Electrophysiology Lab: Studying Single Neurons

1. Neuronal Recordings

In this section of the homework, you will analyze some spiking data from two neurons. The first step will be to generate histograms of the responses of these neurons to the stimuli they were presented with.

Download the 2 datafiles, N1.mat and N2.mat from the homework webpage. Let's assume that the data is recorded from 2 neurons, N1 and N2, during the course of an experiment in which a monkey is shown 10 different stimuli (S1-S10), 6 times each. Load each file into your Matlab workspace (type *load N1*). Notice that each dataset contains 2 variables: *SpikeTime* and *stim*.

The variable *stim* is a structure with 2 fields: the stimulus name and the times at which this stimulus was presented (in msec). (Type *stim(1).name* and *stim(1).trial_times* to see the name and times for the first stimulus.)

The variable *SpikeTime* contains the times (in msec) each time this neuron fired an action potential.

We will first plot the histograms of the responses of N1 and N2 to our 10 stimuli, S1-S10.

- **a.** For each stimulus, you have been given the onset times – the times at which this stimulus came on. Using these times, create a vector that contains the times at which action potentials were fired in the 1 sec interval preceding and following stimulus onset for each trial. (The Matlab command *find* might be of help here). For each trial, subtract the stimulus onset time from the spike times, so that all your spiking events are timed relative to the onset of the stimulus.

- **b.** Data recorded from neurons is often presented in the form of post-stimulus time histograms (PSTH). Essentially, spikes occurring within a certain time period are binned together, and it is these bins that are then plotted. Binning data allows you to look at this data with different time resolutions. For instance, 10 msec bits, where you bin together all spikes that occurred within 10 msec of each other, give you very fine resolution compared to 200 msec bins. However, data plotted in 200 msec bins might be less noisy because you are now grouping together more spikes in each bin and you average out the noise. Thus, there is always a tradeoff between the resolution you want to achieve, and how noisy your data appears. For our purposes, we will use 100 msec bins. Using the Matlab command *hist*, bin the times you obtained above into 100 msec bins for each stimulus. (Type *help hist* to learn more about this command.)

- **c.** Finally, use the *hist* command again in Matlab to plot a bar graph of the average of these binned responses for each stimulus (one bar for baseline=pre-stimulus and one bar for response=post-stimulus). You should consider using the command *subplot* to plot the responses to all stimuli on one page.

d. Repeat the above for the second neuron. Hand in the histogram plots for both neurons. Remember to label each subplot with the correct stimulus number, and make sure your axes have the correct units.

2. Understanding the Responses

Now we will do some simple statistics to determine whether the response of these neurons is significantly enhanced by any of our stimulus. For this question you will need to have some knowledge of what t-tests are. Look at:

http://www.chem.uoa.gr/applets/AppletTtest/Appl_Ttest2.html

for an explanation on t-tests. You can also do a web search for t-tests, or look in any statistics textbook to find more information. The Matlab command to do a ttest is *ttest2* (type *help ttest2*).

a. For our data, the null hypothesis is: the firing rate before stimulus onset and during the interval when the stimulus is present is the same. Any differences observed are entirely due to random noise. We want to test whether this hypothesis is true.

For each stimulus, perform a ttest comparing the average firing rate before stimulus onset to that after stimulus onset. To do this, for each stimulus, count the number of spikes that occurred in the 1 sec interval preceding and following stimulus onset on every trial. Store these two numbers in 2 vectors – an entry in a vector will contain the number of spikes that occurred on a particular trial. Since we have 6 trials, your vectors will have 6 entries each. Now, calculate the ttest using these 2 vectors. Report the p-values you obtain, on the subplots you generated before.

b. Which stimuli are the preferred stimuli for this cell (for $p < 0.05$ and for $p<0.1$)? What do the "p" values that you calculated mean? Based on these p values, at a confidence level of 90%, for which stimuli can you reject the null hypothesis? For the rest of this homework, we will call these stimuli, the preferred stimuli.

c. How strong is the response compared to baseline firing activity? In other words, how much does the firing rate increase for these preferred stimuli?

d. Comment of the differences and similarities in the background firing rates of these 2 neurons. How do the "noise" levels compare?

3. Coding Schemes [Wizard Questions]

Assume now that for neuron N2, stimuli S7, S8, and S9 are the following: S7 is an image of the experimenter in her lab surrounded by testing equipment the monkey is familiar with, S8 is the experimenter on the beach, with other people in the background and S9 is a picture of the experimenter and her monkey.

a. What about the 3 stimuli, S7, S8, S9, could have caused the response you observe? What would you expect of the outcome of your statistical analysis if we decreased the bin size? What can you hypothesize about what neuron N2 codes for and how could you test this hypothesis?

b. Let's consider the coding schemes we've talked about in class: grandmother neurons, sparse coding and population coding. Based on the data you have analyzed here, for which scheme might you have evidence in your data? What objections can be raised against the brain using this coding scheme? In light of these objections and keeping in mind your results, how might the brain choose to code information?