HCP Acquisition Basics

HCP Course 2015

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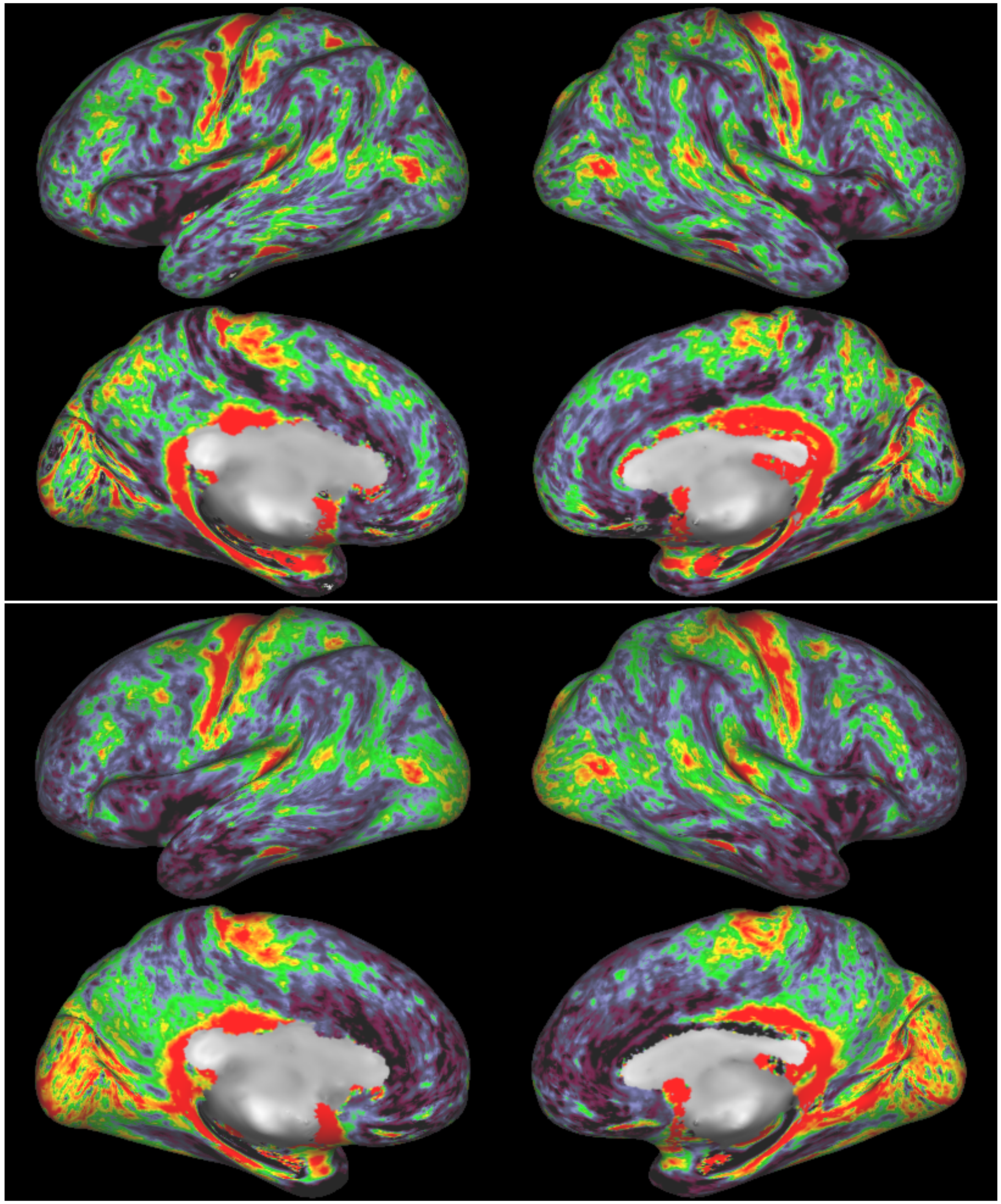
Goals

- Provide an overall introduction/background to the HCP acquisitions
- Understand the different types of files collected
- Understand the acquisition related expectations and requirements if you intend to use the *HCP pipelines* for processing.

Structurals

Required: T1w *and* T2w 3D (isotropic voxels) structurals

- *Highly recommended* that these be acquired at 0.8 mm resolution (or better) for improved cortical surface positioning.
  (HCP-Main uses 0.7 mm; our HCP-LifeSpan piloting uses 0.8 mm)
- SNR at 0.8 mm should not be a problem for most 3T clinical scanners if using 32 channel head coil
- We use Siemen's T2-SPACE sequence. T2-FLAIR is also an option. (However, myelin maps computed using T2-FLAIR have worse CNR).
- Current pipelines *require* a 3D T2w scan for the following reasons:
  - Improved positioning of the pial surface in FreeSurfer
  - Generation of "myelin maps", which are a component of multi-modal registration
  - Used (along with T1w scan) to estimate the receive coil bias field.
    [Note that if using vendor implemented receive coil bias-field corrections (e.g., "Prescan Normalize", "PURE", "CLEAR"), they must be matched for both T1w and T2w scans.]



