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HST.583 Functional Magnetic Resonance Imaging: Data Acquisition and Analysis
Fall 2008

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Final Exam
HST.583
December 15, 2008

Instructions:

There are 7 problems. Points for each problem are indicated. Please immediately confirm you have all 8 pages! This is a closed book/ closed notes exam. You have two hours.

Read the whole exam first. Write legibly. Describe what you are thinking. Even if the final answer is wrong, you will be given credit for your reasoning and approach to the problem. Be efficient, assess what you can answer right away; divide your time so that you can cover all the problems, allocating less time to the easiest parts. Don't spend too much time on a single question.

Problem 1:

a) List the major brain regions that comprise the "Default mode network" as originally described by Marcus Raichle and colleagues in 2001 (3 points)

b) describe the hypothesized role of decreased activation in this network during attention demanding tasks from a cognitive neuroscience perspective (3 points)

c) give an example of how, assuming that this hypothesis is true, this information could be used to improve the sensitivity or specificity of an fMRI experimental paradigm (3 points).

Problem 2:

A physics post-doctoral fellow in Dr. Adelsteinsson's lab shows you a generalized pulse sequence for a common imaging technique used boost T1 contrast. The pulse sequence begins with a 180 degree inversion pulse, and is followed by a delay (TI). After the delay imaging commences:

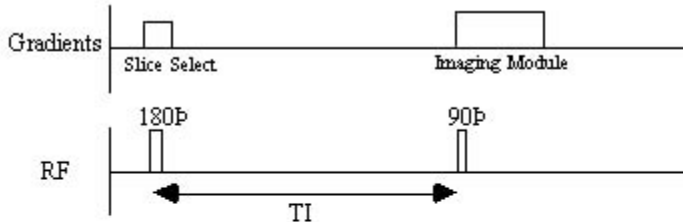


Figure 1.

a) This technique is known as _____, and was used in Dr. Triantafyllou's lab to measure T1 from different tissues. (2 points)

Because the 180 degree pulse flips the net magnetization to the negative state, it effectively doubles the dynamic range of the signal. The Mz magnetization profile for white matter at 3.0 T looks like this:

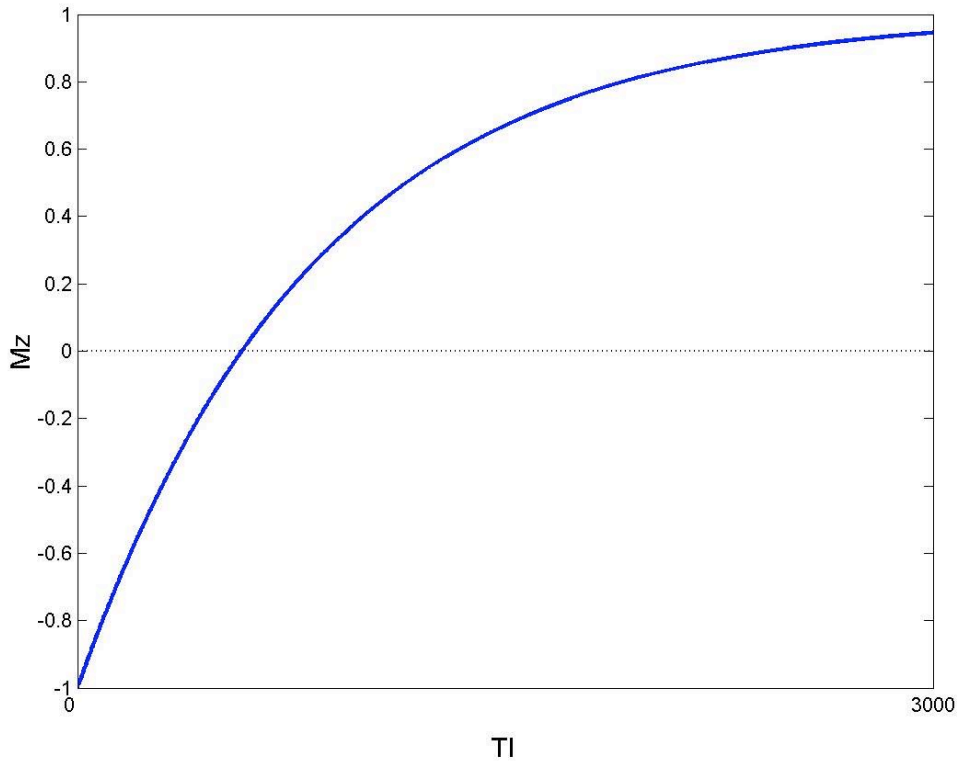


Figure 2.

