You have 15 mins to answer each section of the tutorial with the help of the Matlab scripts.
Try to first answer each question without the support of the scripts, and in a second round use the scripts to help you find the answer.

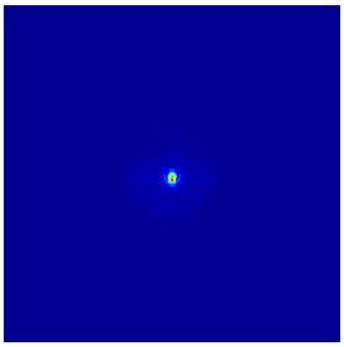
You can download the Material from:
https://github.com/Donders-Institute/QuizzesMRImageEncodingForFMRI
Download the package (go to "code" and select "Download Zip") and extract the zip folder.

Open Matlab, and navigate to the directory where this Pdf can also be found.
Open the live script TutorialOnImageEncodingAndReconstruction.mlx .
You can run each section by pressing Ctrl+Ent or on the "live editor" tab press run section
As a team, agree on the responses and if you have time try to follow some of the suggestions that appear on the live script as comments.

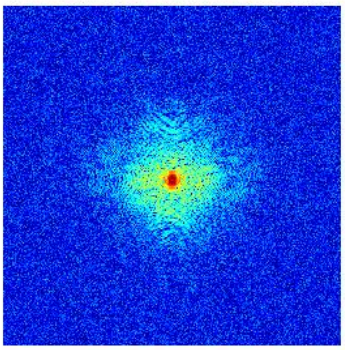
Tutorial on Image Reconstruction

1) Look at the data

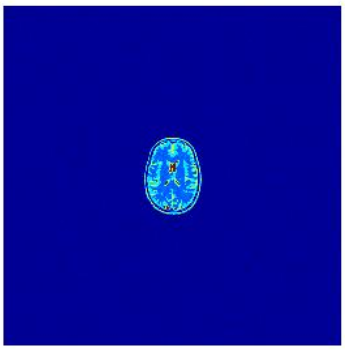
absolute of k-space



log absolute of k-space



absolute of image



a) You can see an transverse/axial slice of a brain
b) You can see a coronal slice of a brain
c) You can see a sagittal slice of a brain

2) Whoever prescribed the protocol asked for a very large FOV;

Image

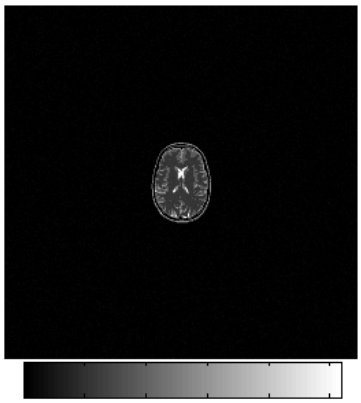


Image with reduced FOV

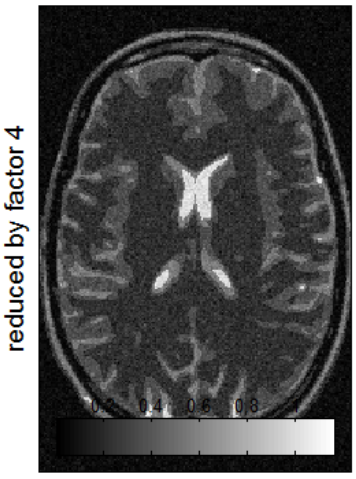
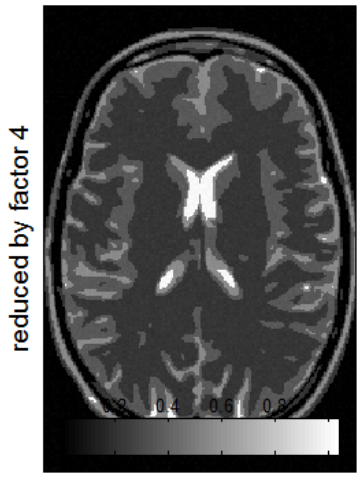


