Anatomical Imaging for fMRI and VBM

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MR Physics for SPM – 26 May 2026

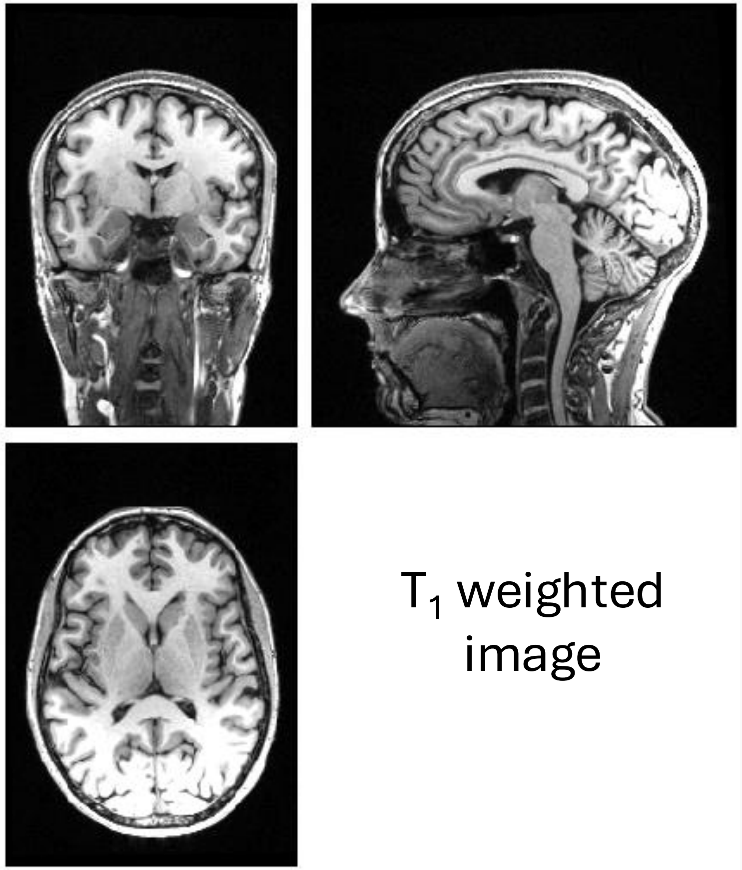
Functional Imaging Laboratory
Department of Imaging Neuroscience

Learning Objectives

- ❑ Understand the uses of anatomical imaging in fMRI and VBM
- ❑ Understand how to generate T_1 weighting
- ❑ Identify key acquisition parameters, sequences and when to choose them
- ❑ Be mindful of the impact of image contrast on VBM conclusions

Requirements for anatomical imaging

- High image contrast that accurately depicts morpohology
- Whole brain coverage
- High spatial resolution
- Minimum acquisition time
- No signal losses or artefacts

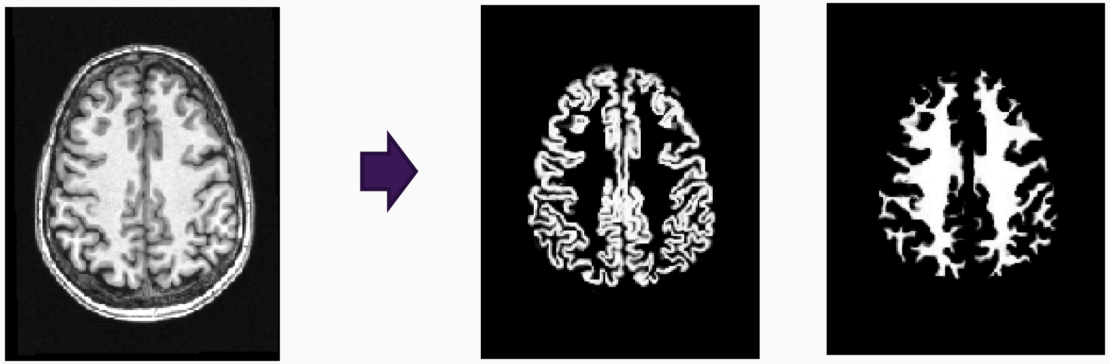


T_1 weighted image

Purpose: Testing for volumetric differences

Voxel-Based Morphometry (VBM) Pipeline

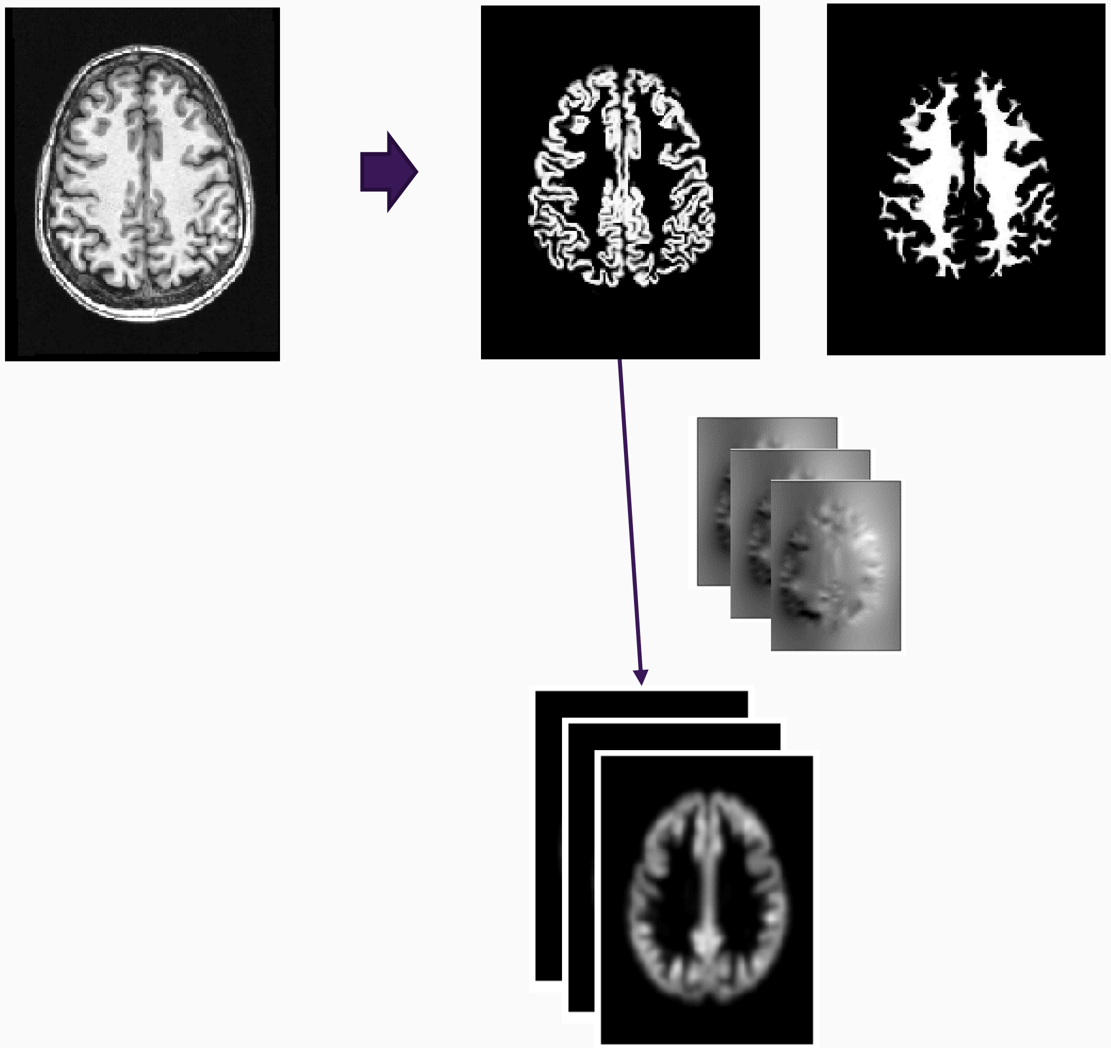
Segment an Anatomical Image Into Tissue Classes



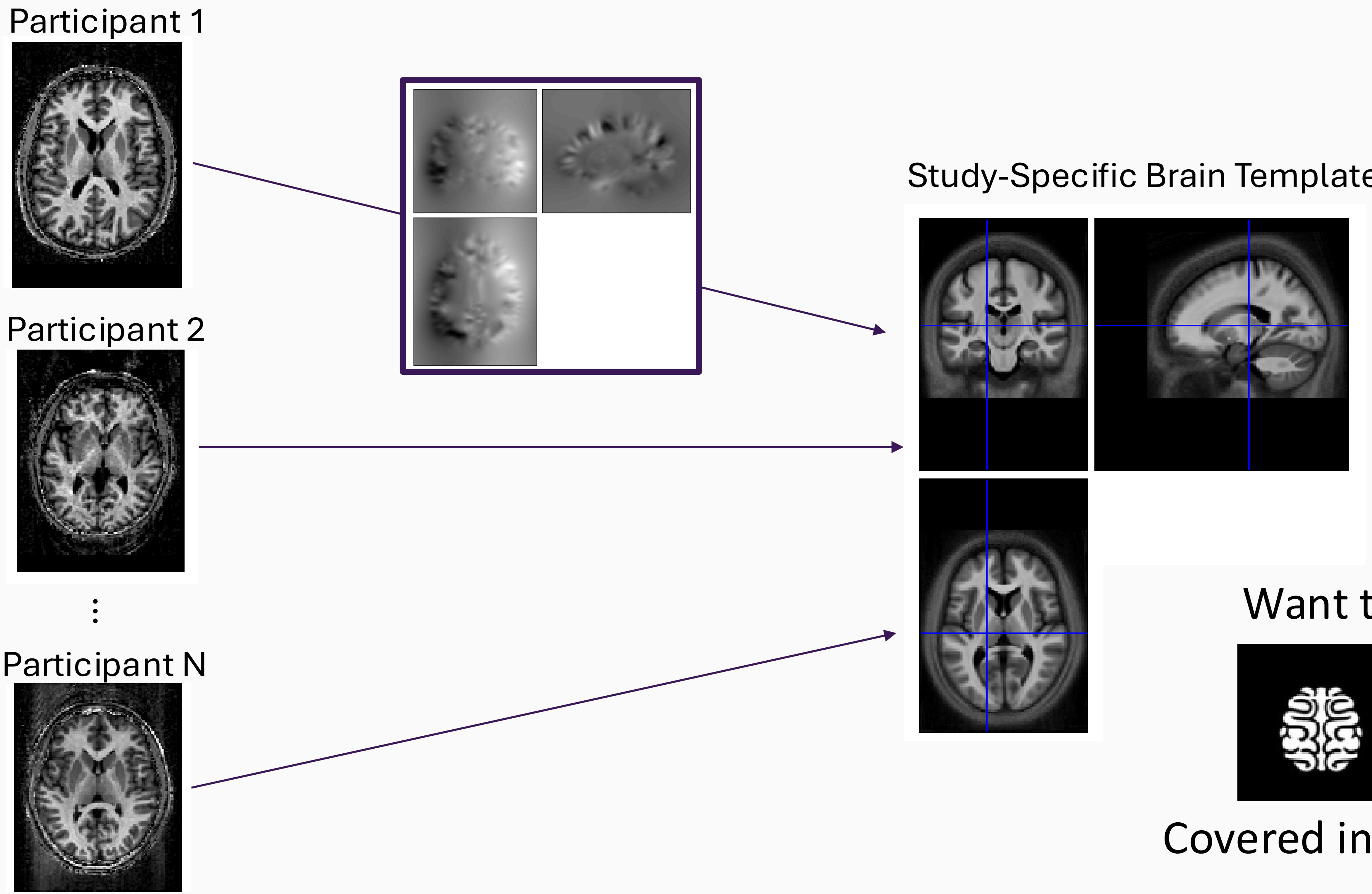
Purpose: Testing for volumetric differences

Voxel-Based Morphometry (VBM) Pipeline

- Segment an Anatomical Image Into Tissue Classes
- Calculate Deformations to Align the Images
- Normalise to Group Space
- Modulate & Spatially smooth
- Run Statistical Analysis



