MRI Acquisition Recommendations for Infinitome & Labs

Market: Global
Product: Infinitome & Labs
Software Release Version: PrOv R.V.0.2.0
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1. Introduction

This document provides an overview of the recommended MRI acquisition protocols when obtaining scans for use with o8t's Infinitome & Labs products.

The Omniscient software utilizes standard high-resolution anatomical MRI along with high-quality diffusion and resting state fMRI (rs-fMRI) acquisitions to generate connectomic maps of the brain.

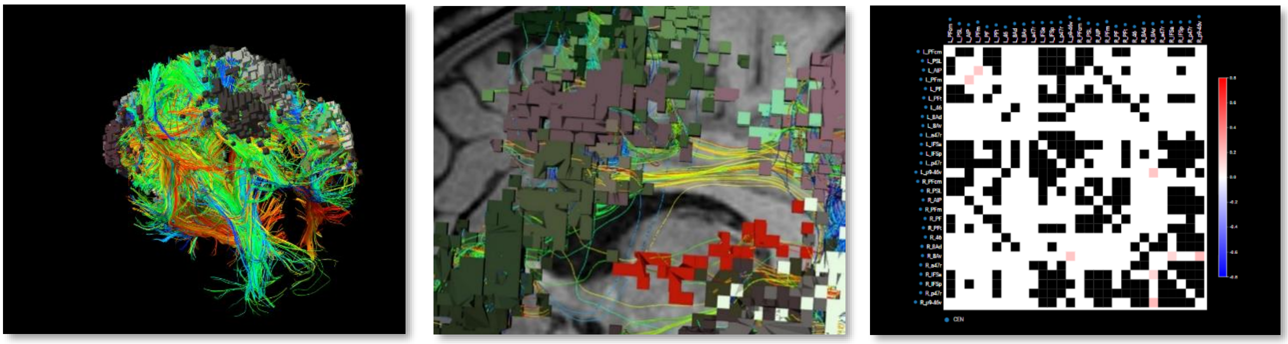


Figure 1 Example outputs generated by Omniscient software. From left to right: whole-brain tractography with parcellations, parcellations and network connections co-registered on anatomical T1, and connectivity correlation matrix showing regions of variance when compared to normative data

These three acquisitions must be obtained for each study:

i. DWI with high scan directions (similar to DTI) → Jump to section
ii. Resting-state fMRI (similar to fMRI BOLD) → Jump to section
iii. 3D or thin-slice T1 (similar to navigation scan) → Jump to section

2. Compatibility

Software is compatible with GE, Philips, Siemens scanners of 1.5T and 3.0T field strength. BOLD EPI and DTI must be enabled on scanner.

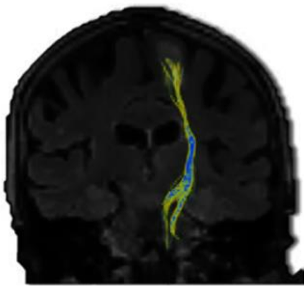
3. Patient setup

- Supine, reduce head angulation as much as possible
- Diffusion and fMRI/BOLD should be acquired BEFORE contrast injection
- During rs-fMRI the patient should be instructed to rest quietly with eyes open, to clear their mind, and to not fall asleep

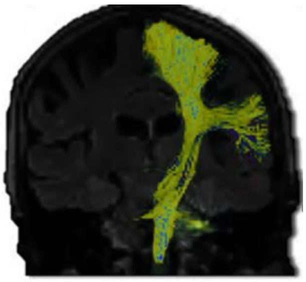
4. Diffusion scan

4.1. Background

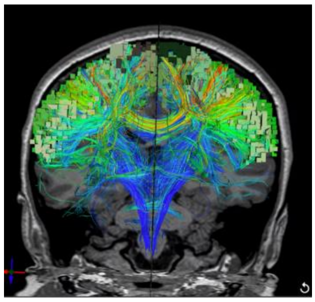
This is a high-resolution multi-scan directional diffusion scan, which is most similar to a diffusion tensor image (DTI) acquisition. From this high-direction DTI acquisition, we utilize an alternative algorithm to DTI called constrained spherical deconvolution (CSD) to generate tracts within the brain, which may improve performance in areas of crossing subcortical fibers.



