This document contains supplementary materials to Dr. Nichols’ publication entitled ‘A Series of Computational Neuroscience Labs Increases Comfort with Matlab’ in the Fall 2015 issue of JUNE. Additionally, zipped folders of each of the labs including code and assignments can be downloaded and modified, if desired.

**Software References**

For schools without access to MATLAB, the code can also run on Octave (<http://www.gnu.org/software/octave/>) which is available for free download. However, the functionality of the figure windows did not seem entirely compatible for the requirements of the exercise based on quick initial inspection. Though the code cannot run in Python without substantial changes in syntax, functionality is similar between the programming languages and Python is available for free (the author recommends the Anaconda installation using the Spyder window to run the program as required libraries, such as numpy, come bundled with the installation). These programs have a similar structure with an editor window that contains the code, a command window that allows for inputs and outputs, and a figure window that allow for visualizing the results and some amount of interaction with the data curve. There is a trend towards the increased use of Python in scientific computing (Davison et al,, 2009) though it is currently not as well developed as MATLAB. Links to websites with similar code in Python have been included in the relevant lab section below for convenience.

Code for the Hodgkin-Huxley Model is widely available online and was initially copied from an online source (<http://www.math.mcgill.ca/gantumur/docs/reps/RyanSicilianoHH.pdf>) and then modified to just use the Euler method and to allow for specific output of relevant variables in the figure window, namely input current. Python code for a similar model can be found online but also requires slight modification (<http://www.neurdon.com/2011/01/26/neural-modeling-with-python-part-2/>).

Code for the Integrate-and-Fire Model was found posted as a homework assignment for a course at another institution that was modified to work for the exercise (<http://courses.cs.washington.edu/courses/cse590rr/03au/homework3.html>). A comparable set of code requiring modification can be downloaded from a Python code sharing site: (<http://www.neurdon.com/2011/01/19/neural-modeling-with-python-part-1/>).

Hopfield memory networks are less commonly used in undergraduate neuroscience courses than the Hodgkin-Huxley and Integrate-and-Fire models and therefore there are not as many resources available online to demonstrate how they function. The basis for the current set of code described above was located through an online search and found as part of a student paper posted online (<http://www.academia.edu/414408/Hopfield_Networks_as_Classifiers_of_Handwriting>) and then heavily modified to meet the desired requirements for the lab. Related Python code is also available online but would require substantial modification to focus in on the key concepts described here (<https://pmatigakis.wordpress.com/2014/01/18/character-recognition-using-hopfield-networks/>).

**Pre-reading Quizzes:** Prior to their scheduled lab section, students were required to have read through the protocol and completed an online quiz about the protocol. The protocol and quizzes were posted to the class online learning portal, i.e. Moodle, 3-7 days before the lab section. The quizzes were incorporated to improve the efficiency of the lab time and better prepare students for the lab activities. It was apparent from a previous semester before the quizzes were used that many students were not reading the protocols ahead of time and this was interfering with the completion of the labs in a timely fashion.

Each quiz consisted of 5 multiple choice questions taken directly from the protocol. They were designed to cover the breadth of the protocol such that if these were the only sections of the protocol that the students looked at they would still be decently prepared for the lab. They were not required to actually read the whole protocol in order to be able to complete the quizzes. The quizzes were taken at home and students were encouraged to view the protocol while completing the quiz with relevant page numbers listed by each of the questions. Questions from the Hodgkin-Huxley lab will be used to illustrate the purpose of various types of questions. Example question 1 covers background concepts that were discussed in the introduction of the protocol which included references to pages within the textbook:

1. Which of the following influence the current

membrane potential? (p 1)

A. The input current

B. The difference between the membrane potential and

the equilibrium potential of a particular ion

C. The permeability of the membrane to a particular ion

D. All of these influence the current membrane potential

Example question 2 focuses attention on the symbols used within the equations that would be modified in the lab:

1. Which symbol represents the permeability of a

particular ion? (p 1)

A. V

B. I

C. g

D. c

Example question 3 covers practical material necessary in order to complete the lab:

1. Where are the files located that you will use in the

lab? (p 2)

A. On Moodle

B. On the desktop

C. On your c-drive

D. On a USB drive

Example question 4 gives an overview of the purpose of the different lab components:

1. Which of the following is not an activity that will be

done? (p 2-3)

A. Comparing the action potentials in vertebrate vs.

invertebrates.

B. Determining the time between action potentials for

different input levels.

C. Finding the threshold for the first and the second

action potential.