Purpose: Bringing brains into alignment

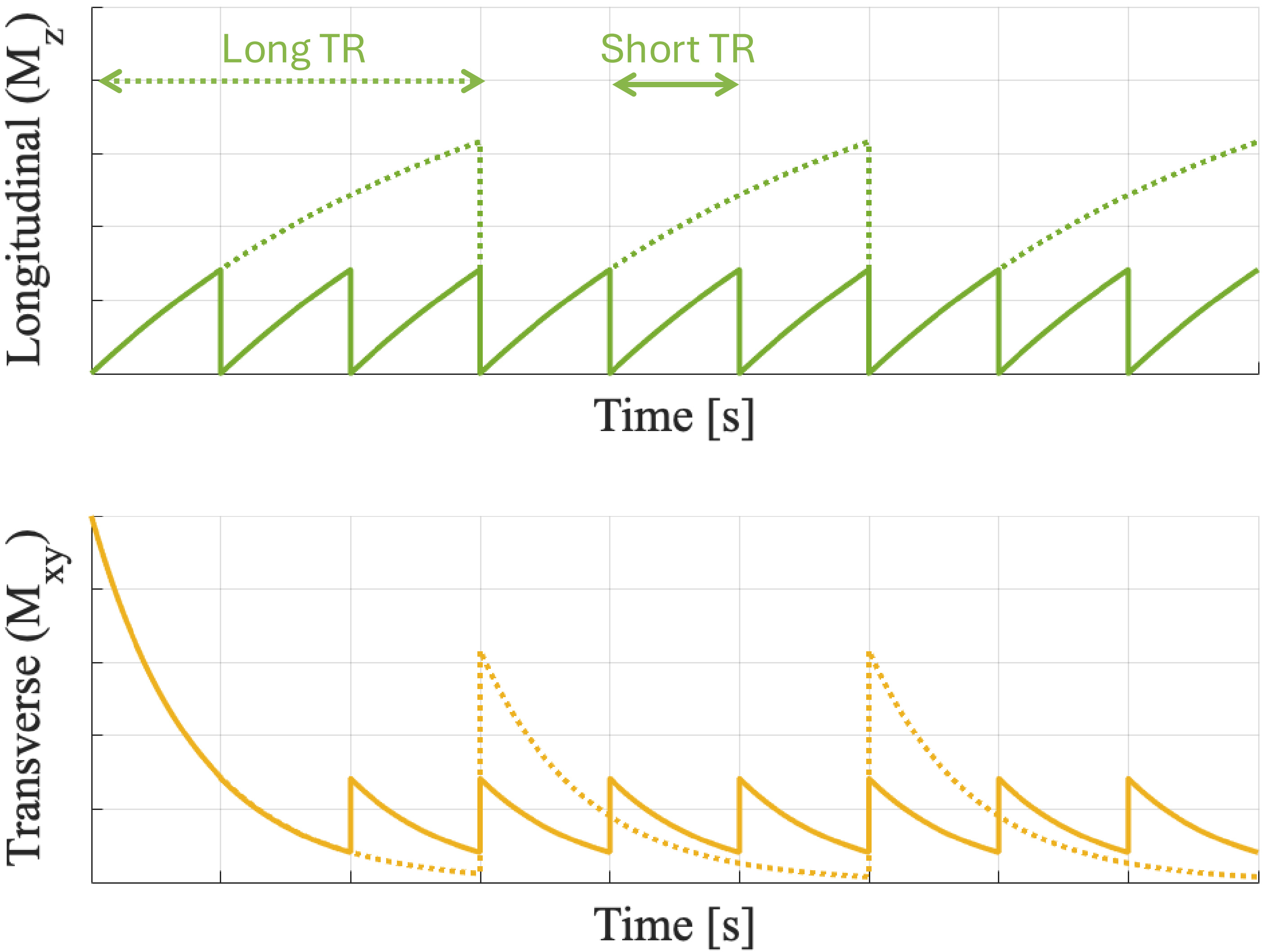


Want to learn more?