Myelin map based on T2-FLAIR

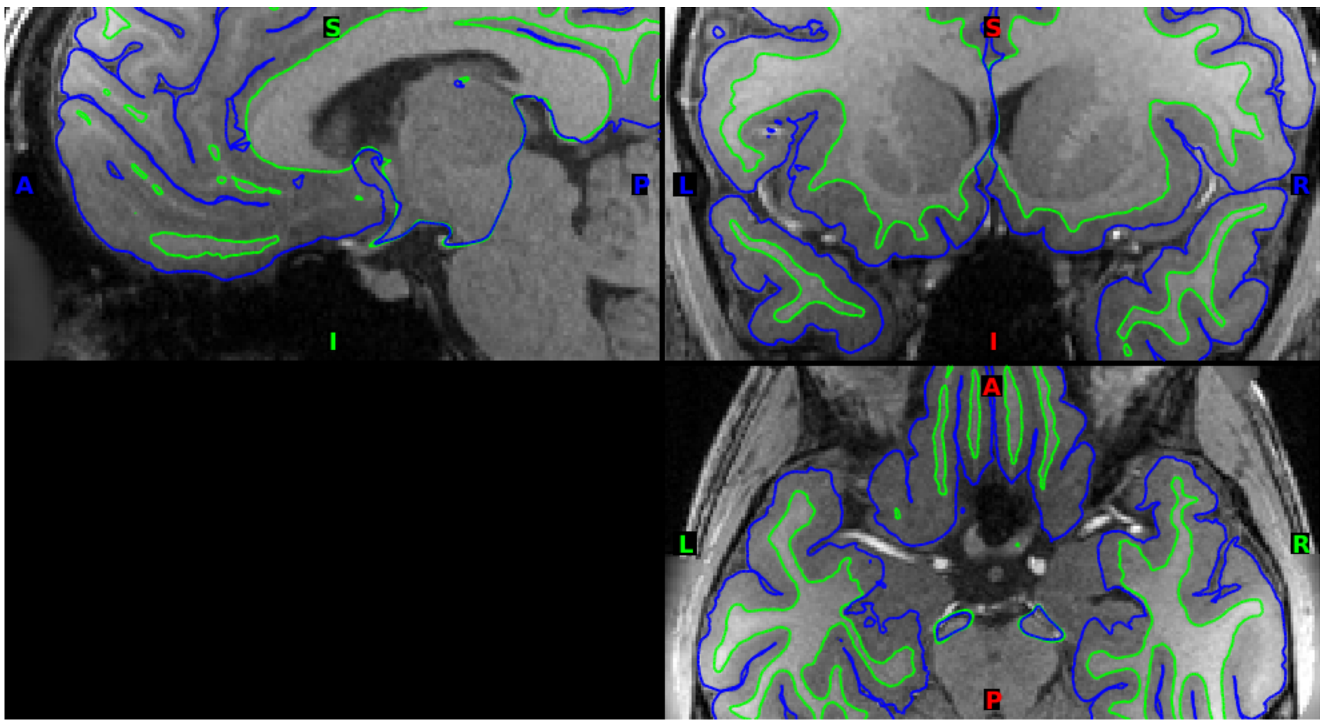
Myelin map based on T2-SPACE (both from same individual)

Structurals

Recommended: Pair of Phase-Encoding reversed spin-echo scans for constructing a fieldmap for readout-distortion correction

- Called *SpinEchoFieldMap* in released HCP scans
- Alternatively, can use traditional dual-echo gradient echo acquisitions to construct a fieldmap.

