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

INTRODUCTION

This Lab consists of three parts:
Part 1 : SNR Measurements – Temporal and Spatial Characteristics in Signal and Noise
Part 2 : Determination of MR parameters (T1, T2, T2*) across tissue types and regions of interest.
Part 3 : EPI distortions due to B0 Inhomogeneity

All experiments will be performed on a human subject. The SNR measurements will also be run on a phantom for comparison. Some of the data analysis will be performed on the scanner console, however you will be asked to note the measurements obtained as you will need them to solve the exercises given in the lab report.
The main goals of this lab are to:

1) Become familiar with basic principles of MRI Physics and measurements (i.e. SNR, relaxation times, etc).
2) Understand the T1, T2 and T2* properties of various tissue compartments.
3) Acquire and evaluate phantom data.
4) Perform a human scanning experiment and investigate the various sources of noise in the fMRI time series.
5) Evaluate EPI distortions through field maps and by varying the readout properties.

1. SNR Measurements

Background

At the most basic level, the SNR depends on the number of protons present in the voxel (proportional to Voxel Volume if we assume a constant density) and the $\sqrt{MeasurementTime}$. The latter is a standard aspect of signal averaging assuming the noise is uncorrelated and distributed in a Gaussian distribution. Each acquisition in the k-space matrix is essentially averaged when the Fourier Transform produces the image. Therefore the total measurement time is the total amount of time the digitizers are actually recording k-space samples. For a readout line of 256 samples acquired with a dwell time (time per sample) of 25μs, this yields an acquisition time of 6.4ms. Sometimes acquisition time for the readout is expressed in terms of the bandwidth of frequencies present across the image (BW_{read}). $BW_{read} = \frac{1}{dwell\ time}$ equal to 40kHz for this example. On the Siemens system the BW is expressed in Hz per pixel across the image, so for the 256 matrix above, this is a $BW_{read} = 156$ Hz/px. The total image acquisition time is the time per line multiplied by the number of lines (# phase encode steps N_{PE}) and the number of times each line was averaged (N_{AVG})

Equation 1 shows the dependence of SNR on some of the above parameters:

$$SNR \propto \frac{Voxel\ Volume \cdot \sqrt{N_{AVG}}}{\sqrt{BW_{read}}} \qquad (1)$$

For fMRI, it is the time-course SNR that is important. Functional MRI is restricted by multiple sources of variance, such as instrumental sources of error including thermal noise and shot-to-shot electronic instability, and subject dependent modulations of the MR signal associated with physiological processes. In addition to respiratory and cardiac cycle contributions, the physiological noise also consists of a noise element with BOLD-like TE dependence (Triantafyllou et al. 2005), (Krueger and Glover 2001), and spatial correlation within gray matter (Krueger and Glover 2001). The origin of this "BOLD noise" is still not fully understood, but is generally associated with hemodynamic and metabolic fluctuations in the gray matter. Since the physiological fluctuations represent a multiplicative modulation of the image signal (Krueger and Glover 2001) their amplitude scales with the MR image intensity. This is in contrast to the thermal noise sources which can be represented by the addition of a fixed amount of Gaussian noise power whose amplitude is determined primarily by the coil loading.

If the noise sources are assumed to be uncorrelated, the total noise in the image time-course (σ) is related to its thermal (σ_0) and physiological (σ_p) components via:

$$\sigma = \sqrt{\sigma_0^2 + \sigma_p^2}, \qquad (2)$$

In our measurements, shot-to-shot scanner instabilities will contribute to both terms, σ_0 and σ_p, depending on their signal dependence. Phantom measurements, however, show that they comprise only a small fraction of the *in vivo* time course noise.
The time-course SNR (tSNR) is then defined as:

$$tSNR = \frac{\overline{S}}{\sqrt{\sigma_0^2 + \sigma_p^2}}, \quad (3)$$

where $\overline{S}$ is the mean image signal intensity. Defining the SNR in an individual image as $SNR0 = \frac{\overline{S}}{\sigma_0}$ and combining with Eq. (3), we determine the relationship between tSNR and SNR0:

$$tSNR = \frac{SNR0}{\sqrt{1 + \lambda^2 \cdot SNR0^2}} \quad (4)$$

where λ is a constant.