Covered in main SPM Course

Let’s revisit: Relaxometry to Generate Contrast

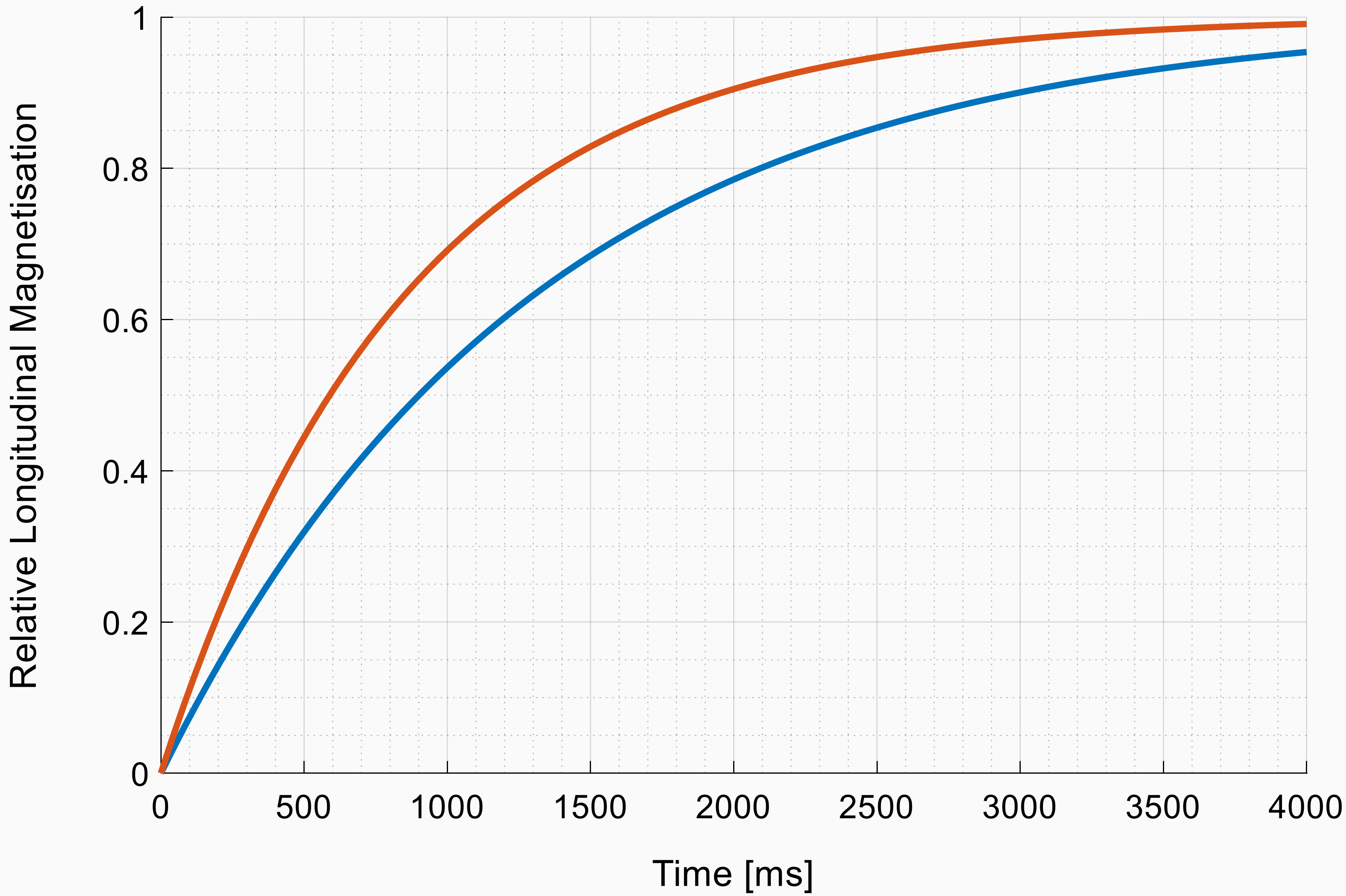
Recap: relaxometry



TR dictates how much time there is for longitudinal magnetisation to relax…

And therefore how much signal there is to sample…

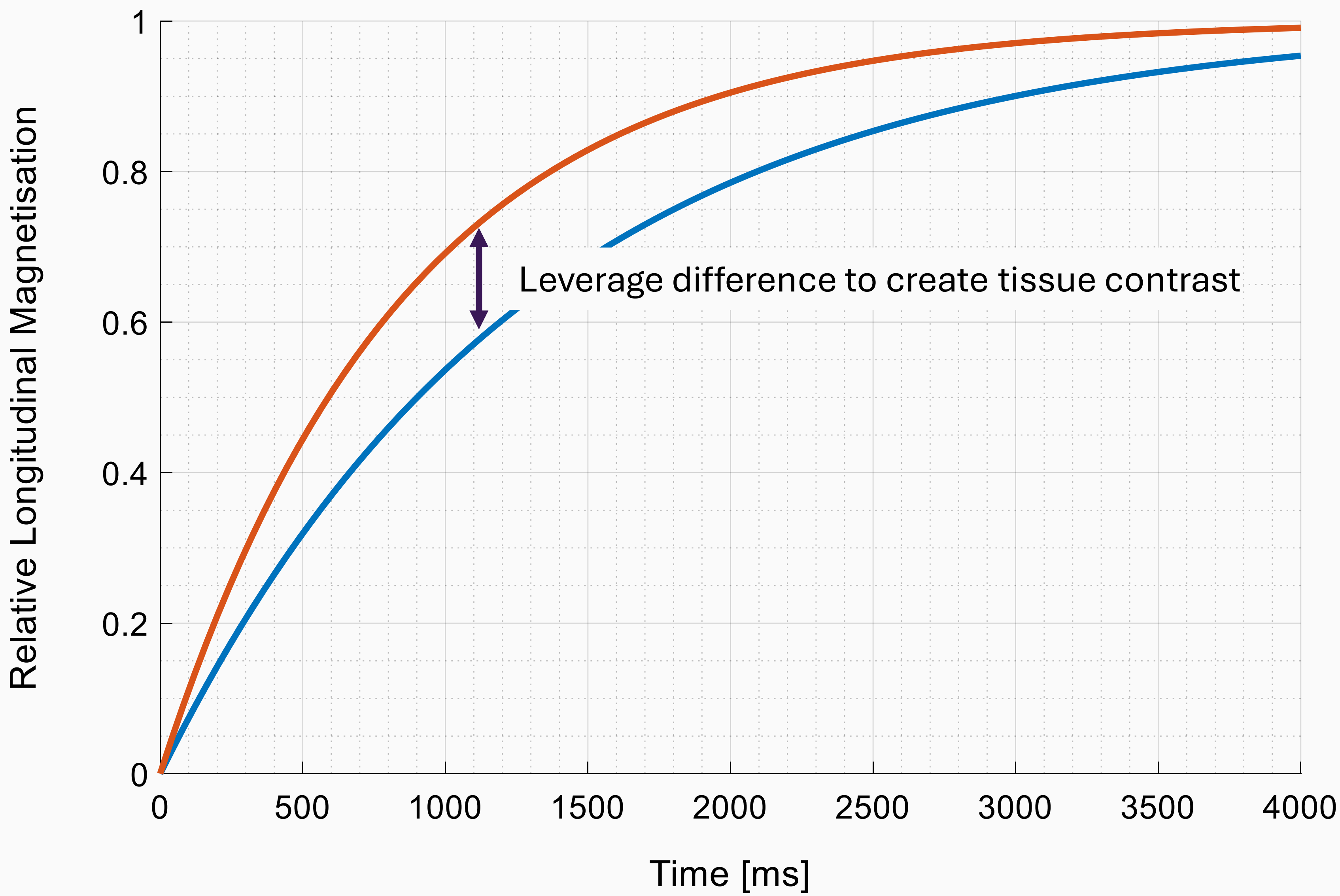
Contrast: T_1 weighting



T_1 describes the relaxation of longitudinal magnetisation

It depends on the local microstructure

Contrast: T_1 weighting

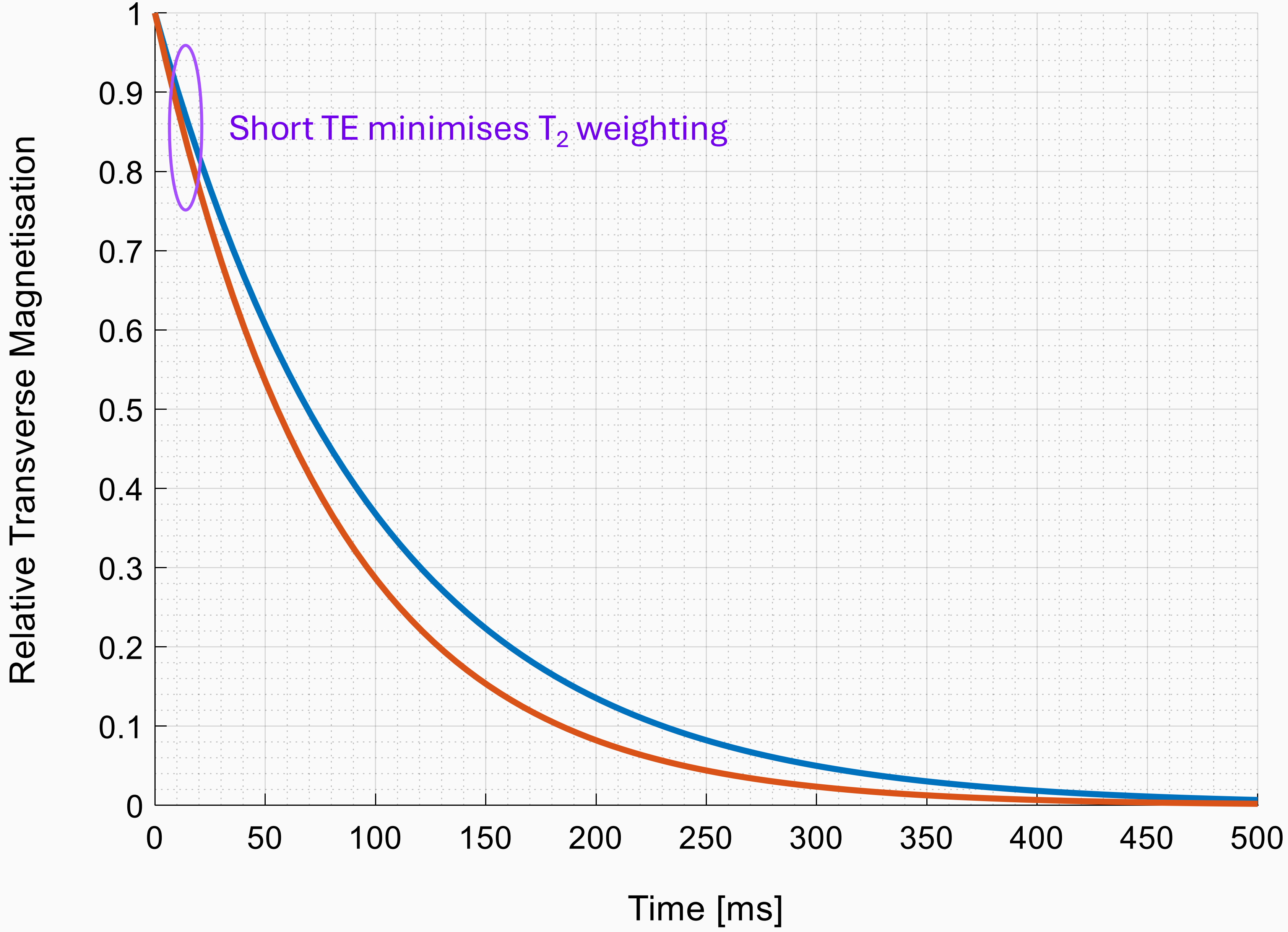


T_1 describes the relaxation of longitudinal magnetisation

It depends on the local microstructure

At 3T:
White Matter T1 ≈ 0.8 s
Grey Matter T1 ≈ 1.3 s

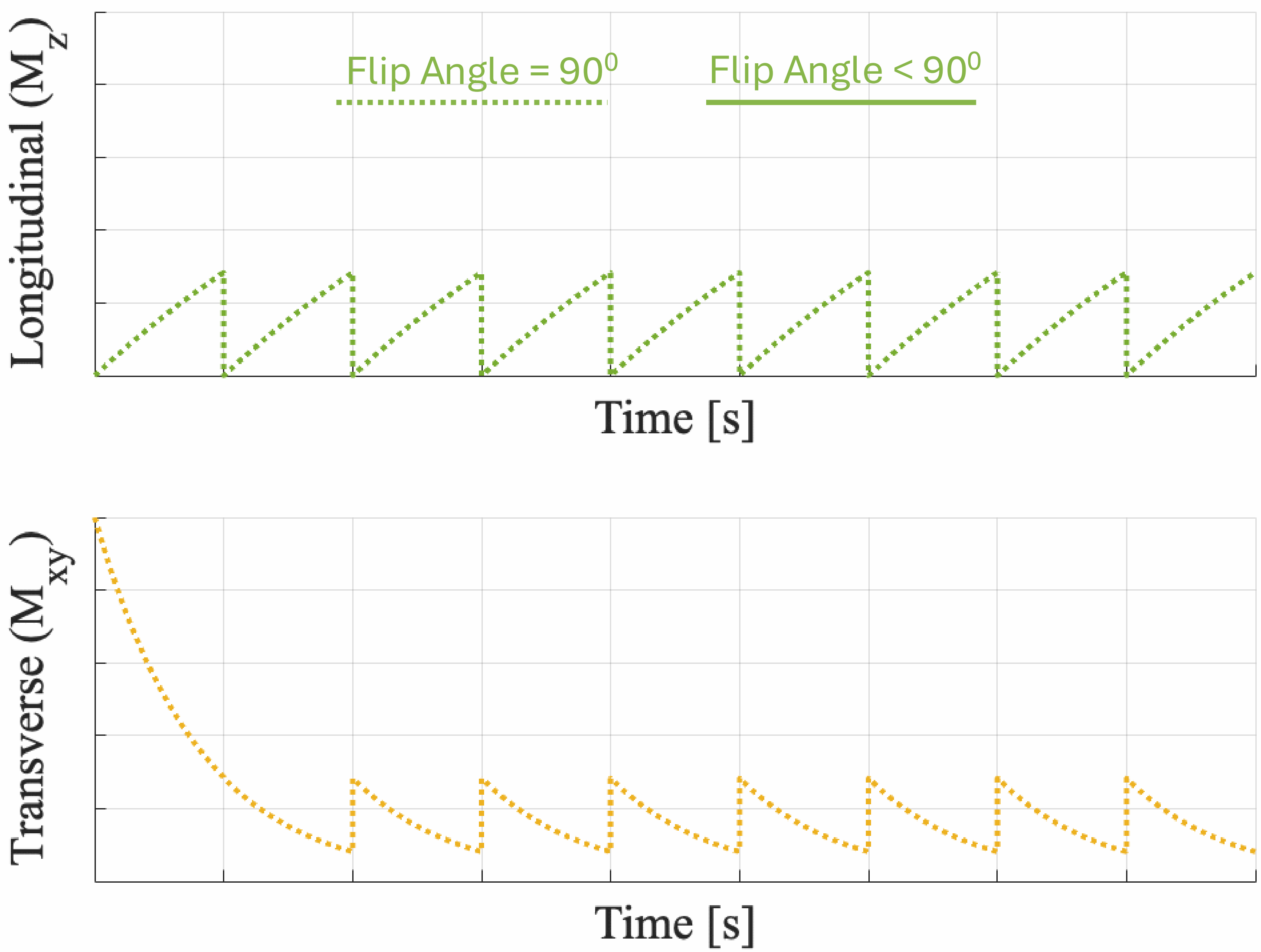
T_2* weighting also occurs!