The readout-distortion effect is rather small



Without readout distortion correction

Structurals

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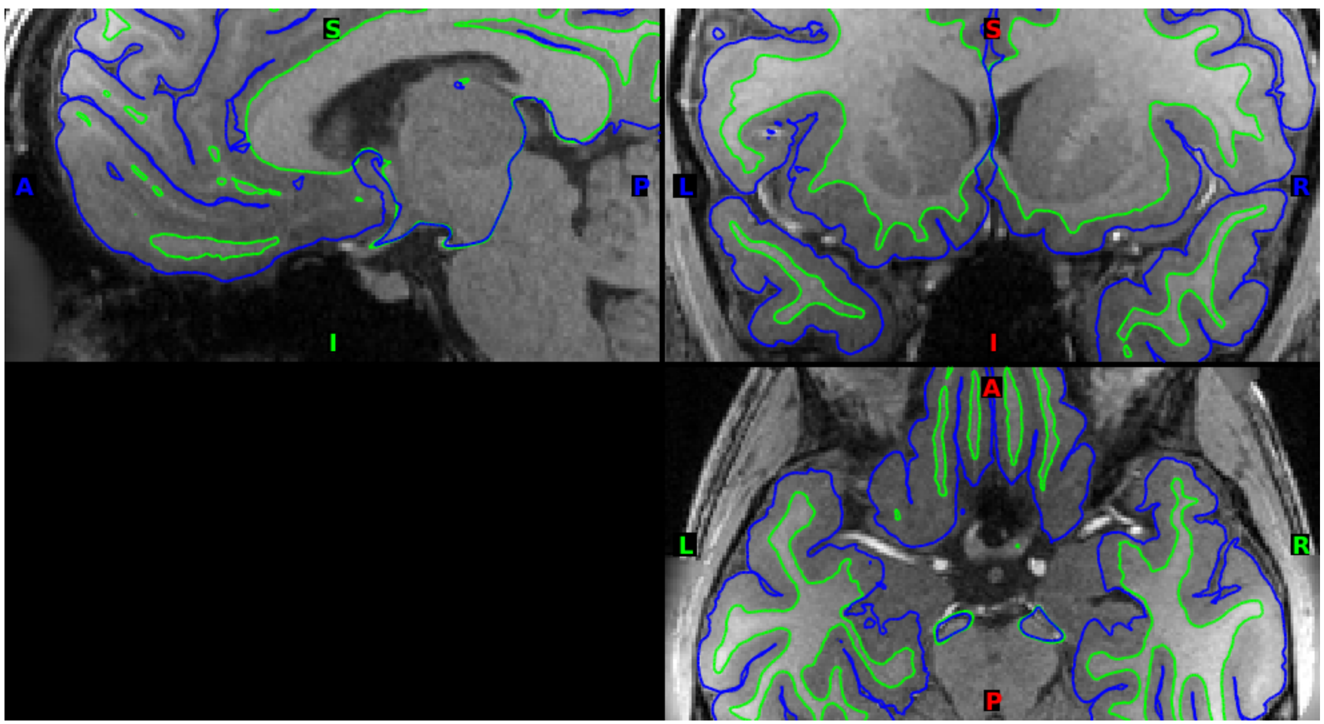
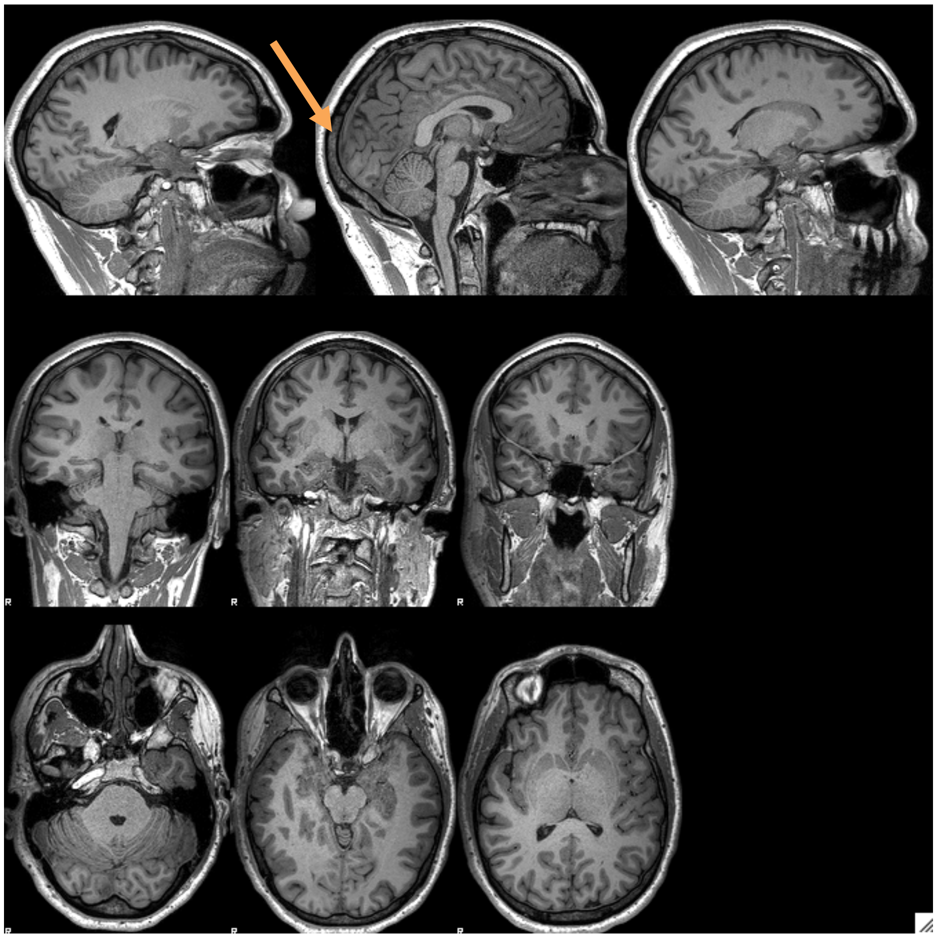