D. Modifying the permeability of the membrane to

particular ions.

Example question 5 covers practical material directly related to collecting data within the lab:

1. What do you use to find the time and amplitude of

individual spikes? (p 2)

A. The command window

B. The data cursor

C. Ion channels

D. A green arrow

**Data Note Sheets:** Students were provided with 1 page data note sheets that they were required to print from the course online page and bring with them to class. Having a data note sheet with them at the start of the lab was required for full participation credit. On the rare occasion that individual students did not print off a data note sheet in advance (n=2), they were able to fairly quickly create one on notebook paper and still record data for that day’s lab. Data note sheets were turned in when the lab questions were turned in, which was either the end of the lab or the following week.

Each lab had a custom designed note sheet with tables focused on the particular exercise to guide data collection and streamline the labs. With the computer simulation labs, the data values that students would be entering was generally known ahead of time and therefore the data entry could be considered correct or incorrect. Having a prepared data note sheet aided in efficient grading of the work the students did during the lab.

**Lab Questions:** For each of the labs students were required to answer a set of questions after the labs were completed. For the computer simulation labs, the questions were completed as a group since there was time in the allotted 1.5 hour lab session for the data to be collected as a group and then the questions answered as a group. The questions tended to be multiple choice though short answer and calculation questions were also included. Multiple choice questions were preferred as it is the opinion of the author that they sufficiently covered the relevant material while also being efficient to grade. Questions in a prior semester tended to be short answer and were found to take significantly longer to grade with much confusion from the students on what the question was getting at and with minimal impact on the overall course grade.

The number of questions varied between labs depending on the amount of concepts covered in the lab and the amount of time allotted to the completion of the questions. They were designed to complete tasks begun in the lab, extend knowledge beyond what was specifically done in the lab to future experimentation, and relate to concepts covered in the lecture course and textbook. Select questions from the different labs will be used to illustrate the purpose of various types of questions. The first question is from the Hodgkin-Huxley lab and illustrates completion of the data collected in a portion of that week’s lab as well as preparing students for a calculation that they will need to complete in a future lab:

Fill in the tables below to calculate the firing rate of the simulated neuron as a function of the input level. Use the formula: Firing Rate=1000/(Peak 2-Peak 1 time difference)

Effect of changing input current:

|  |  |
| --- | --- |
| Input level | Firing rate (Hz) |
| I=0.1 |  |
| I=0.2 |  |
| I=0.3 |  |

The next question also comes from the Hodgkin-Huxley lab and is an application of material covered in the textbook:

In relation to your calculations above from activity 1 and

what you learn about action potentials from page 79 of

your textbook, would you expect the firing rate to

continue to increase as the input level continued to

increase?

a. No, it would level off at I=0.3 because of saturation.

b. Yes, it would increase indefinitely.

c. Yes, it would increase to 500 Hz and stop due to the

relative refractory period.

d. Yes, it would increase to 1000 Hz and stop due to

the absolute refractory period.

An example of a question from the Hopfield Network lab requiring students to demonstrate an understanding of what was found in the lab and draw conclusions without the material being covered directly in the lecture or textbook that could be the impetus for future experimentation:

As part of activity 2 you first determined the similarity of

memories D/M and then J/C and then you measured

the network performance with the two pairs. First state

how the network performance related to similarity, i.e.

was it better for the more or less similar pair, and then

discuss why that might be the case.

**Grading:** The laboratory component was worth 25% of the final grade for the course with the lecture component worth 75%, consistent with other science lab courses. The 10 weekly labs were worth 80% of the laboratory component with the remaining 20% made up of assignments pertaining to creation of research proposals. Therefore each weekly lab was worth 2% of the overall course grade.

The breakdown of the grade for each weekly lab was 50% for the lab questions (whether completed individually or in a small group), 25% for class participation (including bringing their own printed data note sheet), 15% for the pre-reading quiz (completed outside of class time), and 10% for saving relevant files (this was done through USB drives that were turned in at 2 points in the semester). The instructor provided feedback and guidance throughout the lab section, including on the lab questions. Grades were correspondingly high though the inclusion of the pre-reading quiz and individual participation grade components resulted in individual grade differentiation. The final grades in the laboratory component of the course tended to run higher than the averages for this particular set of labs. The lab questions for the Integrate-and-Fire lab for this semester proved to be particularly difficult and will likely be altered for future semesters.

Refs:

Davison AP, Hines ML, Muller E (2009) Basic principles of synaptic physiology illustrated by a computer model. Adv Physiol Educ 25:1-12.