T_2* describes how quickly transverse magnetisation decays

White Matter T_2* < Grey Matter T_2*

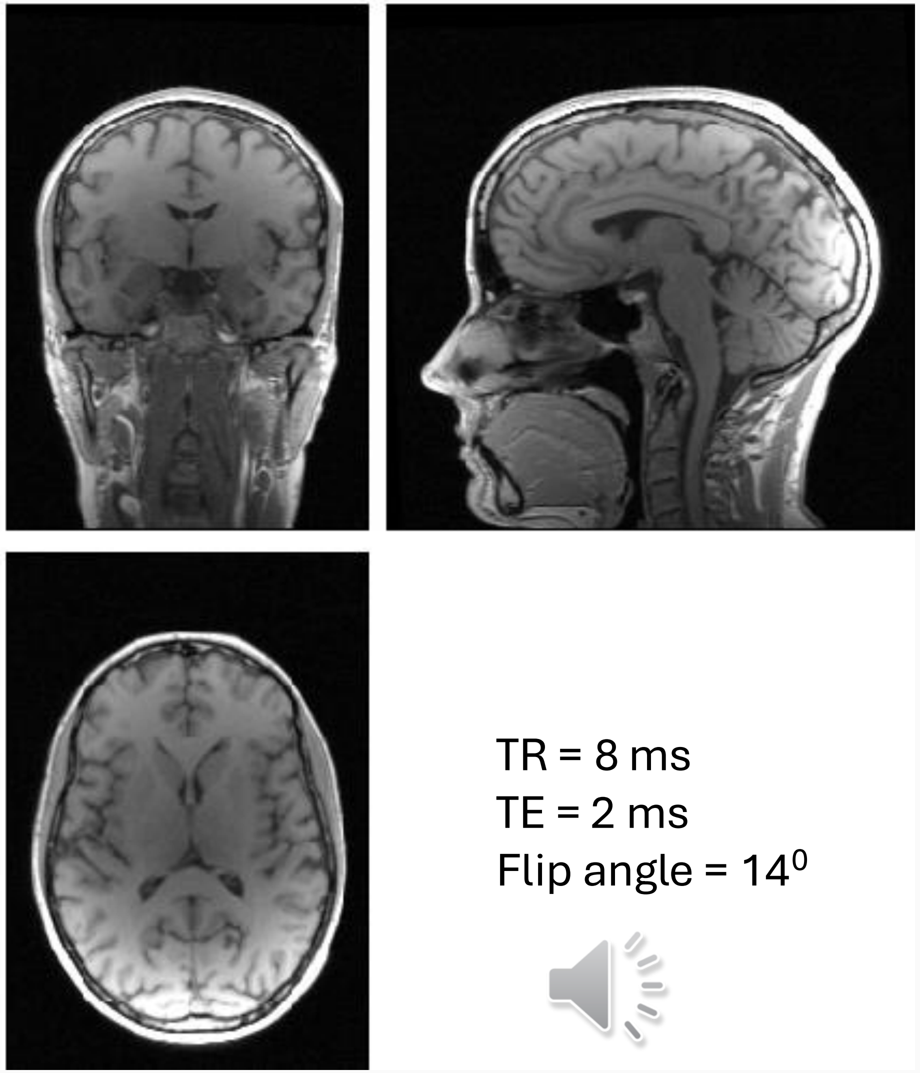
Recap: relaxometry



Flip Angle dictates how much longitudinal magnetisation we use each TR…

And therefore how much signal there is to sample…

Fast Low Angle Shot = FLASH

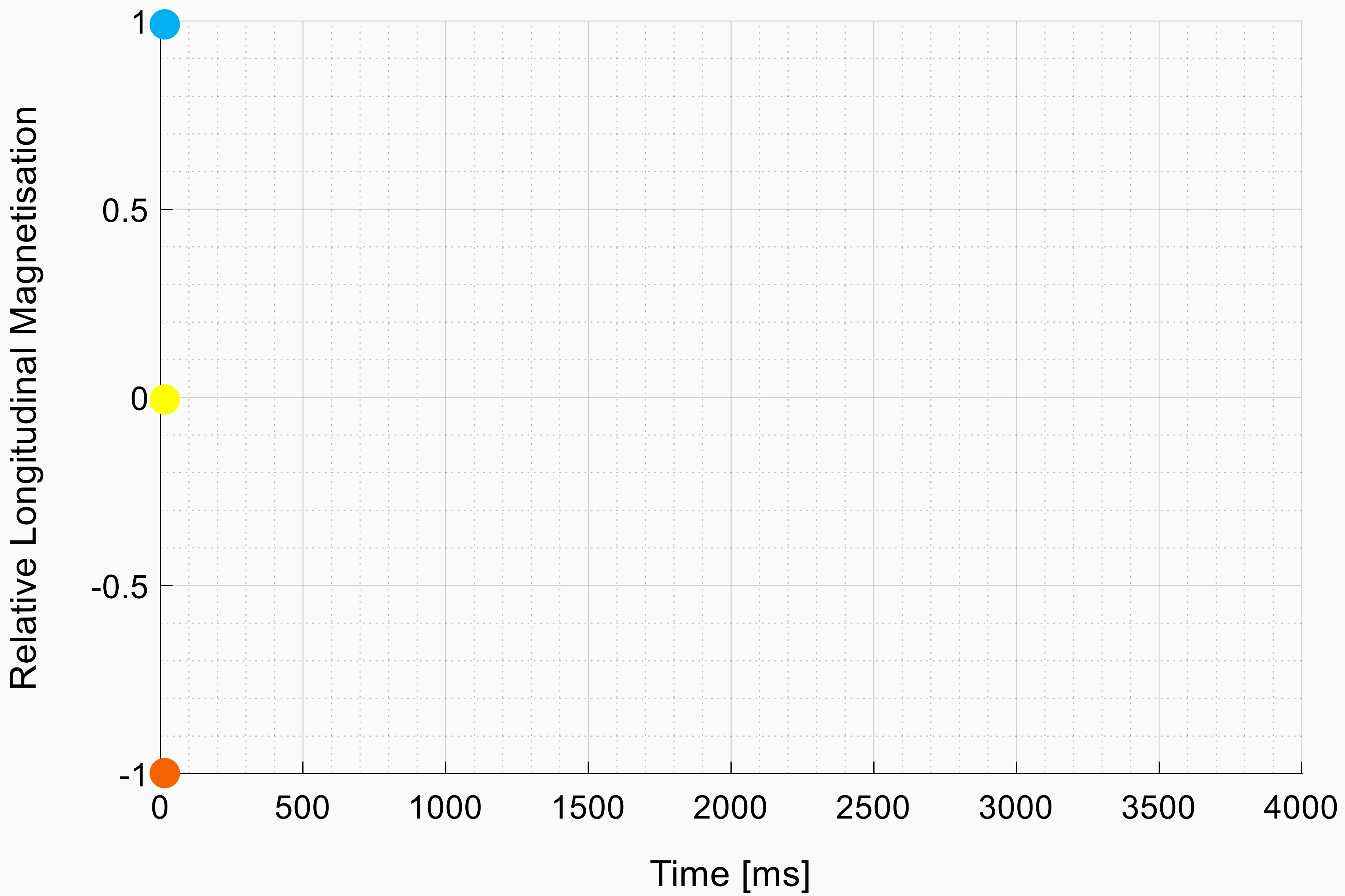


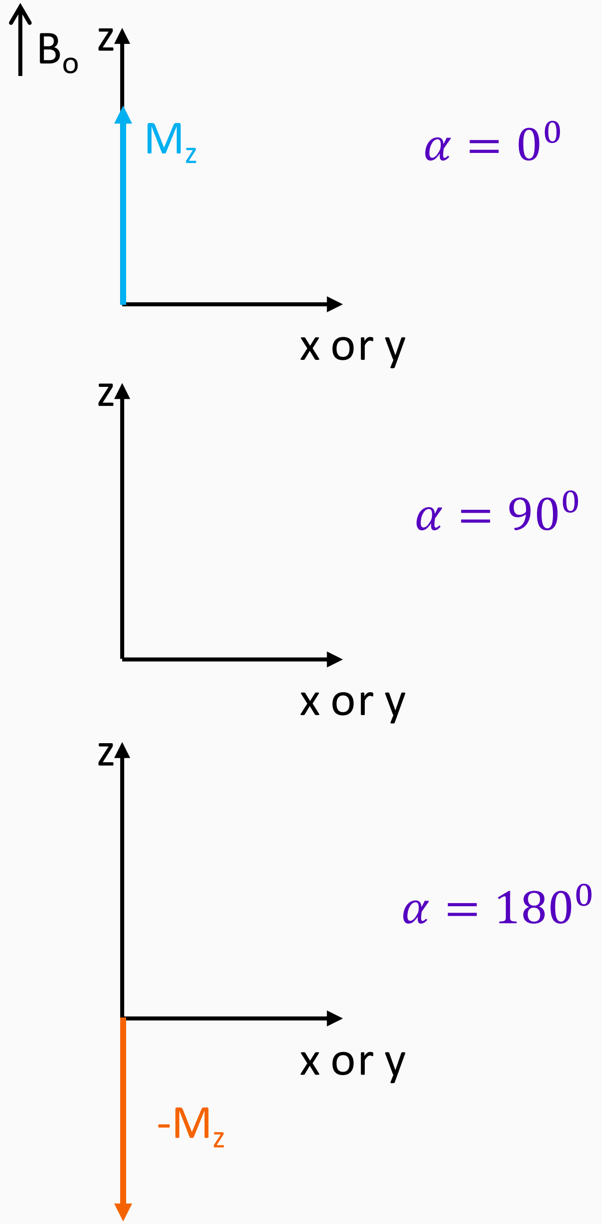
TR = 8 ms
TE = 2 ms
Flip angle = 14^0

An efficient gradient echo that combines short TR with small flip angle

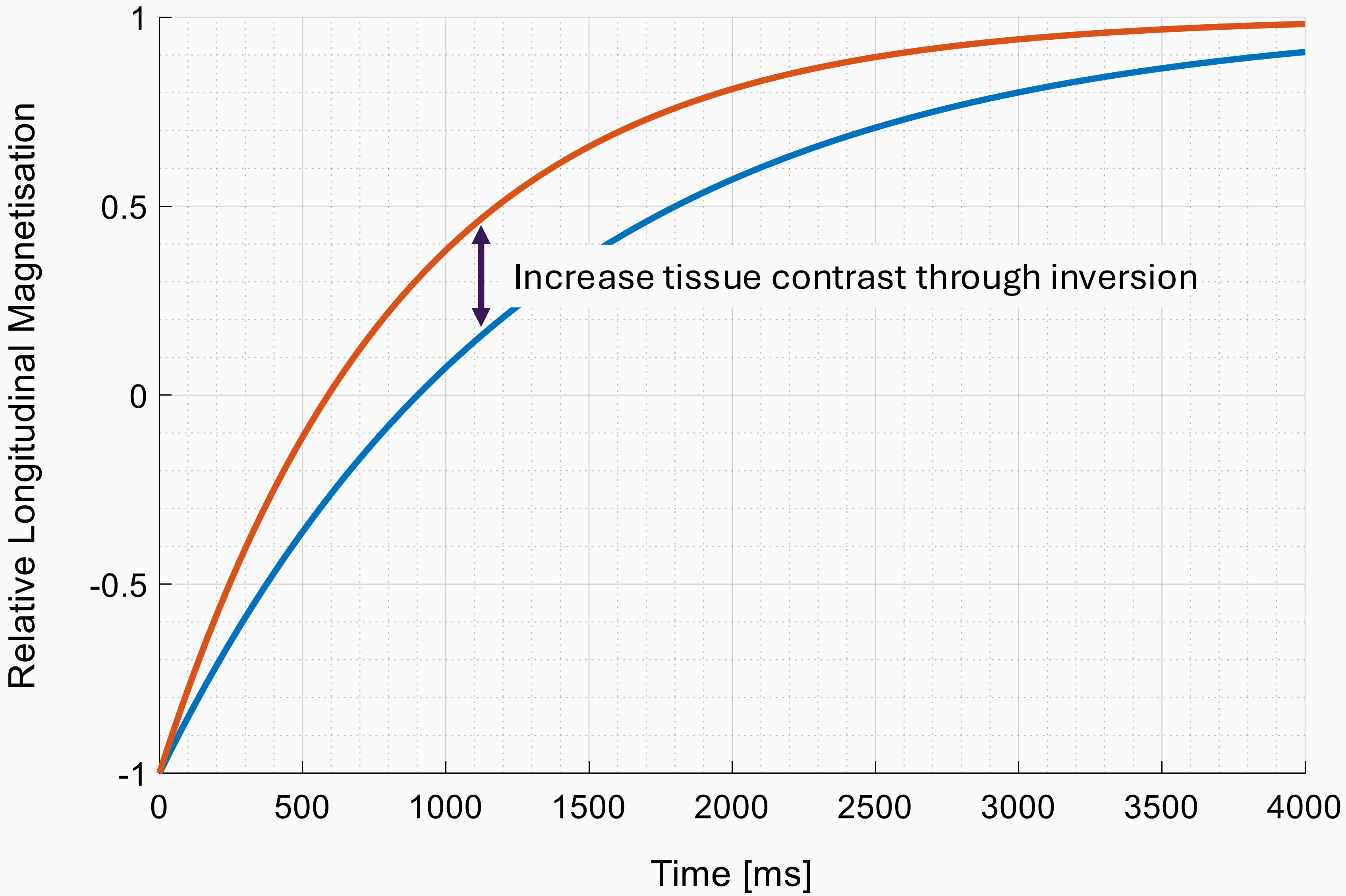
What if we want ***more*** contrast?