References

1. Triantafyllou C., et al., Comparison of physiological noise at 1.5 T, 3 T and 7 T and optimization of fMRI acquisition parameters. NeuroImage 26, 243–250; 2005.
2. Krueger G, Glover GH. Physiological noise in oxygenation-sensitive magnetic resonance imaging. Magn Reson Med 46: 631-7; 2001.

Experiments

In this exercise we will acquire human MRI data in order to characterize image signal and noise characteristics and the time-course signal and noise characteristics. Data will be collected on a 3T Siemens Imager.
We will examine the spatial SNR, time-course SNR and their relationship for three different image resolutions, 5x5x5mm^3, 3x3x3mm^3 and 1.5x1.5x1.5mm^3. In all cases, images with zero RF will also be obtained to capture the thermal image noise. For comparison, time series data using the same parameters will also be acquired on a loading phantom.

Acquisition:

1) Localizer.
2) EPI time series at low resolution 5mm x 5mm x 5mm, 10 slices, 100 time points, TR=2000ms, TE=30ms, (see protocol epi_5x5x5_signal).
3) Same as #2 but with no RF excitation (just thermal noise)
4) EPI time series at medium resolution 3mm x 3mm x 3mm, 10 slices, 100 time points, TR=2000ms, TE=30ms (see protocol epi_3x3x3_signal).
5) Same as #4 but with no RF excitation (just thermal noise).
6) EPI time series at higher resolution 1.5mm x 1.5mm x 1.5mm, 10 slices, 100 time points, TR=2000ms, TE=30ms (see protocol epi_1.5x1.5x1.5_signal).
7) Same as #6 but with no RF excitation (just thermal noise).

Note 1: Typically, thermal noise would be calculated by drawing an ROI outside the signal area in an image. However in EPI acquisition there are a lot of artifacts present. To avoid misreading the noise we thus acquire a separate image without an RF that provides a better representation of thermal noise.

Note 2: Since the thermal noise is random we need to characterize it in terms of its mean, and standard deviation (or variance). Before we can calculate these quantities, we also need to know what kind of statistical distribution this noise belongs to. For example, the most common type of statistical distribution is the Gaussian or normal distribution but the spatial MRI noise outside of the brain has been empirically determined to follow a *Rayleigh* distribution. It is thus simple to compute the mean and variance of the thermal noise by first computing its variance and mean as though it were Gaussian and applying a Rayleigh correction factor to account for this difference.

Spatial SNR (SNR0)

The SNR in an individual image (SNR0) is a measure or the image quality. In our experiments we will evaluate the impact of the spatial resolution on the SNR0. In human data, ROIs will be defined in cortical gray matter. The SNR0 for a given pixel will be calculated as the mean pixel value for all the images in the time-series divided by the standard deviation of the thermal noise of the time-series acquired with no RF excitation (zero flip angle images).

1. Load the EPI images and the Noise time-courses on the mean curve task card (2 separate windows).
2. Select the EPI time-course, draw an ROI within the signal area, and record the mean signal value.
3. Select the Noise time-course, draw an ROI and record the standard deviation.
4. Record your measures in Table 1 and calculate the SNR0.
5. Repeat steps 1-4 for all three spatial resolutions.
6. Repeat steps 1-4 for the phantom data at all three resolutions and record results on Table 2.

    - **Lab Question 1 :** Draw the calculated SNR0 as a function of voxel size and comment on your findings. Describe the differences if any, between the human and phantom data.

Temporal SNR (tSNR)

Temporal SNR is defined as the image-to-image variance in the time-course and will be measured on a ROIs based analysis in the cortical gray matter. Temporal SNR in a given pixel will be determined from the mean pixel value across the 100 time points divided by its temporal standard deviation.