Image by cropping edges

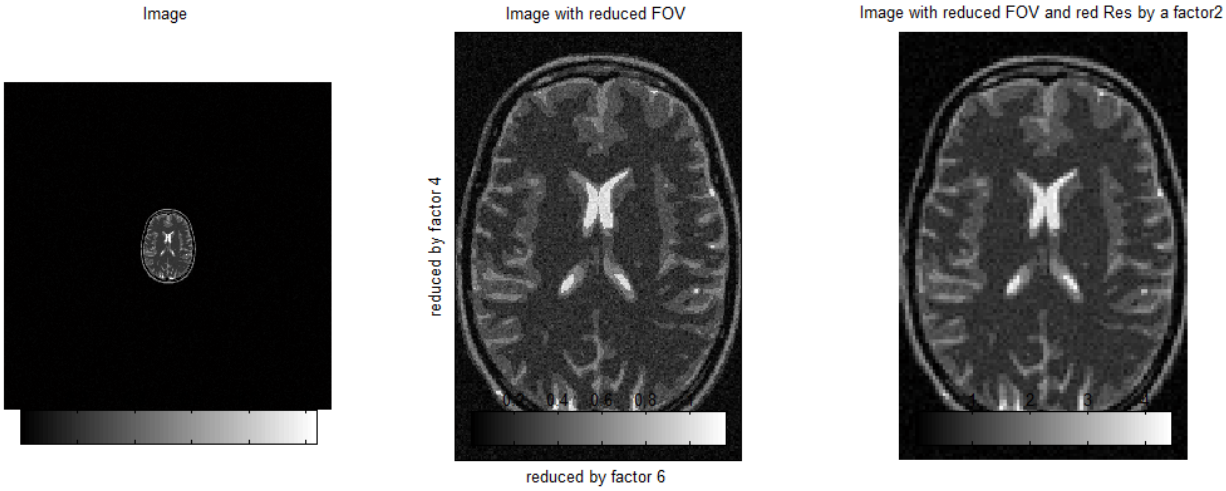


what differences do you see? Why does the data suddenly look so much noisier?

a) The reduction of the FOV can be done by subsampling the k-space and a combined factor of ~20-24 could have been reduced

b) The reduction of the FOV can be done by only taking the center of k-space and a total factor of ~4 could have been reduced without missing too much on the resolution
c) The reduction of the FOV can be done either in k-space or directly in the image space by simply cropping the image… the results are equivalent and a factor ~20-24 can be achieved

3) given the amount of SNR available in the new FOV dataset, it is maybe better to have a lower resolution currently the prescribed resolution was 0.85mm... let us make it 1.7mm both on x and y

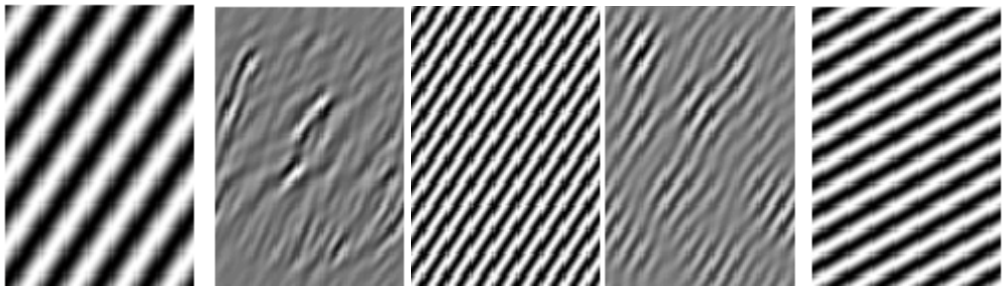


a) The image looks just as noisy as before
b) The image is less noisy than before but some details are now unclear
c) Because the image already had a tight FOV it wasn't possible to reduce the size further

