Cognitive Science 276 -- Neuroimaging

Homework #1: Tissue Contrast in Spin-Echo and Gradient Echo Sequences

The goal of this homework is to learn enough Matlab (or Mathematica) syntax to allow you plot simple exponential functions and their differences, and then use this skill to understand how varying TR (repetition time) and TE (echo time) can result in contrast between tissues with different T1 (longitudinal) and T2 (transverse) time constants. Turn in graphs and code.

1. Plot time course (t=0-1500 msec) of *longitudinal* magnetization regrowth, $M_z(t)$, following a single 120 degree RF pulse. Use equation below assuming T1=820 msec, and equilibrium magnetization, M_{z0}=1.0. N.B.: $M_z(0_+)$ means longitudinal magnetization *immediately* after flip.

$$M_z(t) = M_{z0}\,(1 - e^{-t/T1}) + M_z(0_+)\,e^{-t/T1}$$

2. Plot the time course of the decay of *transverse* magnetization after a 90 degree RF pulse for two different tissue types with T2=65 and T2=75 msec, and then find the time point where their transverse magnetizations are the most *different*. Use equation below and assume that the longitudinal magnetization before the flip, M_{L0}, is the same for both tissue types (1.0).

$$M_{xy}(t) = M_{L0}\,e^{-t/T2}$$

3. Assume the following T1, T2, and spin-density (PD) values for gray matter (GM), white matter (WM), and cerebrospinal fluid (CSF): **T1** (msec): GM=820, WM=590, CSF=2700; **T2** (msec): GM=88, WM=76, CSF=300; **PD** (water=1.0): GM=0.69, WM=0.62, CSF=0.99. Use this equation for *spin-echo* signal intensity:

$$M_{xy} = M_0\,(1 - e^{-TR/T1})\,e^{-TE/T2}$$

(a) In typical T1-weighted images, WM > GM > CSF (signal intensity, brightness). For a fixed TE=8 msec, determine the TR that maximizes the contrast between GM and WM (TR that results in largest value of WM-minus-GM). Do this by plotting M_{xy}(TR) curves for each tissue type (TR=0 to TR=3000). Explain why T1-weighted images have short TR and short TE.

(b) In typical T2-weighted images, CSF > GM > WM. For a fixed TR=3500 ms, determine a TE that maximizes CSF-minus-WM contrast. Plot the curve of M_{xy}(TE) for each tissue (from TE=1 to TE=200 msec). Explain why T2-weighted images have long TR and long TE.

4. Use the following equation for fast (spoiled) *gradient* echo signal intensity (and T1, T2, and PD values from problem 3):

$$M_{xy} = \frac{M_0\,(1 - e^{-TR/T1})}{1 - \cos\alpha\; e^{-TR/T1}}\;\sin\alpha\; e^{-TE/T2}$$

For TR=19 msec and TE=6 msec, find the flip angle, α, that results in the greatest contrast between WM and GM, under the constraint that WM > GM. Plot $M_{xy}(\alpha)$ curves for both types.