1. Load the EPI time series images on the viewer.
2. Calculate the Standard Deviation map from the EPI time series through the scanner UI. Open the Patient Browser, go to Evaluation -> Dynamic Analysis -> Standard Deviation. Press within series, test and assign a name to the new image (STD_mymap). A new series is created on your patient browser, named STD_mymap.
3. Load the images on the mean curve task card. Select both the EPI time course and the standard deviation map and draw an ROI within the signal area.
4. Record the mean value within the ROI on the EPI images; that is your temporal mean of the signal.
5. Record the mean value within the ROI on the standard deviation map; that is your temporal noise.
6. Calculate the temporal SNR from the above quantities and note on Table 1.
7. Repeat steps 1-6 for all three spatial resolutions.
8. Repeat steps 1-6 for the phantom data at all three resolutions and record results on Table 2.

    - **Lab Question 2:** Draw the calculated tSNR as a function of voxel size and comment on your findings. Describe the differences if any, between the human and phantom data.

Relationship between SNR0 and tSNR

The tSNR will be analyzed as a function of SNR0 for the given set of resolutions. Use the recorded values from Tables 1 and 2 incorporating the model for tSNR from Eq. 4 (where λ=0.0107).

- **Lab Question 3 :** Show the relationship of tSNR as a function of SNR0 when SNR0 is modulated by the voxel size. Describe the differences, if any, between the human and phantom data. What is the asymptotic limit for tSNR?

- **Lab Question 4 :** You are asked to perform an fMRI study of medial temporal lobe activation at a high field strength. Which acquisition parameters would you consider most important to optimize in order to achieve the best activation results? For a 3T scanner provide a suggested set of acquisition parameters.

- **Lab Question 5 :** Draw ROIS on various tissue types, generate the tSNR as a function of SNR0 in gray matter, white matter and CSF. Record mean signal and standard deviation of the noise. Comment on your findings.

Table 1 – Human Data - Gray Matter

Average values for SNR measurements as a function of image resolution. SNR0 corrected for Rayleigh distribution.

Resolution (mm^3)	Signal	Thermal Noise	Time-Series Noise	Spatial SNR	Temporal SNR
1.5x1.5x1.5					
3x3x3					
5x5x5					

Table 2 – Phantom Data

Average values for SNR measurements as a function of image resolution. SNR0 corrected for Rayleigh distribution.

Resolution (mm^3)	Signal	Thermal Noise	Time-Series Noise	Spatial SNR	Temporal SNR
1.5x1.5x1.5					
3x3x3					
5x5x5					

Table 3 – Human Data - White Matter
Average values for SNR measurements as a function of image resolution. SNR0 corrected for Rayleigh distribution.

Resolution (mm^3)	Signal	Thermal Noise	Time-Series Noise	Spatial SNR	Temporal SNR
1.5x1.5x1.5					
3x3x3					
5x5x5					

Table 4 – Human Data - CSF
Average values for SNR measurements as a function of image resolution. SNR0 corrected for Rayleigh distribution.

Resolution (mm^3)	Signal	Thermal Noise	Time-Series Noise	Spatial SNR	Temporal SNR
1.5x1.5x1.5					
3x3x3					
5x5x5					

SIEMENS MAGNETOM TrioTim syngo MR B15

\\USER\INVESTIGATORS\HST_583\Physics1\localizer

TA: 9.2 s PAT: Off Voxel size: 2.2×1.1×10.0 mm Rel. SNR: 1.00 SIEMENS: gre

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	Off
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	Off
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	1
Dist. factor	20 %
Position	Isocenter
Orientation	Sagittal
Phase enc. dir.	A >> P
Rotation	0.00 deg
Slice group 2	
Slices	1
Dist. factor	20 %
Position	Isocenter
Orientation	Transversal
Phase enc. dir.	A >> P
Rotation	0.00 deg
Slice group 3	
Slices	1
Dist. factor	20 %
Position	Isocenter
Orientation	Coronal
Phase enc. dir.	R >> L
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	280 mm
FoV phase	100.0 %
Slice thickness	10.0 mm
TR	20.0 ms
TE	5.00 ms
Averages	1
Concatenations	3
Filter	Prescan Normalize, Elliptical filter
Coil elements	HEA;HEP