4) Try to formulate the dependence of SNR an image as a function of: Number of phase encoding steps, N_{PE}; Volume of the voxel, V;
% check what values you have in the 3 images in the CSF region and what is the standard deviation in a region of noise

a) $SNR = Signal(TR, TE, \alpha) \cdot V \cdot N_{PE}$
b) $SNR = Signal(TR, TE, \alpha) \cdot \sqrt{V \cdot N_{PE}}$
c) $SNR = Signal(TR, TE, \alpha) \cdot V\sqrt{N_{PE}}$

5) What k-space information is where? Consider the k-space of Image of reduced FOF and resolution of the previous exercise, what information do you think was present on the k-space coordinate (kx=ky=10)

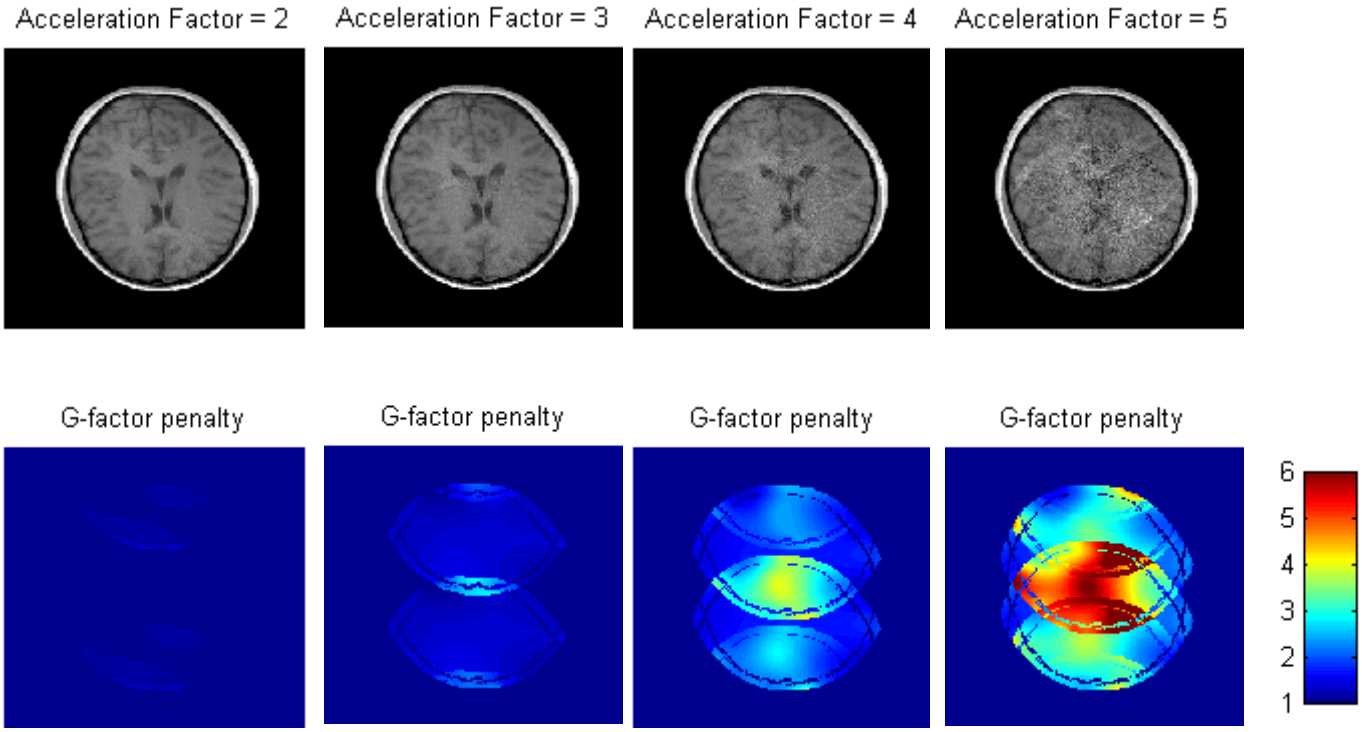


a) b) c) d) e)