Recap: longitudinal magnetisation

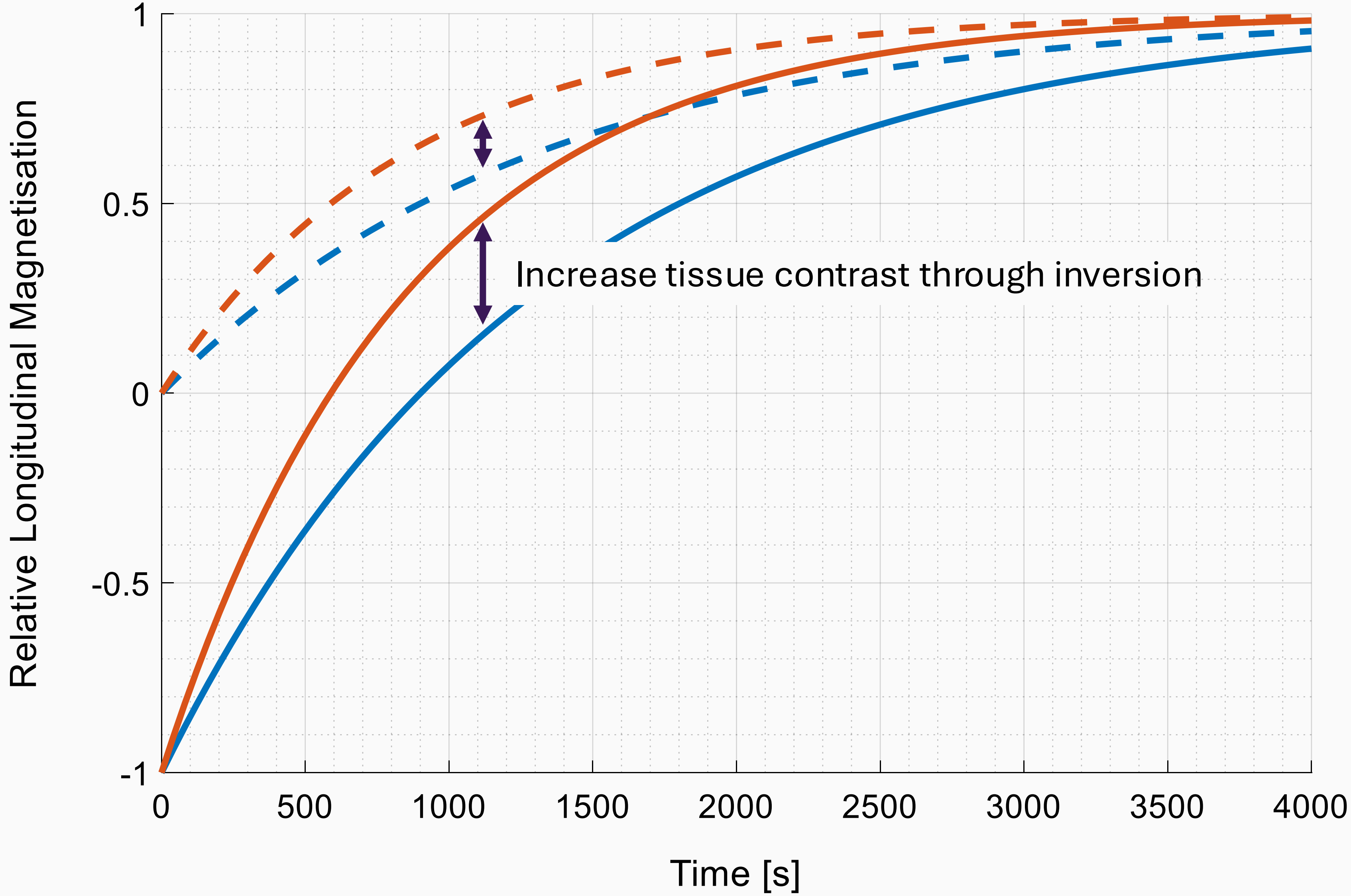




Magnetisation Preparation: Inversion



Magnetisation Preparation: Inversion



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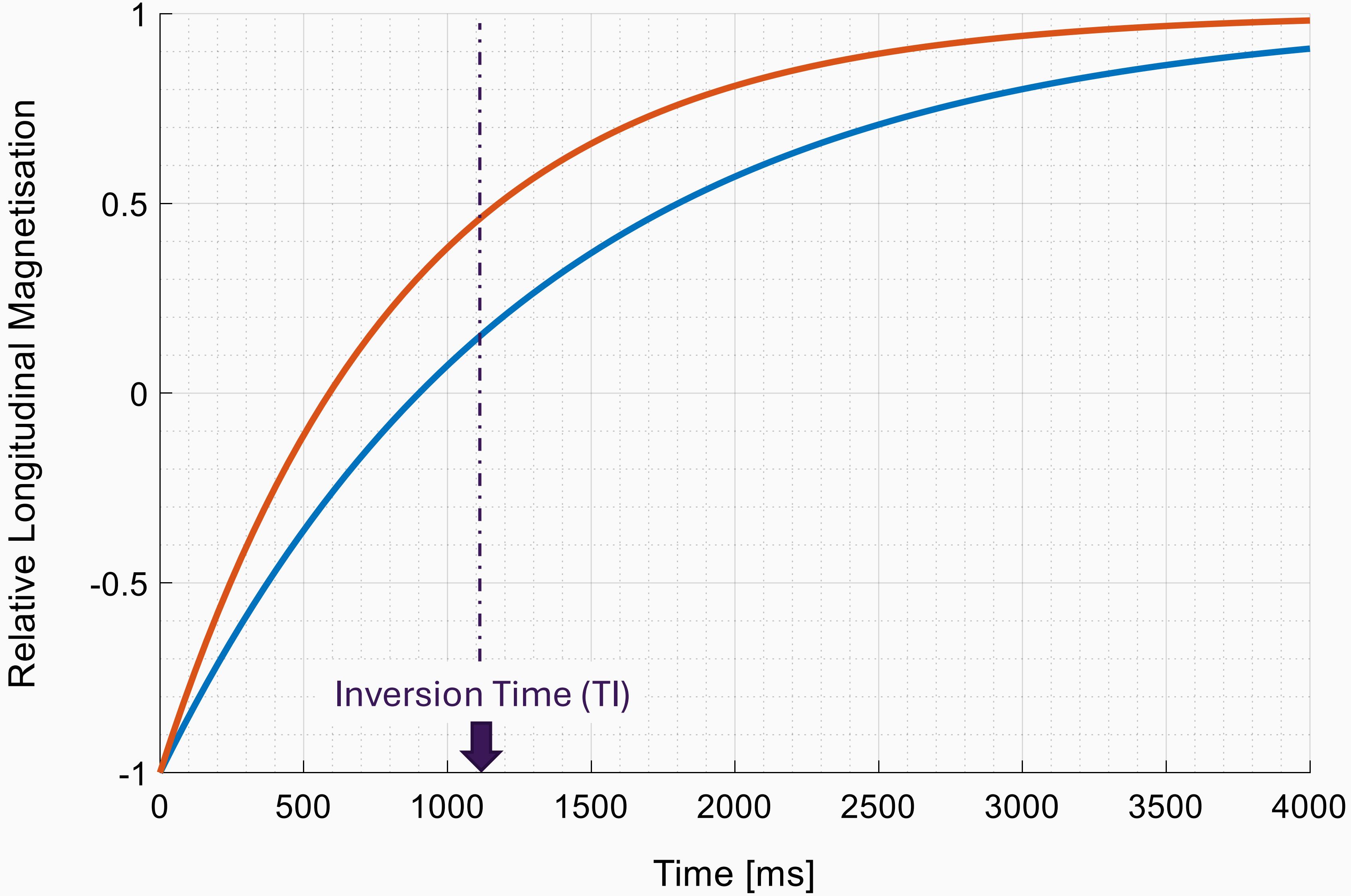
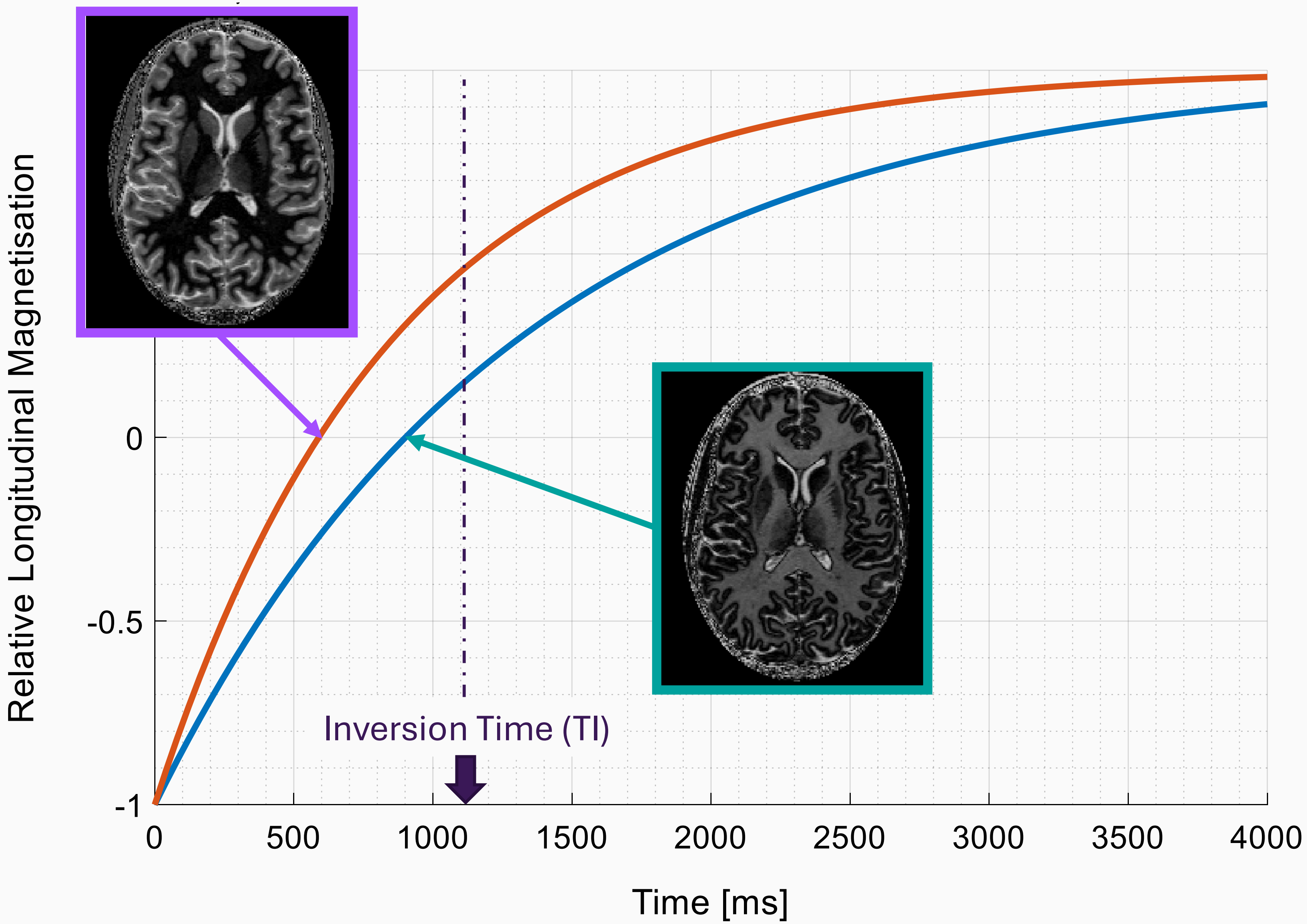


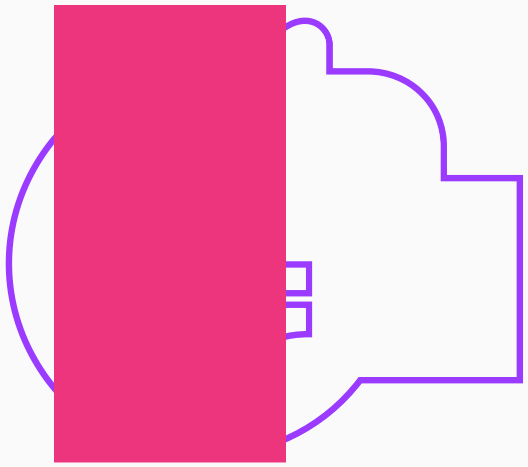
The inversion time is the time we allow contrast to develop between tissues

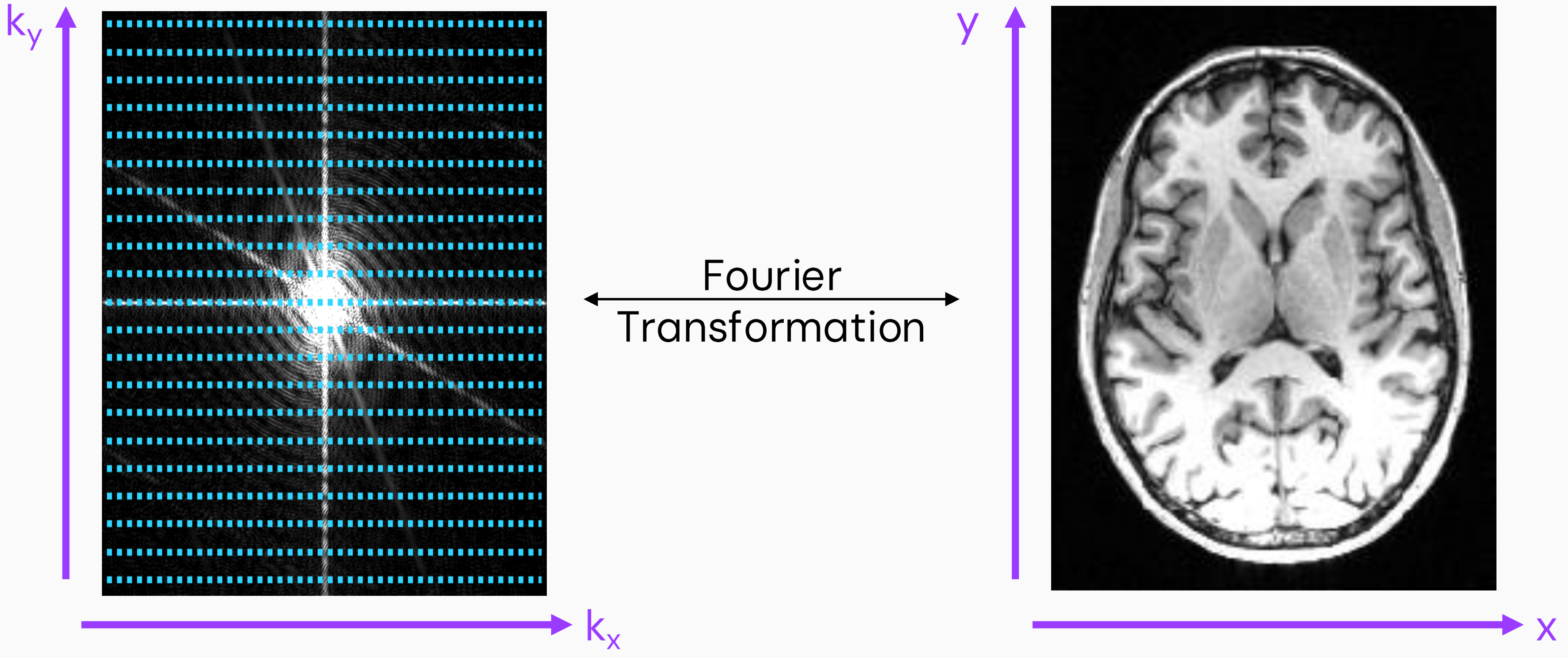
Magnetisation Preparation: Inversion



We can choose a TI to null a given tissue type!