Cortico-spinal tractography using standard DTI[1]



Cortico-spinal tractography using CSD[1]



Motor network generated from Omniscient Neurotechnology software

The most important aspect for this scan to allow for optimal algorithm performance is to achieve whole brain coverage with the highest number of scan directions possible in a clinically achievable time. Isotropic voxels are highly desired, and scan thickness should be as close to 2 mm as possible.

4.2. General requirements – Diffusion Scan

- ***Required:*** Axial DTI (Multi-direction DWI)
- ***Required:*** > 30 gradient directions
    - ***Recommended:*** >40 gradient directions
- ***Required:*** Gradient directions must be equally distributed
    - ***Tip:*** *This is a pitfall specific to our software; pay attention to bold requirements in table below*
- ***Required:*** 1 baseline b0 scan, 1 b-value = 1000 s/mm2 (multiple b-values not supported)
- ***Required:*** Isoptropic voxels in scan plane and full brain coverage
    - ***Recommended:*** Voxel size: 2x2x2 mm (see comment regarding slice thickness)
    - ***Recommended:*** FOV = 240 mm and matrix = 120 x 120
- ***Required:*** Thin slice thickness; <3mm
    - ***Recommended:*** 2mm preferred
    - ***Tip:*** *to achieve full brain coverage with minimal slice thickness, set scan parameters to 2 mm slice thickness and appropriate matrix and FOV size; check for full brain coverage with maximum slice count; increase TR as needed to add slices; when TR is at max, increase slice thickness*
- **Target Scan Time:** 6:30 (30 directions), 13:00 (64 directions)

1 Henderson, F., Abdullah, K. G., Verma, R., & Brem, S. (2020). Tractography and the connectome in neurosurgical treatment of gliomas: the premise, the progress, and the potential, Neurosurgical Focus FOC, 48(2), E6.

4.3. Scanner specific summary – Diffusion Scan

Scanner	Scan	Acquisition Parameters	DTI specific parameters
Siemens	In Siemens library: Head > clinical libraries > advanced applications libraries > diffusion and perfusion Select: ep2d_diff_mddw_20_p2	<u>Routine:</u> Slices: 90 (adjust for full brain) Dist. Factor: 0% Orientation: Transversal Phase enc. Dir. A>>P Phase oversampling: 0% FoV read 240 FoV phase 100.0% Slice thickness: 2.0 TR: SHORTEST TE: SHORTEST Averages: 1 <u>Resolution-Common :</u> Base resolution: 120 Phase resolution: 100% <u>Resolution-IPAT :</u> PAT mode: GRAPPA Accel. Factor PE: 2 <u>Geometry-Common:</u> Multi-Slice mode/Series : Interleaved	<u>Diff-Neuro</u> *Diffusion mode: MDDW *Directions: Select 30 or 64 *Diffusion Scheme : Bipolar Diff. weighted images: On Trace weighted images: Off Mosaic: On Diff. weightings: 2 b-Value: 0 b-Value: 1000
GE	<u>Parameters</u> Pulse Seq: Spin Echo Imaging Mode: 2D Imaging Options: EPI, DIFF, Asset	<u>Acquisition Timing</u> Freq: 120 Phase: 120 NEX: 1 Freq DIR: R/L Phase FOV: 1 <u>Scanning Range</u> FOV: 24.0 Slice Thickness: 2.0 Spacing: 0 # of Slices: 80 (adjust for full brain) Auto Shim: Auto Phase Correction: Yes <u>Scan Timing</u> TE: Min TR: 8000 (adjust to increase slices for full brain)	Number of Diffusion Directions: 40 b-value: 1000 Optimized TE : Yes Dual Spin Echo: Off Diffusion Directions: Tensor Number of T2 images: 1
Philips	EPI Single Shot <u>Contrast</u> Scan Mode: MS Technique: SE Fast imaging mode: EPI Shot mode: Single-shot	<u>Geometry</u> FOV: RL(mm): 240 AP(mm): 240 ACQ voxel size: RL(mm): 2 AP(mm): 2 FH(mm): 2 Slice Thickness (mm): 2 Reconstruction matrix: 120 Sense: yes Stacks Slices: 90 (adjust for full brain) Gap: 0 Slice Orientation: Axial <u>Contrast</u> TE: Shortest TR: Shortest	<u>Contrast</u> Directional resolution = High (32) ***Gradient Overplus = No** Gradient Duration = Maximum Nr of b-factors = 2 b-factor order = Ascending max b-factor = 1000 average high b = No