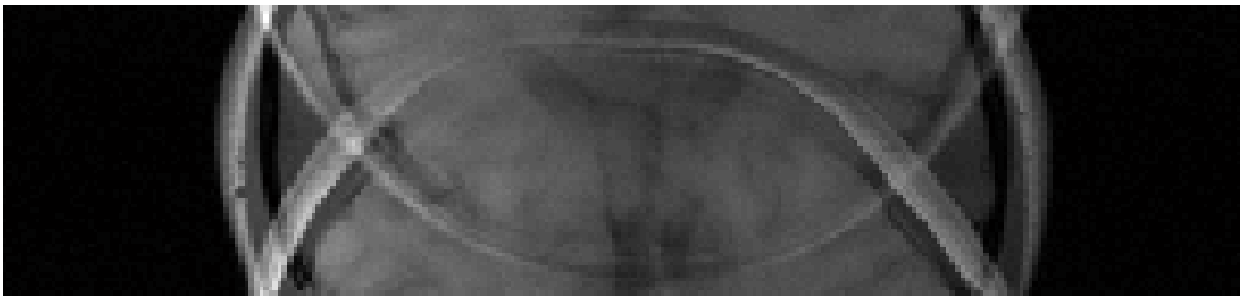
Tutorial on Parallel Imaging

6) Parallel imaging can be used to accelerate the acquisition of single slice. In the case of structural imaging it shortens the acquisition time. In case of echo planar imaging, EPI, it reduces the echo train length and distortions.
It comes with a penalty in the SNR of the image obtained because of the reduced number of measurements performed, and a G-factor penalty due to noise amplification associated with disentangling overlapping pixels. SNR_af=SNR/(sqrt(af) x G-factor)

See the examples below:



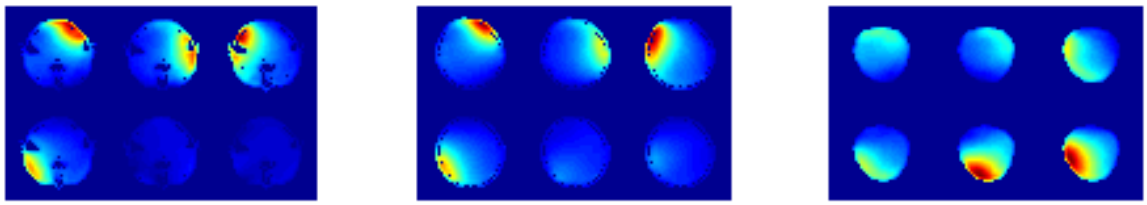
The raw data (after Fourier Transforming) of one of the above acceleration factors looked like this.



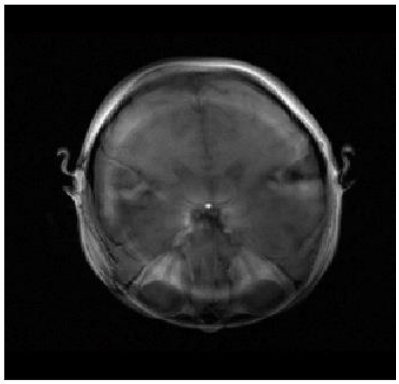
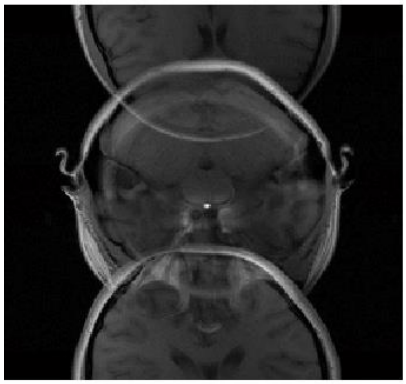
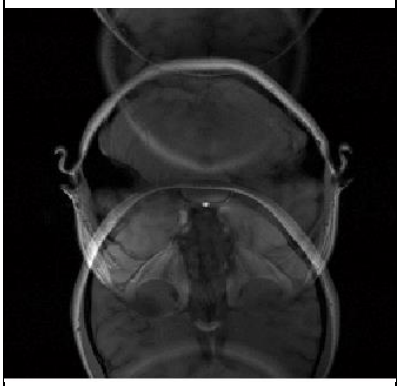
Which one?
a) Acceleration factor 2
b) Acceleration factor 3
c) Acceleration factor 4
d) Acceleration factor 5

7) Consider the case where three slices were simultaneously excited for which you have the information from 6 coils with the following sensitivity maps:

Sensitivity Slice 1 | Sensitivity Slice 8 | Sensitivity Slice 15



When encoding the acquisition, three different CAIPI factors were applied:

1 - no FOV shift;	2 - 0.5xFOV shift;	3 - 0.33xFOV shift
		

Which of the data sets would be better reconstructed using standard parallel imaging?