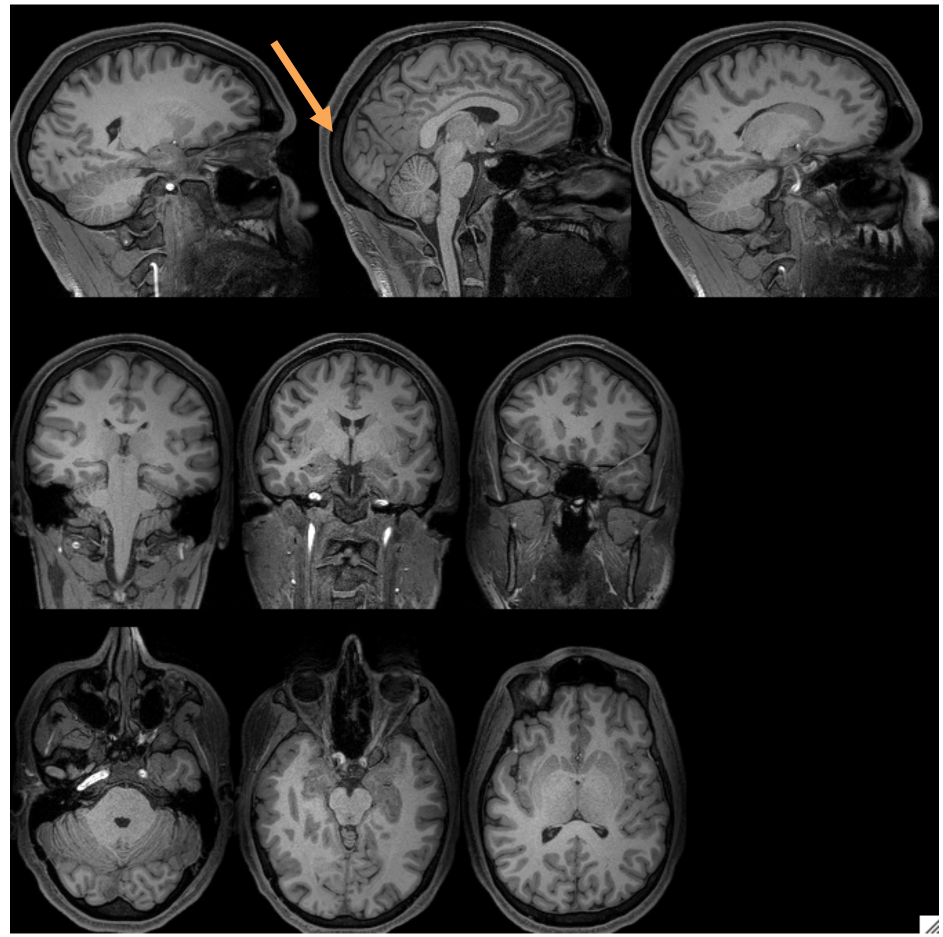
With readout distortion correction

Structurals

Recommended: Acquire T1w with "fat suppression" to reduce signal from bone marrow and scalp fat.



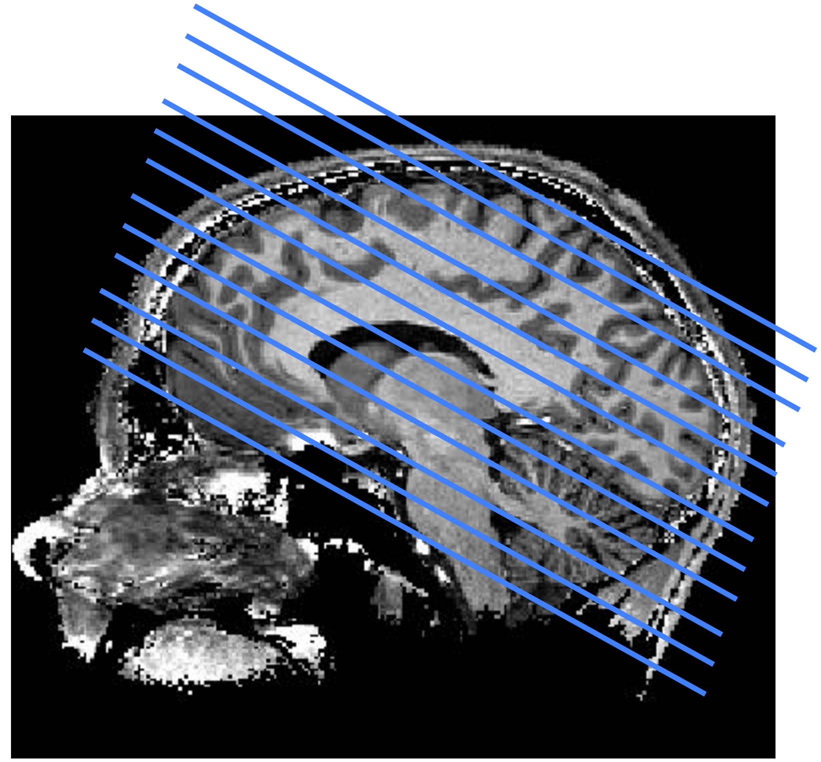
no fat suppression



water specific excitation
(with 1 - 1 binomial pulse)