Recap: filling k-space





Example: axial Field of View (FoV) = 180 mm (left-right) x 220 mm (anterior-posterior) with 1mm resolution => 39,600 TRs!
TR ~ 10 ms => scan time of 6.6 minutes

Magnetisation Preparation

<u>3D Magnetisation Prepared RApid Gradient Echo:</u>

1. **Invert the magnetisation with a non-selective 180^0 pulse to amplify T1 based contrast**
2. **Wait some inversion time**
3. **Excite and acquire a series of gradient echoes for the inner phase-encoded direction**
4. **Allow further magnetisation recovery**
5. **Repeat for the outer phase-encoded direction**

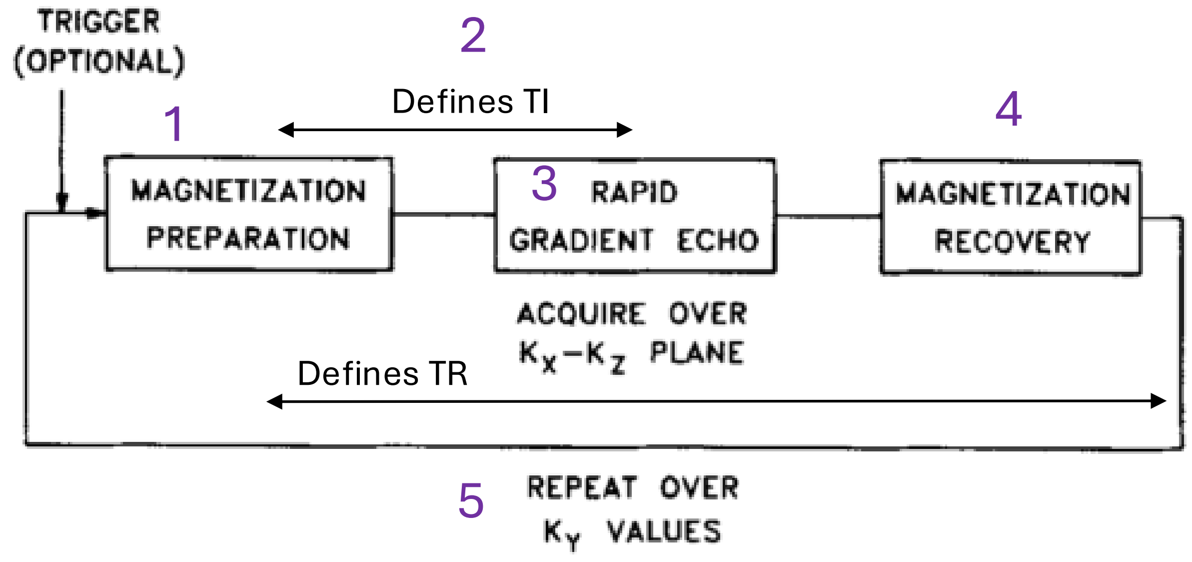


FIG. 1. Schematic diagram of the 3D MP RAGE sequence.

3D MPRAGE: Mugler & Brookeman, MRM 1990

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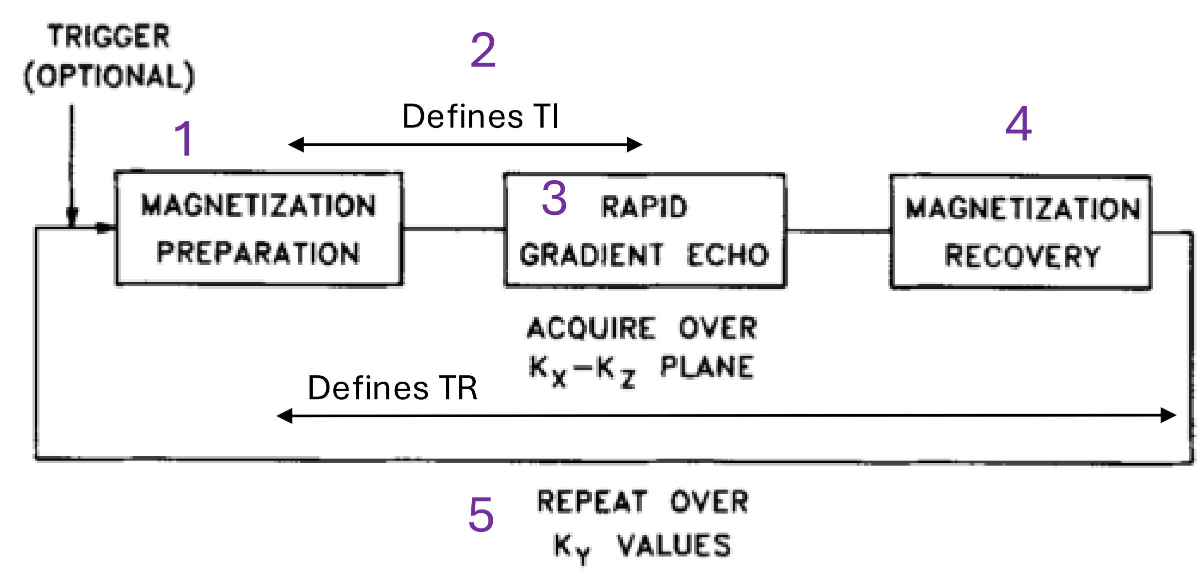
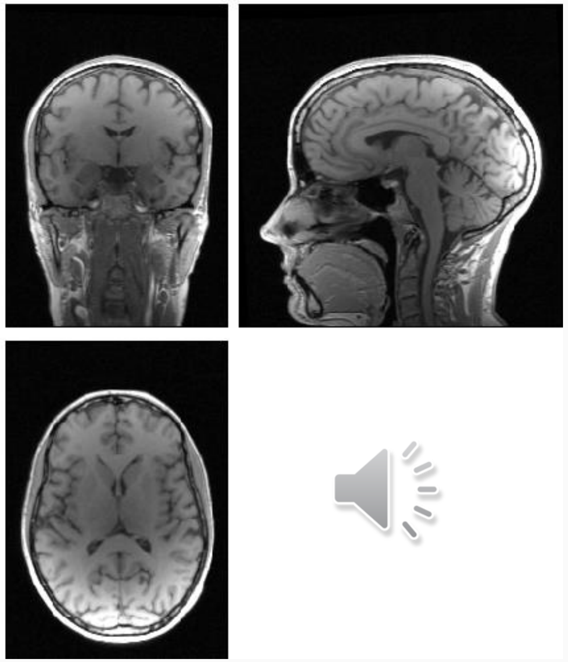


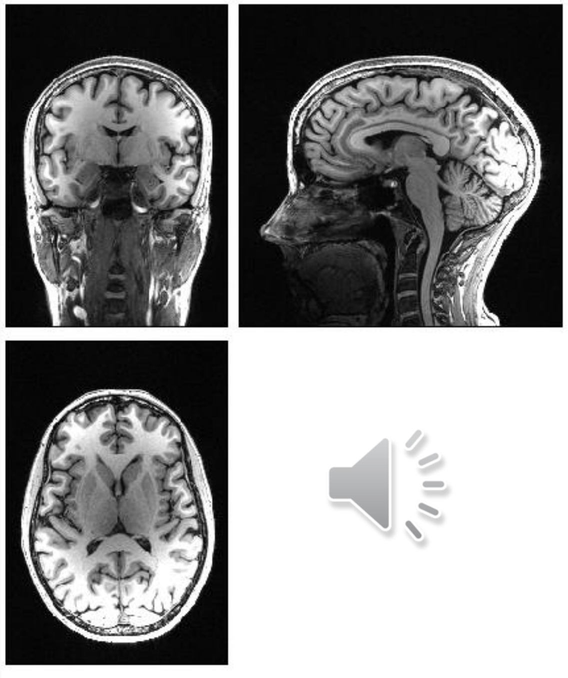
FIG. 1. Schematic diagram of the 3D MP RAGE sequence.

3D MPRAGE: Mugler & Brookeman, MRM 1990

FLASH

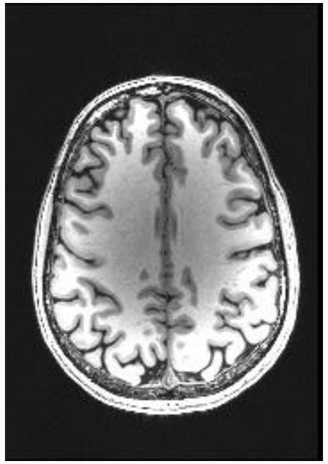


MPRAGE

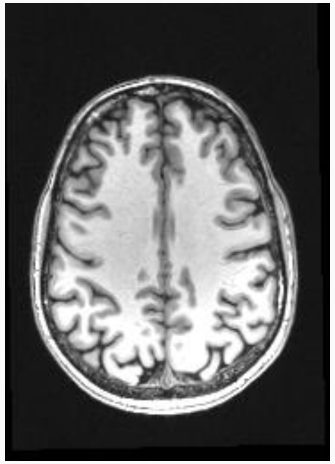


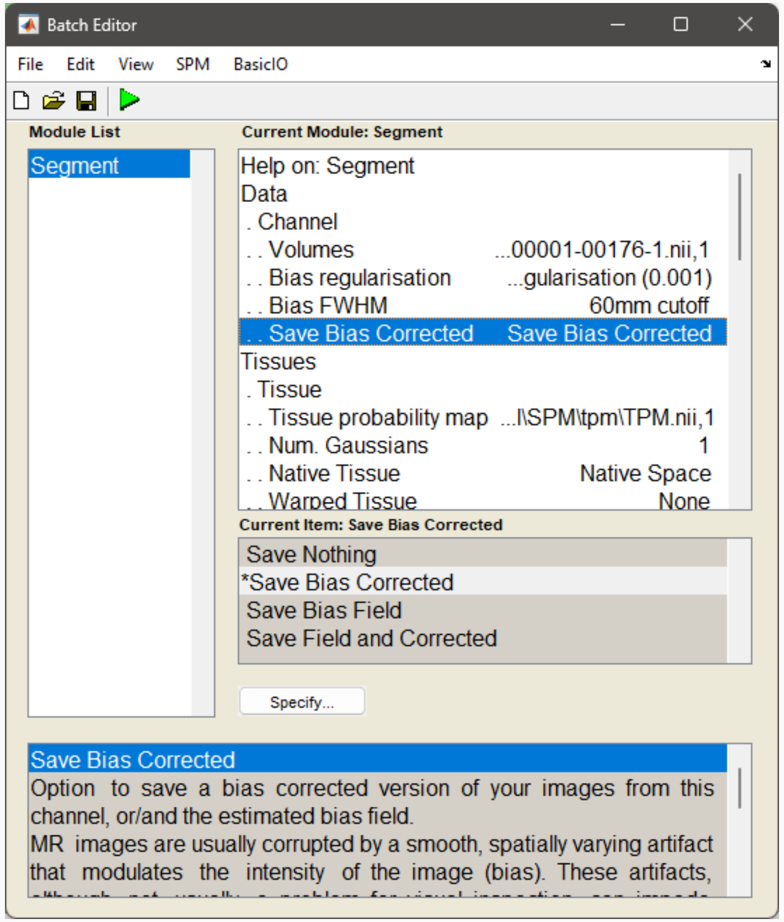
Impact of receiver coil

64 channels



20 channels



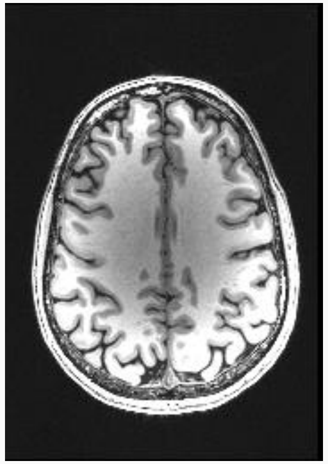


Impact of receiver coil

Bias Field or Non-Uniform Intensity (NUI)