5. EPI BOLD Resting State fMRI

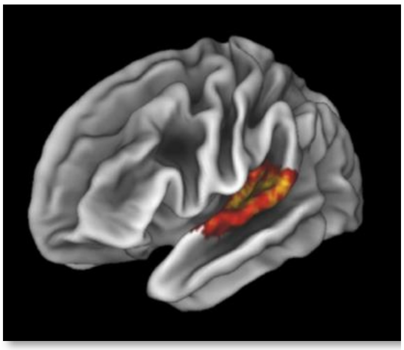
5.1. Background

This is a routine fMRI acquisition similar to task-based fMRI, however the patient is not instructed to perform a task. Instead, the number of acquisitions (time) is increased and the patient is given instructions to rest quietly with eyes open, to clear their mind, and to not fall asleep.

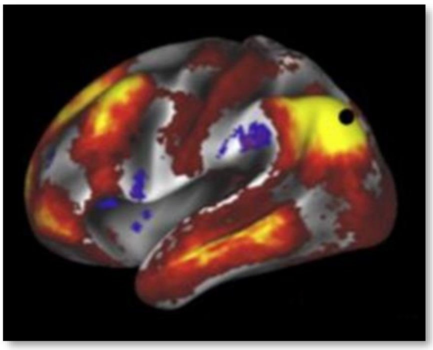
Resting state fMRI can be used to see synchronized BOLD response in different areas of the brain; the method is based on the idea that networks in the brain need to rapidly respond synchronously; so they remain "always on" in a synchronous state during the 'resting state'. Thus much of the analysis in rs-fMRI is related to studying if different areas of the brain have synchronously fluctuating BOLD response, possibly indicating connection as part of a network.

This is different than standard task-based fMRI in that task based seeks to link an action (tapping finger) to one specific area in the brain (increased BOLD activation in motor strip).

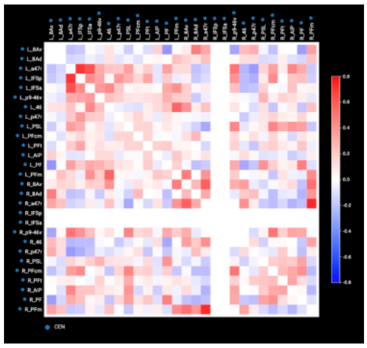
Omniscient software utilizes this information to display a matrix showing connectivity which can be analyzed for research purposes.



BOLD response: Task-based fMRI



BOLD response: rs-fMRI



Correlation matrix: rs-fMRI

5.2. General Requirements – EPI BOLD rs-fMRI

- ***Required:*** Axial BOLD EPI
- ***Required:*** 180 volumes/run
- ***Required:*** Full brain coverage
    - ***Recommended:*** Slice thickness: 3 mm
    - ***Recommended:*** 3.0 mm x 3.0 mm isotropic voxels highly preferred
- ***Recommended:*** TE/TR : Optimized for T2* contrast, TE = 30 ms and TR = ~2000 ms on a 3.0T an TE = 50 ms on a 1.5T
- ***Required:*** The patient should be instructed to rest quietly with eyes open, to clear their mind, and to not fall asleep
- ***Target scan time:*** 6-8 min