Conventional Multi-slice Imaging

Whole Volume TR
$= N_{slice}$ x Time per slice



Multi-band Imaging

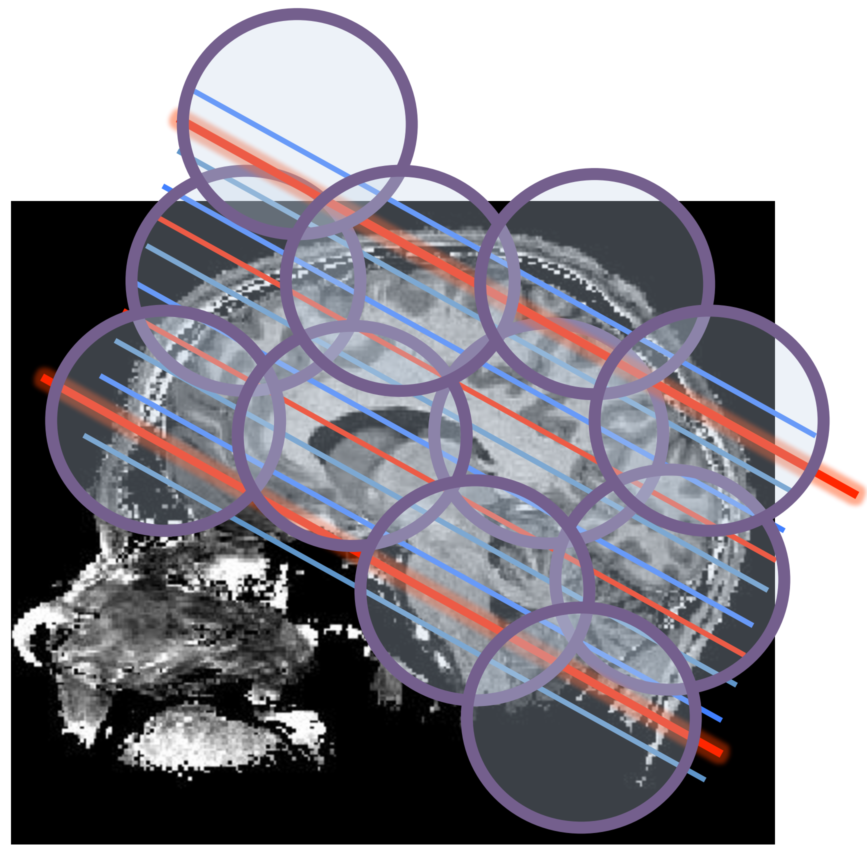
Multiband: simultaneous slices separated via multiple coils

[Larkmann MRM 2001, Moeller MRM 2010, Feinberg PLoS ONE 2010, Setsompop MRM 2012]

UMinn: Steen Moeller, Junqian Xu, Ed Auerbach, Essa Yacoub, Kamil Ugurbil

UCB/AMRIT: David Feinberg

- Excite ***multiple*** slices simultaneously
- Each coil yields a linear combination of signals from the different slices (weighted by sensitivity profiles)
- Matrix inversion provides a solution to separate slices

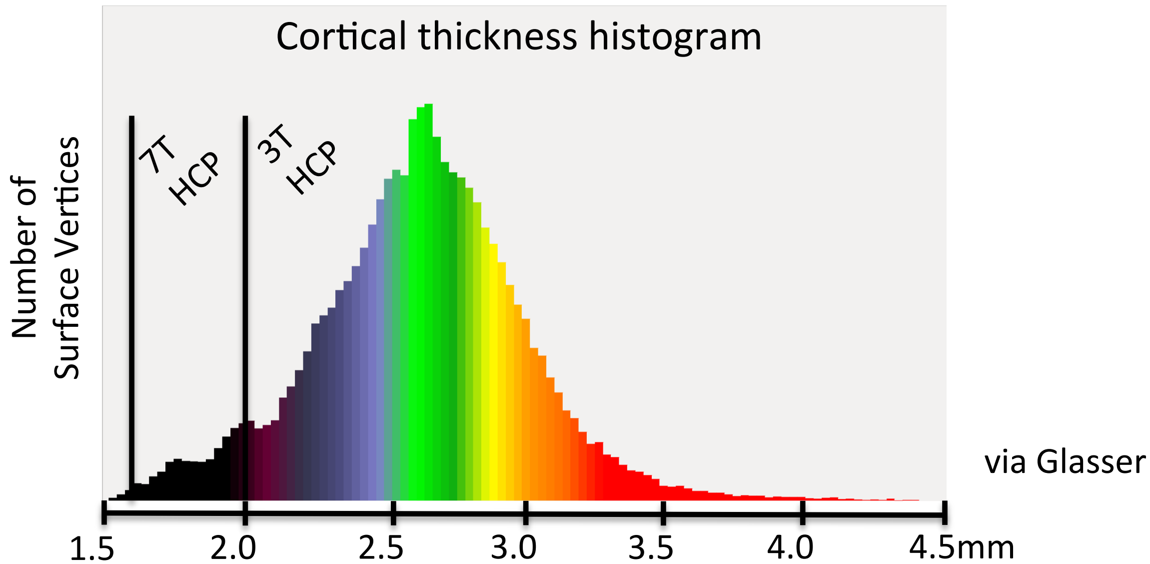


fMRI

HCP: BOLD fMRI with MB=8, 2 mm voxels, TR=720 ms (on both 3T WashU Connectom scanner and UMN Prisma)