The physicist points out to you that it is possible to eliminate MR signal from a particular tissue type by properly choosing TI.

b) Qualitatively show on the above Figure 2. the TI that would eliminate white matter signal. Explain your choice. (3 points)

c) Why would it be useful to eliminate white matter signal when performing functional imaging analyses? (1 point)

d) The T1 of white matter is 832 ms. Compute the TI needed to null white matter signal. (Hint: Modify the longitudinal (T1) magnetization equation to accommodate double the dynamic range). *Points for original equation, modified equation, and solution. (3 pts)*

Problem 3:

Given a stimulus schedule where Condition 1 is presented at $t=2$ and $t=14$ sec and Condition 2 is presented once at $t=6$ sec

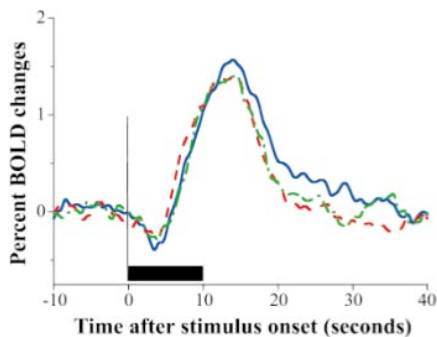
a. Write out the FIR design matrix assuming $TR=2$ s, Number of time points =10, and the FIR is window=8s. Include regressors for offset and linear drift (5 points).

b. Write out a contrast matrix that tests for the difference between condition 1 and condition 2 at 2s post-stimulus (5 points).

What are the trade-offs between using an FIR model and assuming a shape to the HRF? (5 points)

Problem 4:

One controversial claim for BOLD fMRI is that the positive change in signal amplitude is preceded by a smaller decrease in signal. This postulated decrease has been termed the "initial dip" or "early dip":



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a) Suggest a possible physiological mechanism for the initial dip. (5 points)

b) If the initial dip does exist, why could it be useful for functional imaging? (5 points)

c) Why do you think it has been difficult to observe with fMRI? (5 points)

Problem 5:

List three possible ways CBF may be regulated in the brain; give a brief description of each. (5 points)

Problem 6:

a) When registering the fMRI data from one of your subjects to his/her own structural MRI data collected in the same scan session, what are the sources of noise (variance)? For each source of variance listed, indicate what you could do to minimize the variance (5 points).

b) Describe one method for inter-subject registration of the fMRI data from the subjects in one of your experiments so that you can perform a group analysis. What are the sources of noise (variance, error) inherent in this method? (5 points)

Problem 7:

One of your best friends aspires to do an fMRI experiment to test their hypothesis about how the brain shifts attention from doing a single task to doing two simultaneous tasks. The hypothesis is that there is only a “fixed” amount of attentional ability in the brain and that when shifting from one to two tasks the ability will be “divided” and hence less will be available for either one of the two tasks. The trouble is that they know nothing about fMRI. Since you have just completed HST.583, your friend assumes you are an expert on this topic and has come to you for advice. Most importantly, there is a rich donor who has given unrestricted funds to pay for the scans, subject remuneration and generous consulting fees to you, the expert, for providing the following information. So you accept the job (just in time to pay for your Holiday fun!) and get to work.

(Hint: No knowledge of the cognitive neuroscience in this domain beyond what you learned in the course is required; just apply your own best logical effort and common sense to that base. If you happen to know specific, pertinent references please cite and use them in your response. Take your time thinking all the way through this so that you do the best job you can. Five bonus points are awarded for a fully integrated response.)

Design an fMRI experiment to test the hypothesis. Provide:

i. A description of the putative functional neuroanatomic attentional network you will be investigating. (4 points)

ii. A simple statement of the hypothesis you are testing. Include an explicit statement of what and where you will be measuring to determine if H_0 is true or false. If you are able to give an estimate of an appropriate Power analysis please do so, and/or specify the number of subjects that will be required to test the hypothesis. (5 points)

iii. A description of the fMRI paradigm that includes exactly what the subjects will be doing and when and how. (5 points)

iv. A description of the experimental set-up as needed to perform the experiment. (4 points)

v. A list of the image acquisition sequences you will collect including key parameters and a justification for each (why you need it, what you will use it for). (5 points)

vi. A detailed description of your proposed data analysis methods, including any pre-processing steps, for the single subject and group analyses. (9 points)

vii. Your prediction of what you will find when the study is completed. (5 points)

FILL IN BLANK FOR EXTRA CREDIT!

Top ten signs you've been scanning too much...

(Courtesy of Jody Culham,

<http://psychology.uwo.ca/fmri4newbies/ScanningTooMuch.html>)

10. While pouring syrup on your Eggo waffles, you note that you missed a few voxels.
9. Your knowledge of brain anatomy exceeds your knowledge of geography. As in, "The transverse occipital sulcus intersects the intraparietal sulcus near the level of the parieto-occipital fissure" and "The Sahara is in Afghanistan, I think."
8. You have developed a rapid ritual for checking your body for metal that resembles the macarena.
7. When you see drawings of brains in the popular media, you instantly decide whether or not they are anatomically correct.
6. Friends wonder how you can run a four million dollar scanner and still fail to program a VCR.
5. You suffer frequent left/right confusion and find yourself saying things like, "Make a left turn at the lights... No, I meant a *radiological* left!"
4. At parties, you scope out people's subject-worthiness: "It was great talking to you. Say, what are you doing Friday night?... Do you have any metal in your body?..."
3. Not only can you recognize the brains of your frequently-scanned co-workers, but also their teeth from the bite bar impressions.
2. When reminded of a special occasion, you remember it fondly because the scanner was free all day long and you collected lots of good data.
- 1.

THANKS FOR YOUR PARTICIPATION AND HAVE A GREAT HOLIDAY!!

- Randy