64 channels

=



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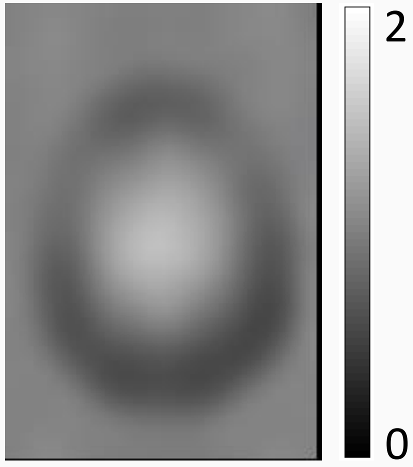
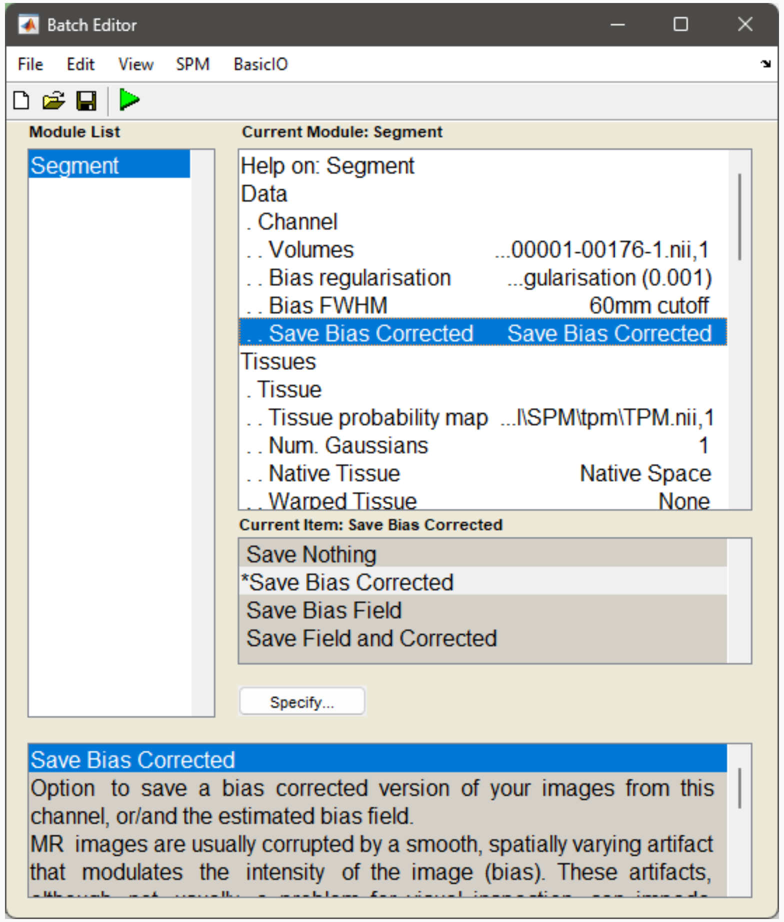
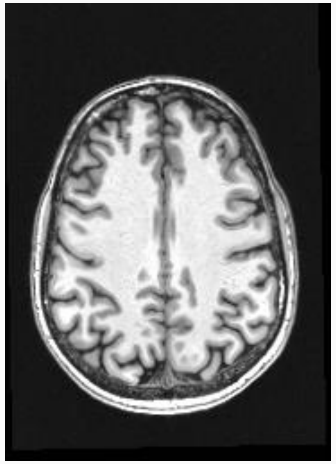




20 channels



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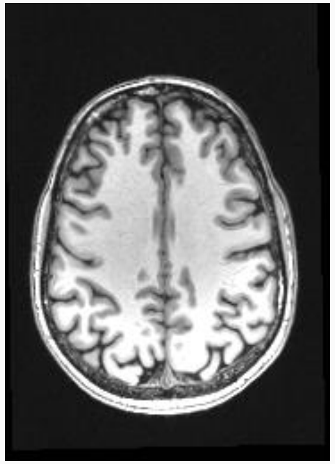

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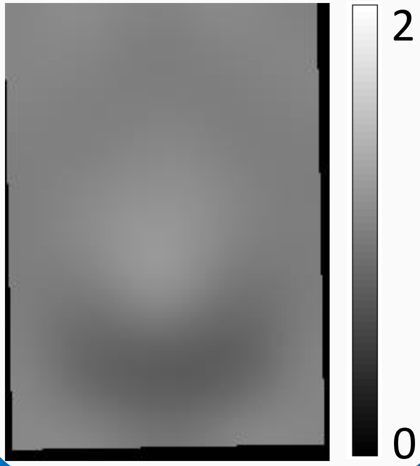
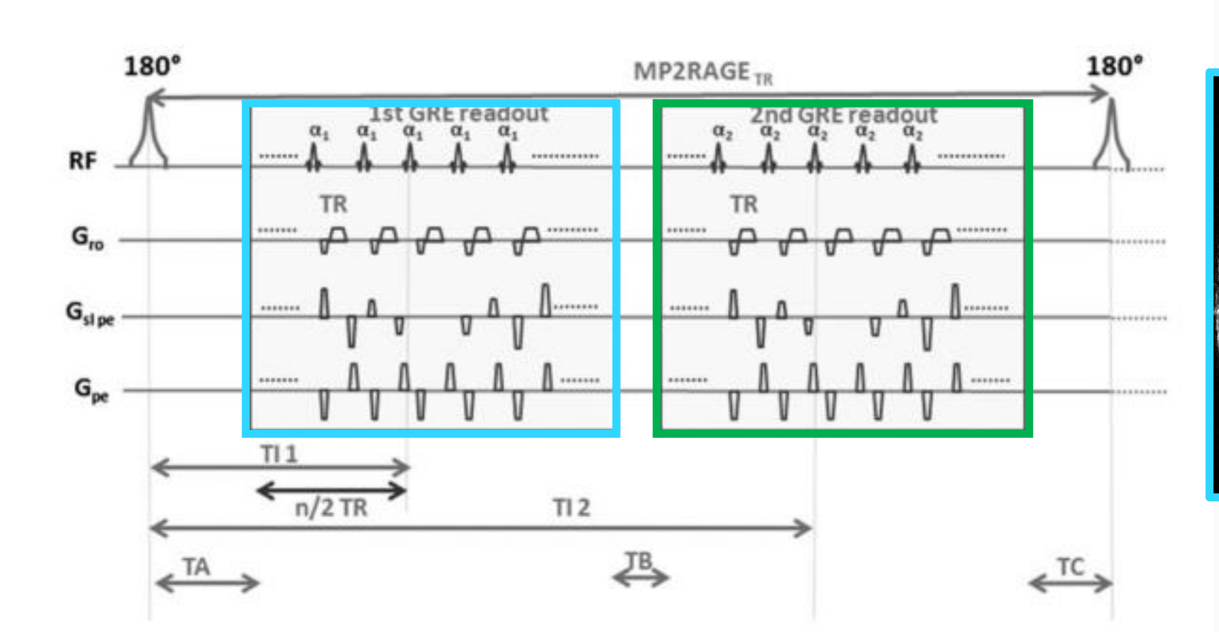
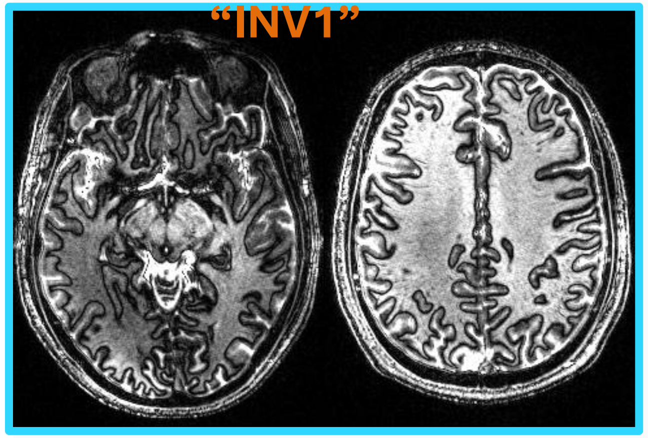


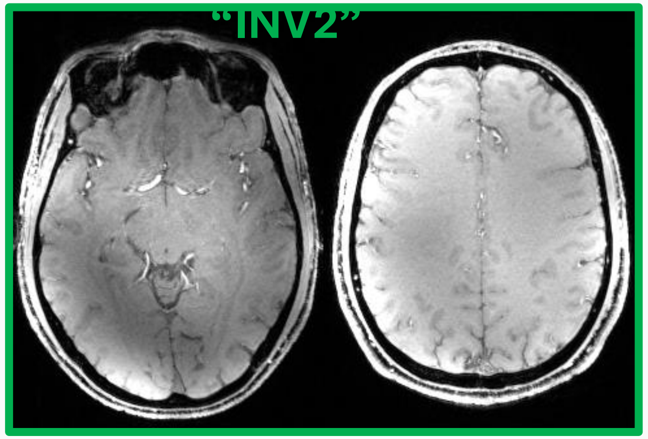
7T: MP2RAGE



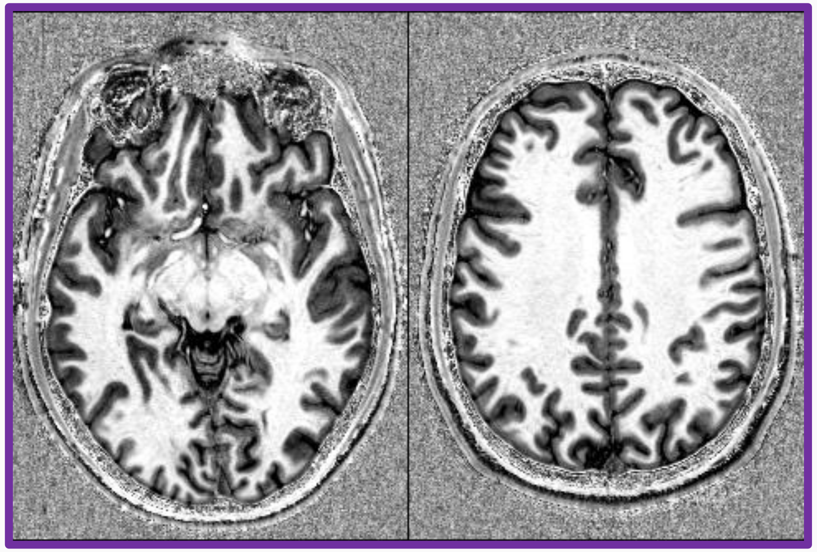
GRE$_{TI1}$
"INV1"



GRE$_{TI2}$
"INV2"