5.3. Scanner specific summary – EPI BOLD rs-fMRI

Scanner	Scan	Acquisition Parameters	BOLD specific parameters
Siemens	In Siemens library: Head > clinical libraries > advanced applications libraries > bold imaging Select: ep2d_bold_moco_p2	Routine: Slices: 45 (adjust for full brain) Dist. Factor: 0% Orientation: Transversal Phase enc. Dir. A>>P Phase oversampling: 0% FoV read 240 FoV phase 100.0% Slice thickness: 3.0 TR: SHORTEST TE: 30 (50 if 1.5T) Averages: 1 Contrast-Common: Flip angle: 90 Resolution-Common: Base resolution: 80 Phase Resolution: 100 Geometry-Common: Multi-slice mode/Series: Interleaved	BOLD: Motion correction: Off Ignore meas. At start: 0 Ignore after transition: 0 Measurements: 180 Delay in TR: 0 Multiple Series: Off Model transition states (BOLD tab): Off GLM Statistics : On Dynamic t-maps : On
GE	Parameters: Mode: 2D Pulse Seq: Gradient Echo Imaging Options: MPh, EPI	Acquisition Timing Freq: 80 Phase: 80 NEX: 1 Freq DIR: R/L Phase FOV: 1 Shim: Auto Phase Correction: Yes Scanning Range FOV: 24.0 Slice Thickness: 3.0 Spacing: 0 # of Slices: 80 (adjust for full brain) Scan Timing TE: 30 TR: Shortest	Multi-Phase Screen Slice per Location : 200 Initial State : Control PSD Trigger : Internal Slice Order : Interleaved
Philips	EPI Single-Shot Contrast Scan mode: MS Technique: FFE Fast imaging mode: EPI Shot mode: Single-shot	Geometry FOV: RL(mm): 240 AP(mm): 240 ACQ voxel size: RL(mm): 3 AP(mm): 3 FH(mm): 3 Slice Thickness (mm): 3 Reconstruction matrix: 80 Sense: yes Stacks Slices: 65 (adjust for full brain) Gap: 0 Slice Orientation: Axial Contrast TE: 30 TR: Shortest Flip angle: 90 Fat suppression: SPIR, strong	DYN/ANG Dyn scan: 200 Dyn scan times: Shortest Fov time mode: Default Dummy scans: 0 Immediate subtraction: No Fast next scan: No Synch ext. device: No Manual start: yes Dyn stabilization: Regular Prospect. Motion. Corr.: No

6. High-resolution anatomical scan

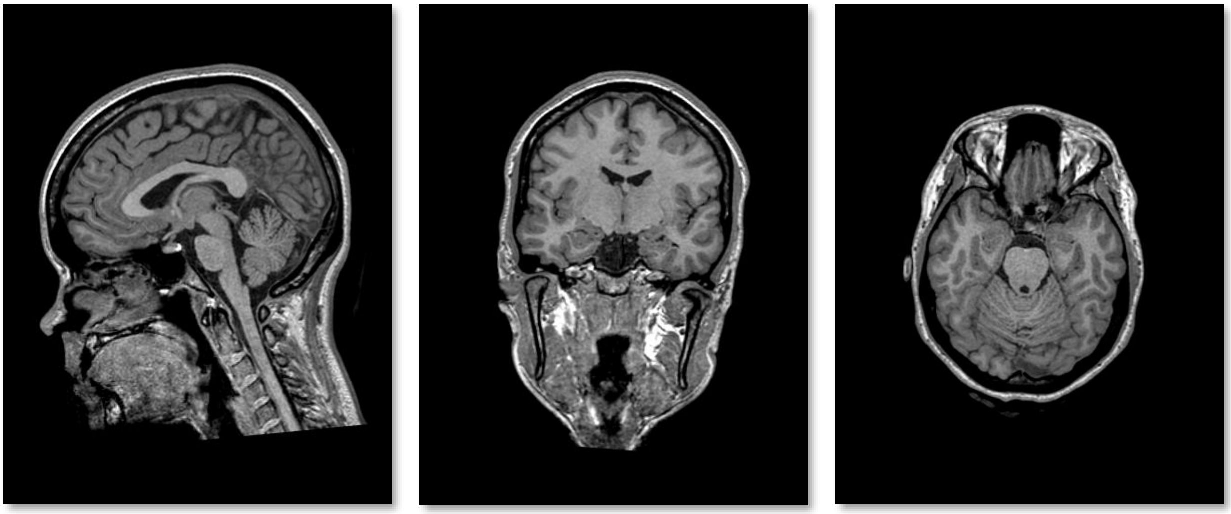


Figure 2 Example high-resolution anatomical scans

6.1. Background

This is a standard acquisition similar to navigation quality scans (Stealth scan, Brainlab scan, etc). This scan should balance high-resolution and high-tissue contrast (T1 weighting).

