity with normal distributions would be helpful but is not necessary.

Understand signal detection theory in terms of a signal distribution (or just a signal) added to a noise distribution. Probably best represented graphically.

Understand and be able to interpret 4 outcomes from a binary decision matrix. Draw a decision matrix.

Review and be able to compute a z-score z=x-mean(X)/SD(X) and understand it graphically. *(Do they need to do this here, for the graphical part?)*

Be able to compute and understand the d’ measurement from hits and false positives, using a standard normal distribution (cumulative probability) table. Z(FA)=50%-%FA. CumProb(FA)=1-(.5-FA). Z(H)=50%-%H. CumProb(H)=1-(.5-H). D’=Z(FA)-Z(H) or vice versa, depending on which tail is used for calculation of Z.

Understand difference between sensitivity (Hits/(Hits + False Neg.), aka True Positives) and specificity (True Neg./(True Neg. + False Pos)).

False positive = type I error, false negative = type II error

Define and compute criterion

Use signal detection theory to make decisions (set a criterion) under two sets of cost conditions, high penalty for false positive or high penalty for false negative

Describe a biological situation in which an organism or experimenter would use signal detection theory and a decision matrix.

b. Suggestions for using the exercise

This includes logistical suggestions, such as “assign part 1 as homework before class” or “use the questions in part 2 for small group discussion”. Also includes suggestions to shorten or expand the exercise as well as any potential misunderstandings or difficulties the students may have for the instructor to anticipate when teaching the exercise.

c. Assessment and evaluation

d. Additional resources

Background material and applets can be found at

Signal detection theory. Claremont Graduate University, Web Interface for Statistics Education (WISE), from http://wise.cgu.edu/sdtmod/index.asp (accessed January 10, 2012).

$d' = Z_{FA} - Z_{Hit}$

Tables for the z-score distribution or percent area under the normal curve typically present the z-score distances between the mean and the Criterion value (β). If you are using such a table, Z_{FA} can be found by looking up the z-score associated with (50 - False Alarm %). If this number is positive, then the z-score to be put into the above formula will also be positive, if it is negative, the z-score value for the formula will also be negative. It is essential that the proper signs be used. A good way of checking would be to draw the distributions and the criterion and see the relationship between d' and the two z-scores. Similarly, to find Z_{Hit}, look up (50 - Hit %), again, the resulting sign will be the same as is used for the z-score in the formula.

E.g.,

	Proportion of Responses	
Signal	***Yes***	***No***
Present	.60	.40
Absent	.20	.80

$$d' = Z_{FA} - Z_{Hit}$$
$$d' = Z_{(50-20)} - Z_{(50-60)}$$

looking up the z-score associated with 50-20= 30% of the area under the normal curve, it is .842; for 50-60= -10% it is .253. Since 50 - 60 is a negative, -.253 is put into the formula to get:

d' **=.842-(-.253) = .842+.253= 1.095**

from: http://brain.mcmaster.ca/SDT/dprime.html