**CS/NEUR125 Brains, Minds, and Machines**

**Assignment 2: Hippocampus of London Cabbies**

**Due: Friday, March 3**

This Assignment is a guided reading of the 2000 PNAS article, Navigation-related structural change in the hippocampi of taxi drivers. Reading this article will prepare us to discuss this work during our second Journal Club in class on Tuesday, March 7.

To begin, create a copy of this Google document and modify the title of the copy to include your name. Questions that you should submit answers to are shown in blue. As with labs, you'll turn in this Assignment by sharing your copy of this Google document with Ellen and Mike.

This PNAS article by Maguire et al. is a primary research paper. As we said in the first Assignment, reading primary research literature is challenging and takes some practice, so don't be discouraged if you're not understanding every line. Authors are likely to assume knowledge in the reader, or leave out details that are familiar to experts. We'll try to fill in some of the assumed knowledge with this document, but we'll also have to accept that we won't digest and understand every line in this technical paper. Our goal for this Assignment is not to understand every line, but to explore the general idea that neural tissue can be modified by experience, and to learn about how such changes can be measured in human populations that may place exceptional demands on a particular processing capability.

Over the course of the semester, we will use these non-lab assignments to develop your ability to express scientific ideas clearly and precisely. However, for this assignment our emphasis is again on helping you understand the paper rather than testing your ability to interpret it on your own. Part of what we're practicing, is choosing where to put our reading effort in order to get what we want to get out of the paper. For now what we want is a basic understanding of their experimental results, and we want to learn enough about their methods to understand what they're trying to show in each figure. Many of the questions below are trying to get you to look up information in specific paragraphs or sentences of the paper. If you use phrases from the paper in answering the questions, you must put them in quotation marks, and you should try to reformulate the idea in your own words. (If the answer is simply a name or a number this is not necessary.)

Because it's easy to get bogged down in technical details in a paper, you first want to understand what is the question or hypothesis the authors are trying to address with their study. That way you can try to relate everything else you read to answering that question--and if it doesn't help address the main question, you might be able to safely ignore it.

**Q1.** What is the main question addressed by this paper, and what was the authors' hypothesis?

**Q2.** Why are London taxi drivers a good population to use for this study? On average, how many years of experience did these participants have as taxi drivers?

This study examines differences in **structural MRI** scans of human brains, which differ from the **functional MRI (fMRI)** scans that we have been talking about in this course. Structural MRI captures the anatomical structure of the brain at a high spatial resolution, distinguishing different tissue types. Functional MRI registers metabolic function in the brain, providing an indirect measure of neural activity. fMRI scans are obtained at a much lower spatial resolution relative to structural MRI. Among other things, structural MRI distinguishes **grey matter** and **white matter** in the brain. The grey matter contains mostly the cell bodies, dendrites and axon terminals of neurons, so it is where all the synapses are found. White matter is mostly made of axons connecting different parts of grey matter to each other. The white matter looks white because of the fatty myelin substance that wraps around many axons. The volume of grey matter tissue is a measure of the volume of a region of the brain.

**Q3.** What were the two methods used to analyze the MRI data in this study, and what does each method identify?

**Q4.** What was the control group used in this study, and why might it be important to include a control group?

This study uses statistical techniques for analyzing the data that include **ANOVA** (analysis of variance) and **correlations**. ANOVA provides a way to determine whether the means, or averages, of multiple groups of data are significantly different from one another. We have informally used the term “correlation” to capture the intuitive notion that two groups of data are related to one another, for example, as one measure increases, so does the other. Later in the course, we will introduce these methods in more detail. For our discussion of this paper, it is not essential for you to understand the details of the statistical analyses described. The authors also mention the method, “general linear model,” which you will learn about in a later lab in which you analyze real fMRI data to find a language area in the brain.

**Q5.** Consider the **VBM** findings described in the first paragraph of the **Results** section. In what specific areas of the brain were differences observed between the taxi drivers and control group? What were the particular differences in brain volume that were observed?

**Q6.** In **Figure 1b**, what do the yellow-highlighted regions represent? In **Figure 1c**, what do the red-highlighted regions represent?

**Q7.** What did the **pixel counting technique** reveal about hippocampal volumes for the two groups? Were the results consistent for the two analysis methods (VBM and pixel counting)?

**Q8.** In **Figure 2**, what is shown on the x axis (i.e. what do anterior, body, and posterior refer to?) For the right and left hippocampus, is the hippocampal area of the anterior region larger or smaller than the area of the posterior region? What are the bold asterisk symbols highlighting? How do the relative heights of the bars showing taxi driver and control group data relate to the basic conclusions that you described in **Q7**?

**Q9.** What did the authors observe about the change in volume of the hippocampus with amount of time spent as a taxi driver? What is the difference between what is shown in Figure 3b vs. 3c, i.e. what quantity, and in what region of the hippocampus, is plotted on the y axis? What do the black diagonal lines through the scatter plots suggest?

**Q10.** How did the authors distinguish between the following two hypotheses: (1) an individual's particular arrangement of hippocampal gray matter predisposes them toward professions that have substantial dependence on navigation skills vs. (2) the hippocampus changes (over time) in individuals whose profession places great demands on navigational skills.

**Q11.** What do you think the authors mean by the "mental map" of the city that may be highly developed in taxi drivers? How might an increase in "neural real estate" for this mental map benefit a taxi driver?

**Q12. Please submit two questions you have about terms, figures, concepts or anything in this article that confused you or that you'd like to pursue further during our Journal Club discussion. For example, one question might be related to a technical detail, and another might be broader (e.g. related to assumptions, methods, interpretation, or open questions for future research).**