Contrast

TD	0 ms
MTC	Off
Magn. preparation	None
Flip angle	40 deg
Fat suppr.	None
Water suppr.	None
Averaging mode	Short term
Reconstruction	Magnitude
Measurements	1
Multiple series	Each measurement

Resolution

Base resolution	256
Phase resolution	50 %
Phase partial Fourier	Off
Interpolation	On
PAT mode	None
Matrix Coil Mode	Auto (CP)
Image Filter	Off
Distortion Corr.	Off
Unfiltered images	Off
Prescan Normalize	On
Normalize	Off
Raw filter	Off
Elliptical filter	On
Mode	Inplane

Geometry

Multi-slice mode	Sequential
Series	Interleaved
Saturation mode	Standard
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	REF
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Save uncombined	Off
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Tune up
Adjust with body coil	On
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	Isocenter
Orientation	Transversal
Rotation	0.00 deg
R >> L	350 mm
A >> P	263 mm
F >> H	350 mm

Physio

1st Signal/Mode	None
Segments	1
Dark blood	Off
Resp. control	Off

Inline

Subtract	Off
Liver registration	Off
Std-Dev-Sag	Off
Std-Dev-Cor	Off
Std-Dev-Tra	Off

Std-Dev-Time	Off
MIP-Sag	Off
MIP-Cor	Off
MIP-Tra	Off
MIP-Time	Off
Save original images	On
Wash - In	Off
Wash - Out	Off
TTP	Off
PEI	Off
MIP - time	Off

Sequence

Introduction	On
Dimension	2D
Phase stabilisation	Off
Asymmetric echo	Off
Contrasts	1
Bandwidth	180 Hz/Px
Flow comp.	No
Allowed delay	0 s
RF pulse type	Fast
Gradient mode	Normal
Excitation	Slice-sel.
RF spoiling	On

\\USER\INVESTIGATORS\HST_583\Physics1\epi_5x5x5_signal

TA: 3:24 PAT: Off Voxel size: 5.0×5.0×5.0 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	10
Dist. factor	0 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	240 mm
FoV phase	100.0 %
Slice thickness	5.00 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	100
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	48
Phase resolution	100 %
Phase partial Fourier	Off
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	240 mm
A >> P	240 mm
F >> H	50 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	3472 Hz/Px
Free echo spacing	Off
Echo spacing	0.36 ms
EPI factor	48
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

\\USER\INVESTIGATORS\HST_583\Physics1\epi_5x5x5_noise

TA: 0:24 PAT: Off Voxel size: 5.0×5.0×5.0 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	10
Dist. factor	0 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	240 mm
FoV phase	100.0 %
Slice thickness	5.00 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	10
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	48
Phase resolution	100 %
Phase partial Fourier	Off
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	240 mm
A >> P	240 mm
F >> H	50 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	3472 Hz/Px
Free echo spacing	Off
Echo spacing	0.36 ms
EPI factor	48
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

\\USER\INVESTIGATORS\HST_583\Physics1\epi_3x3x3_signal

TA: 3:24 PAT: Off Voxel size: 3.0×3.0×3.0 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	10
Dist. factor	67 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	192 mm
FoV phase	100.0 %
Slice thickness	3.00 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	100
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	64
Phase resolution	100 %
Phase partial Fourier	Off
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	192 mm
A >> P	192 mm
F >> H	49 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	2520 Hz/Px
Free echo spacing	Off
Echo spacing	0.47 ms
EPI factor	64
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