Recommended: Resolution < 2.6 mm and TR ≤ 1000 ms

- Keeps voxel size below mean cortical thickness



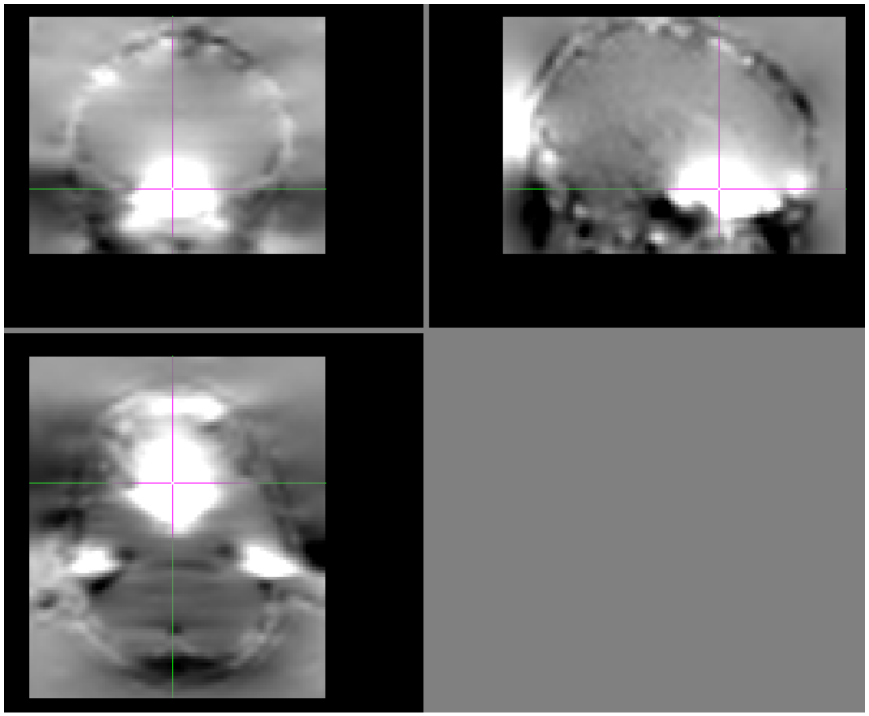
- Sufficient temporal sampling is important for denoising via "FIX"
- MB factor of 6 probably ok on most scanners (if using 20+ channel coil), but important to assess recon-quality at chosen MB factor *on your particular scanner and with your particular head coil.*

fMRI

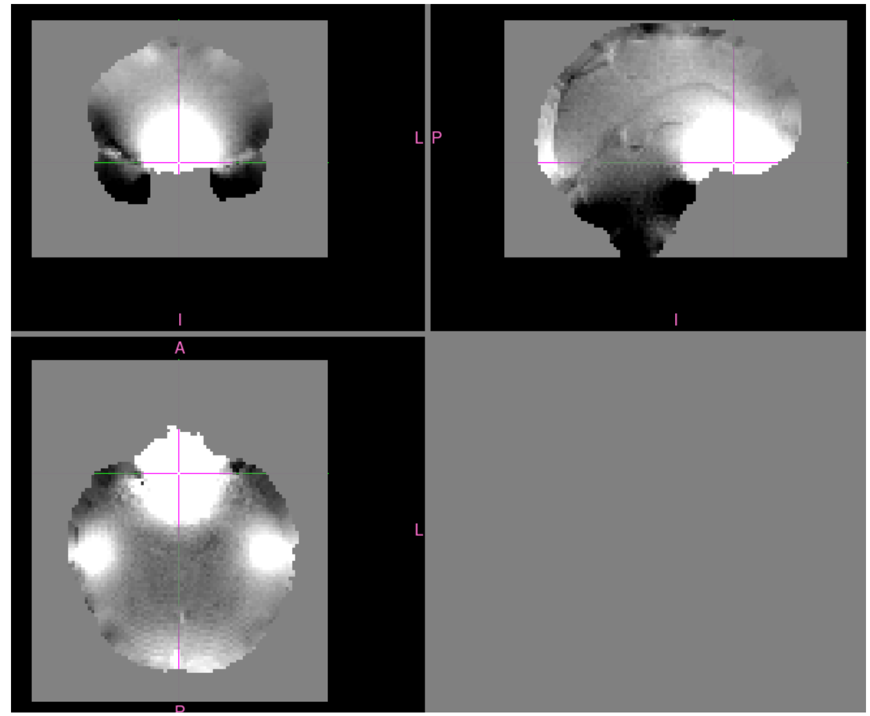
Required: field map for distortion correction.
(Again, either Spin Echo or Gradient Echo allowed, with SE recommended).

- In HCP acquisitions, we make a concerted effort to keep the shim setting (i.e., shim currents) constant between the fieldmap and fMRI scans.