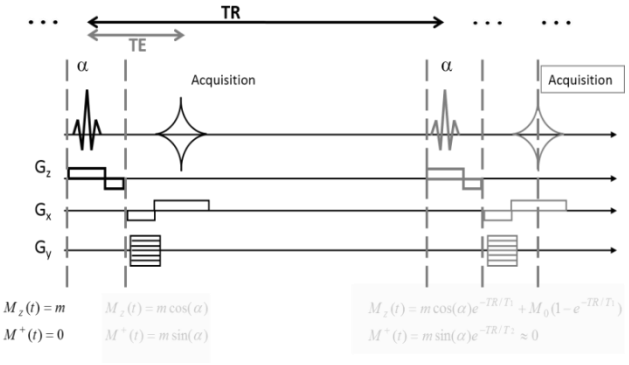
a) The three data sets can be equally well reconstructed because the same information is present in all of them
b) Because the six coil sensitivities used don't have much variations across the slice direction, the reconstruction will fail
c) The reconstruction for the no FOV shift will fail, and the remaining ones will be better.

8) The in-plane acceleration (along the phase encoding direction) achievable without significant g-factor penalty is independent of using or not simultaneously multi-slice excitation

a) True
b) False

Tutorial on Image Contrast

Open now the Live Script **TutorialOnImageContrast.mlx**



All time values will be given in ms

9) If 2 tissues have the same T1 but different T2s (60 and 100ms respectively), what sequence parameters will give a stronger contrast?
   a) TR=1000ms; TE=77 ms; α=90
   b) TR=1000ms; TE=160 ms; α=90
   c) TR=1000ms; TE=10 ms; α=90

10) If the excitation was done only once, the signal at the time TE would be given by $M_0 \sin(\alpha) e^{-TE/T2}$. If you repeat the sequence until it reaches steady state, what will the signal be given by $M_0 sin(\alpha) e^{-TE/T2} \frac{1-e^{-TR/T1}}{1-\cos(\alpha)e^{-TR/T1}}$

This Steady state is achieved:
   a) after two volumes
   b) instantaneously
   c) depends on the repetition time, flip angles used as well as T1

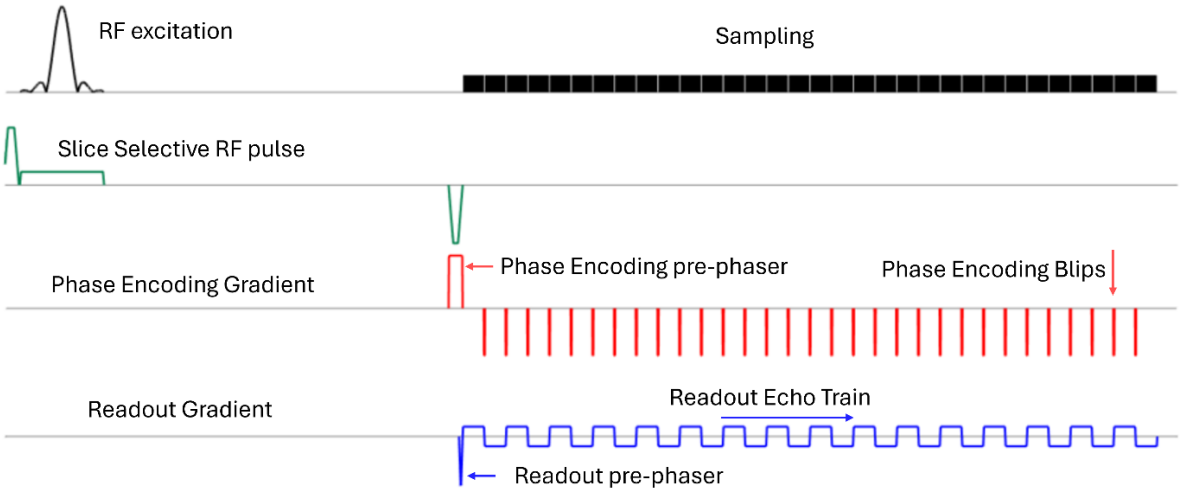
11) Grey matter has a T1=1330ms (@ 3T), if imaging with a TR=3000ms (standard fMRI TR), the flip angle that generates the maximum signal for that tissue is ~84°. If the tissue would have a longer T1 (for example if you would be imaging @ 7T), the optimum flip angle for the same TR would be:
   a) Bigger than 84°
   b) 84°
   c) Smaller than 84°