6.2. Summarized Checklist – Anatomical Scan

- ***Required:*** T1 weighting
  - ***Recommended:*** *3D volume acquisition preferred, thin-slice 2D is permitted*
  - ***Recommended:*** *Axial preferred; sagittal is permitted*
- ***Required:*** Thin slices: ~1mm – 2mm
- ***Required:*** FOV to cover whole head
  - ***Recommended:*** 256 x 256 matrix to achieve isotropic, other matrix sizes are permitted
  - ***Recommended:*** Isotropic voxels are preferred but not required
- ***Required:*** 0.0 mm gap/spacing between slices, no overlap between slices
- ***Required:*** 1 single acquisition, no concatenation
  - ***Recommended:*** Select for T1 weighting and optimal tissue contrast
- ***Required:*** 1 average
  - ***Recommended:*** More if desired for higher SNR
- **Target scan time:** <6 mins

6.3. Scanner Specific Summary – Anatomical Scan

Scanner	Scan	Acquisition Parameters	Contrast Parameters	Other
Siemens	MPRAGE (3D)	Routine FoV read: 256 FoV phase: 100% Slice thickness: 1.00 Slices per slab: 190 (adjust for full head) Averages: 1 Resolution-Common Base resolution: 256 Phase resolution: 100 Slice resolution: 100	TE: SHORTEST TR: SHORTEST	Resolution-Filter Image - Distortion Corr.: On - Mode: 3D Resolution-IPAT - PAT mode: GRAPPA - Accel. Factor PE: 2
GE	BRAVO (3D) or MPRAGE (3D)	Acquisition Timing Freq: 256 Phase: 256 NEX: 1 Phase FOV: 1 Scanning Range FOV: 25.6 Slice Thickness: 1.0 Spacing: 0 # of Slices: 190 (adjust for full head)	Scan Timing TE: Min TR: Auto	Graphic RX Location per Slab : 180 (adjust for full head)
Philips	3D T1-TFE or MPRAGE (3D)	Geometry FOV: RL(mm): 256 AP(mm): 256 ACQ voxel size: RL(mm): 1 AP(mm): 1 FH(mm): 1 Reconstruction matrix: 256 Sense: yes Stacks Slices: 190 (adjust for full head) Slice Orientation: Axial	Contrast Scan mode: 3D Contrast enhancement: T1 TE: Shortest TR: Shortest	

7. Routine Protocol Example

Series	Scan	Parameters	Check
1	Scout		
2	Calibration		
3	DTI	2 mm x 2 mm x 2 mm voxels - FOV = 25.6 cm - Matrix = 128 mm x 128 mm - Slice thickness = 2.0 mm b = 0, b = 1000 40 directions, bipolar/no gradient overplus Gap = 0.0 mm TE = Shortest, TR = Shortest Flip angle = 90 Full-brain coverage	
4	rs-fMRI	3 mm x 3 mm x 3 mm voxels - Fov = 240 mm - Matrix = 80 x 80 - Slice thickness = 3 mm 180 volumes/run TE = 30 ms TR = Shortest Flip angle = 90	
5	Axial T2 FLAIR (only if requested)	FOV = 25.6 cm Matrix = 256 x 256 Slice thickness = 2.0 mm (2D) Gap = 0.0 Full brain coverage	
6	Axial 3D T1 pre-contrast (only if requested)	3D FFE FOV = 25.6 cm Matrix = 256 x 256 Slice thickness = 1.0 mm (3D) Axial Gap = 0.0 TE = Shortest TR = Shortest Full head coverage	
7	Contrast Injection		
8	Axial 3D T1 post-contrast	3D TFE FOV = 25.6 cm Matrix = 256 x 256 Slice thickness = 1.0 mm (3D) Axial Gap = 0.0 TE = Shortest TR = Shortest Full head coverage	