Spin Echo based FieldMap



Gradient Echo based FieldMap



Same low frequency spatial pattern between the two approaches

fMRI

Recommended: Save "SBRef" (sequence option)

- Single-band reference that is acquired anyway at the start of the scan
- Proton density, plus T2* weighting with good GM/WM contrast, so good as an "intermediate" for registration to T1w structural
- Also used as the target for motion correction
- If not available, first volume of BOLD timeseries will be used in pipeline

fMRI

Other considerations – phase encoding (PE) direction for BOLD scans:

- Pairs of PE-reversed scans vs. single PE direction
- HCP/LifeSpan on Connectom scanner have been using RL and LR *pairs* of scans
- If study design only allows a single run, AP or PA phase encoding may be a more natural choice
- Many other scanners (e.g., Prisma) may not even allow RL/LR phase encoding in these parameter ranges due to limits to prevent peripheral nerve stimulation

dMRI

dMRI parameter choices are highly dependent on your scanner (gradient strength) and available scan time.

e.g., for a sampling of what we are using:

	WU HCP-Main 3T Connectom	WU HCP-LifeSpan ("Phase 1b") 3T Connectom	UMN HCP-LifeSpan 3T Prisma	UMN HCP-LifeSpan 7T Prisma
MB factor:	3	3	4	2 (w/ iPAT=3)
TR/TE (ms)	5520/89.5	3730/76.6	3222/89.2	5100/66.2
Voxel sizes (mm):	1.25	1.5	1.5	1.25
Num shells:	3	2	2	2
b-vals:	1000, 2000, 3000	1500, 3000	1500, 3000	1000, 2000
Num directions (each shell)	90	75	92	53
Total min	60	20	22	25
PE polarity	RL and LR	RL and LR	AP and PA	AP and PA

dMRI

Eddy current distortion prominent in HCP data

Required:

- Diffusion directions that sample whole sphere OR acquire pairs of scans with reversed PE (OR both) – requirement for '`eddy`'
  - If angular resolution is "limited" (< 30 unique directions), probably advantageous to use available time to acquire more directions, rather than pair with reversed PE
  - If angular resolution is "plentiful" (> 60 directions) and time is available, acquiring a pair with reversed PE ensures robust eddy current correction.

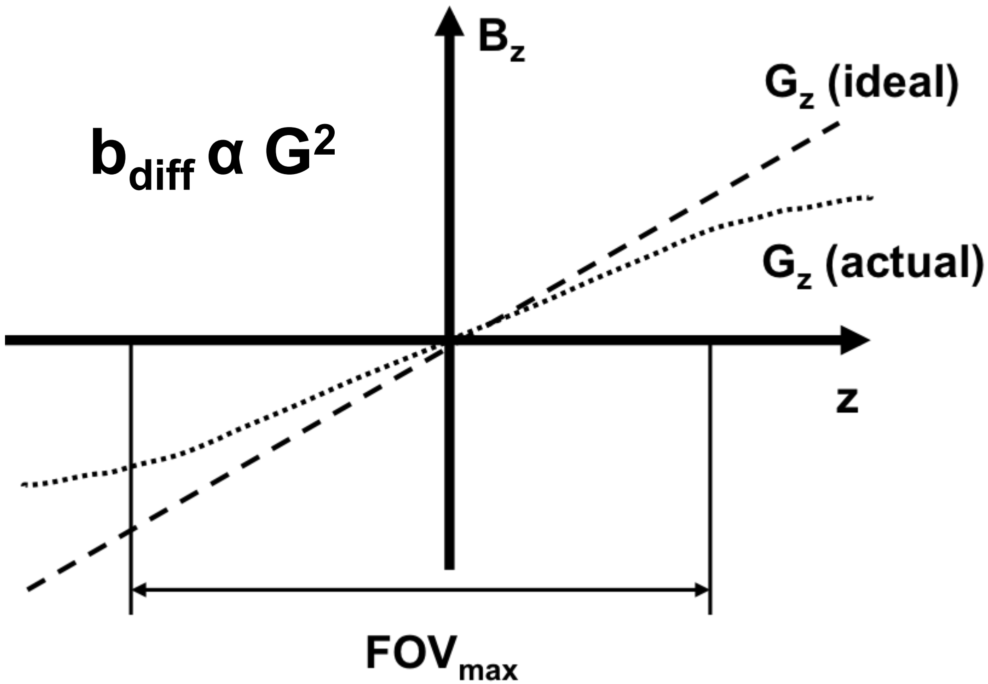
dMRI

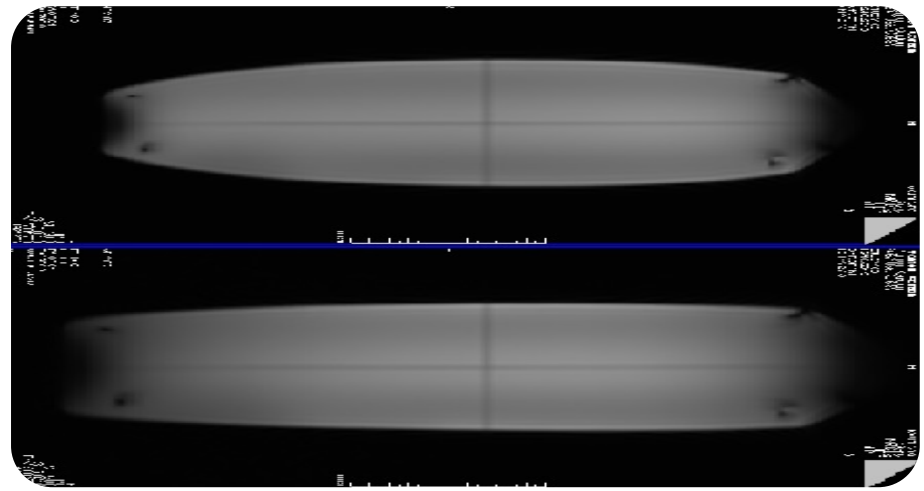
Required (cont):

- b=0 scans acquired with reversed PE – requirement for '`topup`'
- All scans acquired in a single "session", so that all have similar distortions and receive coil bias field (i.e., no intervening repositioning, or restroom breaks)

Recommended: Use SENSE1, instead of conventional Sum-of-Squares reconstruction, to reduce elevated noise floor from multi-channel coil combination.