12) Grey matter has a T1=1330ms (@ 3T), and you were imaging it with a TR=3000ms, the flip angle that would generate the maximum signal for that tissue would be ~84°. If the sequence would be much faster (thanks to multiband 6), the flip angle should change to:
   a) Bigger than 84°
   b) Remain at 84°
   c) Smaller than 84°

13) When comparing the acquisitions TR=3000 and 60ms (standard 2D - EPI and 3D - EPI), the signal in GM (T1s of 1330ms) will be 0.9 and 0.5 of the total magnetization available. Which acquisition has the maximum signal in a same total amount of time? (note that the SNR for a given number of averages, N_{av}, increases $\sqrt{N_{av}}$)
   a) TR = 3000ms
   b) TR = 60 ms
   c) They have the same signal

Tutorial on Echo Planar Imaging sequence

This is an EPI!



In this tutorial you will get familiar with the Echo Planar Imaging sequence commonly used in functional MRI to achieve BOLD contrast.

Open the Live script MacroHandsOnExerciseEPI.mlx and run the first set of cells to get familiarized with how EPI traverses k-space

14) The EPI sequence is an highly demanding acquisition on the gradient system when trying to achieve high spatial resolution. Consider the case where you have received a protocol to perform EPI with an echo time of 35ms and an in-plane resolution of 4mm.
You will refuse to use such a protocol because:
- you want to be able to spatially distinguish hand 'sensory' from 'motor' activity, and those cortices are back-to-back.
- You want to distinguish the activity between two thalamic nuclei very close to each other

You will aim having a 2mm in-plane resolution… But sadly the computer "says no" and suggests that for that resolution your echo time should be >50ms. What can you do?
    a) Acquire a 4mm dataset and interpolate it to 2mm
    b) Reduce the readout gradient duration (while increasing the amplitude)
    c) Use in plane acceleration
    d) Buy a new MR system with incredibly powerful gradients

15) For a new fMRI experiment, you are now not so worried about spatial resolution, but about making sure you have BOLD sensitivity over the whole brain (in regions of signal dropout-short T2*~15ms and in regions of long T2*~50ms), some of them located in the centre of the brain.
You read a paper about Multi-echo EPI, from a Donders group saying this is the way to go. What considerations will you have to take into account:
    a) Your shortest echo time should be ~30ms
    b) You should try to have echo times encompassing the range of T2* values of gray matter
    c) You should have short EPI echo trains, achieved that by using in-plane acceleration (but don't get greedy)

Reflection Questions

Tutorial image reconstruction

What are the consequences for your functional image acquisition of the answer to point 4?

What resolution should you choose?

Tutorial on Parallel imaging

Given your answer g-noise maps in question 6, consider functional MRI study of (1) the auditory cortex, (2) visual cortex and (3) the thalamus. Which of these studies has the biggest penalty when using parallel imaging?

Tutorial on Image Contrast

What are the consequences of your answer to question 10 in an fMRI experiment? What happens when a subject moves?

What are the consequences of your answer to question 13?