\\USER\INVESTIGATORS\HST_583\Physics1\epi_3x3x3_noise

TA: 0:24 PAT: Off Voxel size: 3.0×3.0×3.0 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	10
Dist. factor	67 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	192 mm
FoV phase	100.0 %
Slice thickness	3.00 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	10
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	64
Phase resolution	100 %
Phase partial Fourier	Off
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	192 mm
A >> P	192 mm
F >> H	49 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	2520 Hz/Px
Free echo spacing	Off
Echo spacing	0.47 ms
EPI factor	64
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

\\USER\INVESTIGATORS\HST_583\Physics1\epi_1.5x1.5x1.5_signal

TA: 3:24 PAT: Off Voxel size: 1.5×1.5×1.5 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	10
Dist. factor	233 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	192 mm
FoV phase	100.0 %
Slice thickness	1.50 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	100
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	128
Phase resolution	100 %
Phase partial Fourier	5/8
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	192 mm
A >> P	192 mm
F >> H	47 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	1502 Hz/Px
Free echo spacing	Off
Echo spacing	0.75 ms
EPI factor	128
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

\\USER\INVESTIGATORS\HST_583\Physics1\epi_1.5x1.5x1.5_noise

TA: 0:24 PAT: Off Voxel size: 1.5×1.5×1.5 mm Rel. SNR: 1.00 USER: ep2d_bold_MGH_pro_tb

Properties

Prio Recon	Off
Before measurement	
After measurement	
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
AutoAlign Spine	Off
Start measurement without further preparation	On
Wait for user to start	Off
Start measurements	single

Routine

Slice group 1	
Slices	9
Dist. factor	233 %
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Phase enc. dir.	A >> P
Rotation	0.00 deg
Phase oversampling	0 %
FoV read	192 mm
FoV phase	100.0 %
Slice thickness	1.50 mm
TR	2000 ms
TE	30 ms
Averages	1
Concatenations	1
Filter	None
Coil elements	HEA;HEP

Contrast

MTC	Off
Flip angle	90 deg
Fat suppr.	Fat sat.
Averaging mode	Long term
Reconstruction	Magnitude
Measurements	10
Delay in TR	0 ms
Multiple series	Off

Resolution

Base resolution	128
Phase resolution	100 %
Phase partial Fourier	5/8
Interpolation	Off
PAT mode	None
Matrix Coil Mode	Auto (CP)
Distortion Corr.	Off
Prescan Normalize	Off
Raw filter	On
Elliptical filter	Off
Hamming	Off

Geometry

Multi-slice mode	Interleaved
Series	Interleaved
Special sat.	None

System

Body	Off
HEP	On
HEA	On
Positioning mode	FIX
Table position	H
Table position	0 mm
MSMA	S - C - T
Sagittal	R >> L
Coronal	A >> P
Transversal	F >> H
Coil Combine Mode	Sum of Squares
Auto Coil Select	Default
Shim mode	Standard
Adjust with body coil	Off
Confirm freq. adjustment	Off
Assume Silicone	Off
Ref. amplitude 1H	318.659 V
Adjustment Tolerance	Auto
Adjust volume	
Position	R3.0 A3.0 H0.0
Orientation	T > C-12.5
Rotation	0.00 deg
R >> L	192 mm
A >> P	192 mm
F >> H	42 mm

Physio

1st Signal/Mode	None

BOLD

GLM Statistics	Off
Dynamic t-maps	Off
Starting ignore meas	0
Ignore after transition	0
Model transition states	Off
Temp. highpass filter	Off
Threshold	4.00
Paradigm size	1
Meas	Baseline
Motion correction	On
Interpolation	3D-K-space
Spatial filter	Off

Sequence

Introduction	Off
Bandwidth	1502 Hz/Px
Free echo spacing	Off
Echo spacing	0.75 ms
EPI factor	128
RF pulse type	Normal
Gradient mode	Fast
Dummy Scans	2

References

See Triantafyllou, C., R. D. Hoge, G. Krueger, C. J. Wiggins, A. Potthast, G. C. Wiggins, and L. L. Wald. "Comparison of physiological noise at 1.5 T, 3 T and 7 T and optimization of fMRI acquisition parameters." *NeuroImage* 26 (2005): 243-250.