Illustration of gradient non-linearity





Top: distorted image of water phantom 30 cm long

Bottom: 3D corrected image with vendor supplied spherical harmonic coefficients for unwarping.

Gradient nonlinearities

Due to the positioning of the table in the WU Connectom scanner, there are appreciable distortions due to gradient nonlinearities.

Before gradient nonlinearity correction | After gradient nonlinearity correction

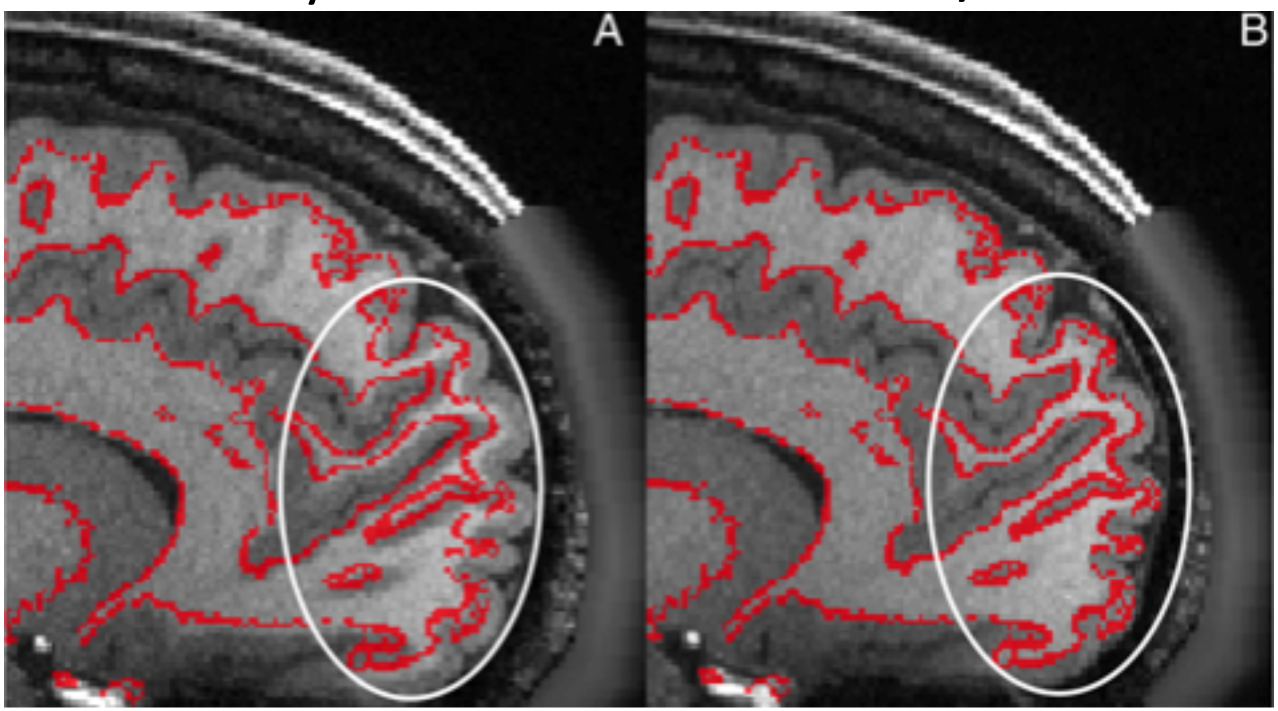


Figure 10, Glasser et al, 2013

Gradient nonlinearities

Due to the positioning of the table in the WU Connectom scanner, there are appreciable distortions due to gradient nonlinearities.

- These distortions are corrected for all scan types in the HCP processing.
- Short bore scanners also typically have increased gradient nonlinearities.
- Easily correctable in the HCP pipelines by supplying the appropriate "gradient coefficient" file for your scanner

See Appendix I of the HCP-Main release documentation for

- More details for consideration for "HCP-style" acquisitions on other magnets
- Detailed parameters for HCP protocols

http://humanconnectome.org/documentation/S500/HCP_S500+MEG2_Release_Appendix_I.pdf

Acknowledgements:
Matt Glasser
Junqian "Gordon" Xu

Daily Login & Internet Access Setup

- HCP Course
  - User: HCP Course Password: hcpcourse
- Internet Access
  - Click on Upper right hand screen icon of 2 computer screens
  - Select Marriott_CONFERENCE network
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  - Select Please click here to login to the internet
    - Enter Passcode: HCP-FSL
    - Leave email blank
    - Select check box to agree to terms of service
    - Press Submit
- Please log out but do not turn off your machine at the end of each session.