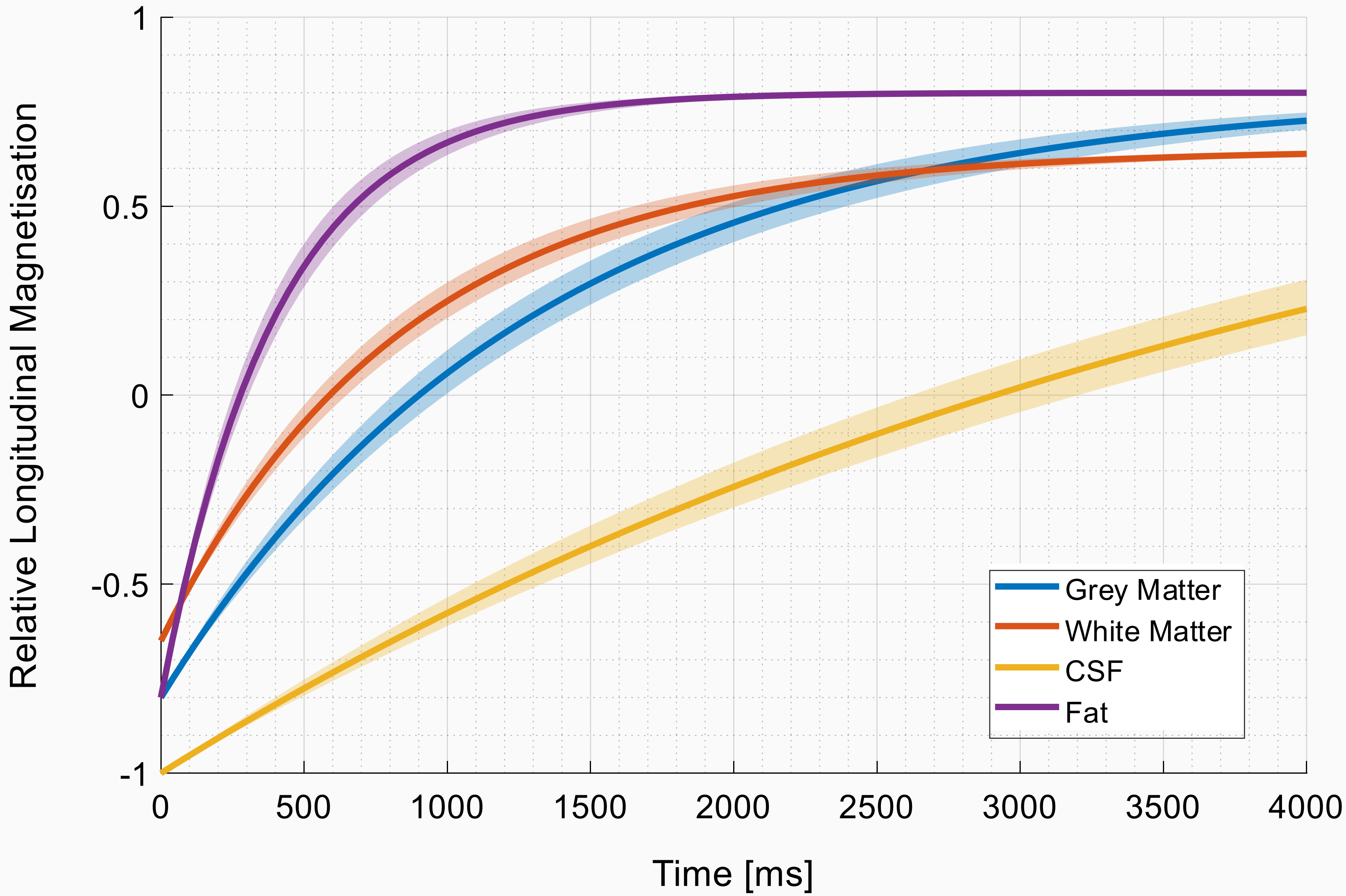
MP2RAGE "UNI"



$$MP2RAGE = \frac{GRE_{TI1}GRE_{TI2}}{GRE_{TI1}^2 + GRE_{TI2}^2} \in [-0.5, 0.5]$$

MP2RAGE: Marques et al., NeuroImage 2010

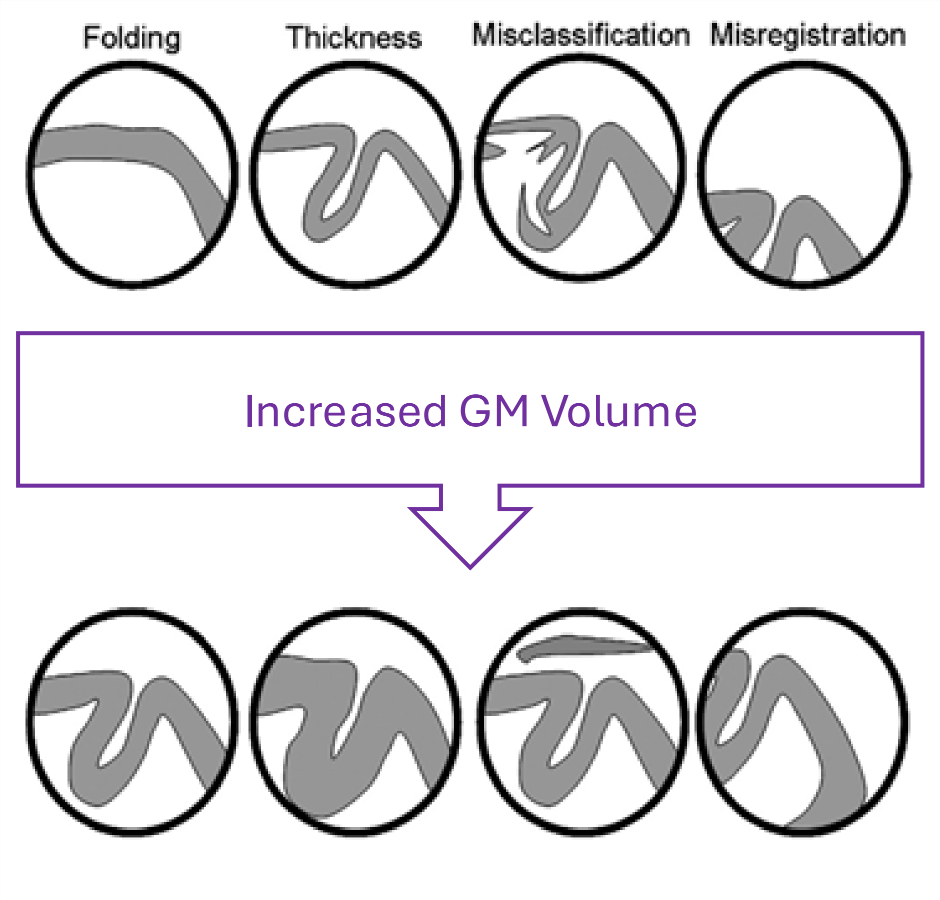
Magnetisation Preparation: Inversion



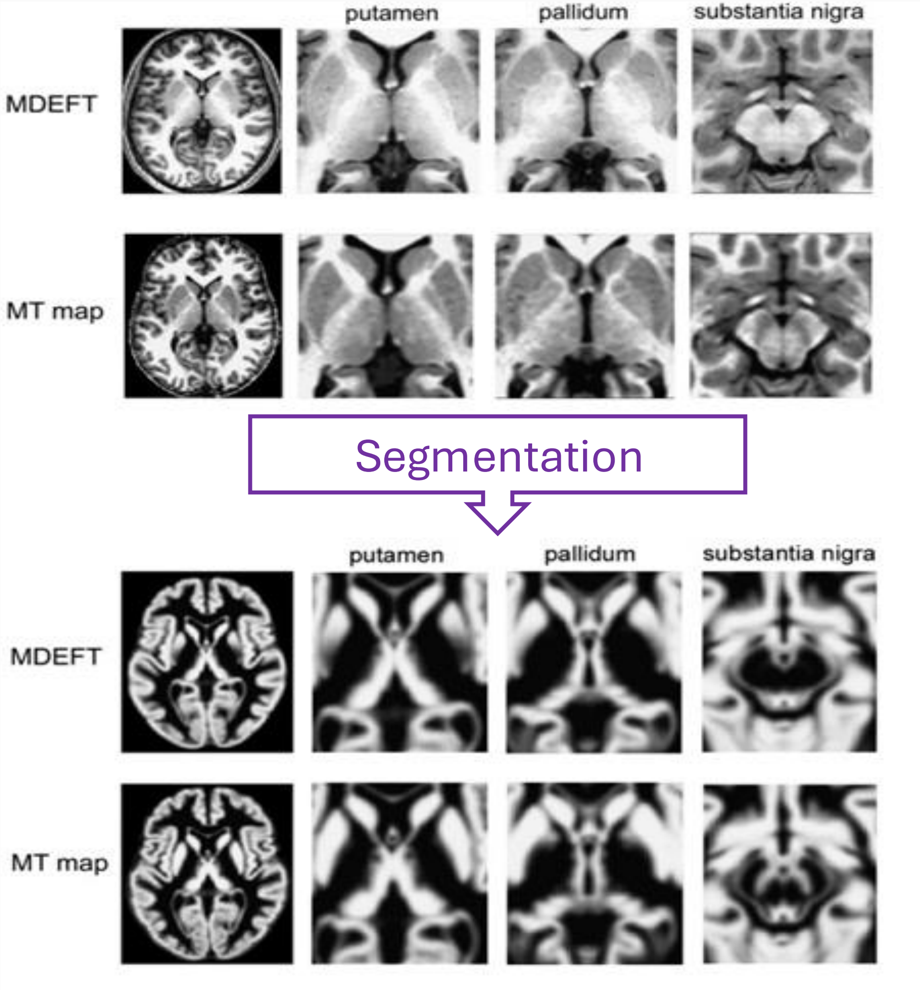
Optimisation must account for multiple tissue types, each with a range of T_1 times…

Contrast and Interpretation

Interpreting Morphological Differences



Ashburner, MRI, 2009

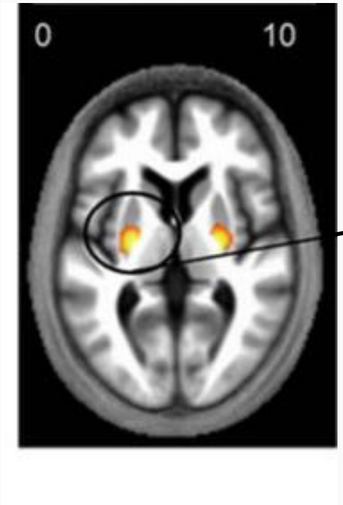


Helms *et al.*, NeuroImage, 2009

Interpreting Morphological Differences

Neurobiological Origin of Spurious Brain Morphological Changes: A Quantitative MRI Study

Lorio et al., HBM, 2016



Age-related atrophy

Interpreting Morphological Differences

Neurobiological Origin of Spurious Brain Morphological Changes: A Quantitative MRI Study

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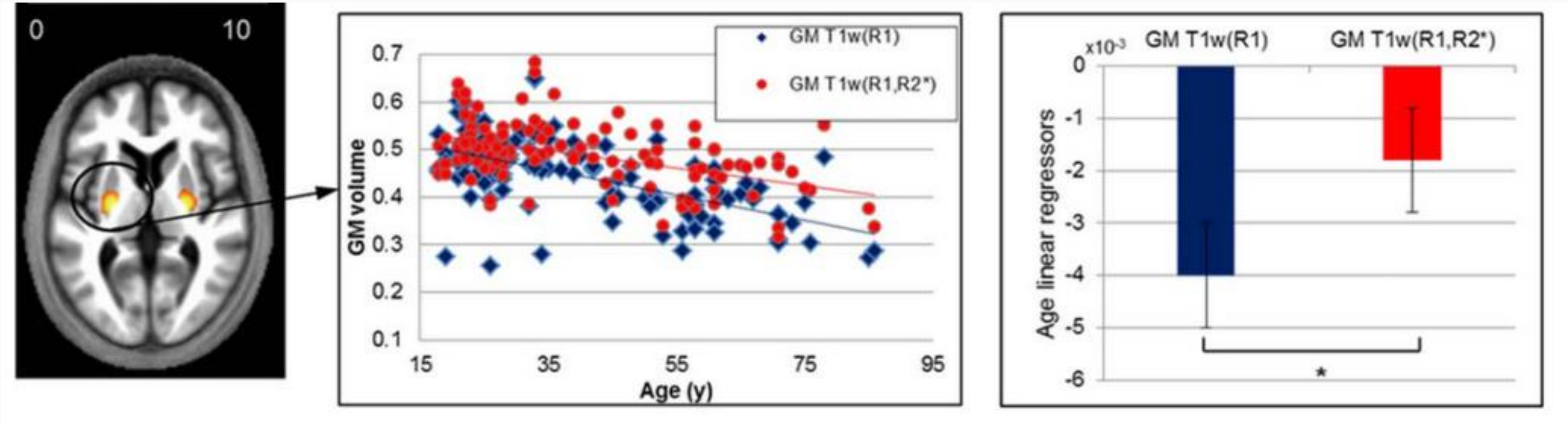
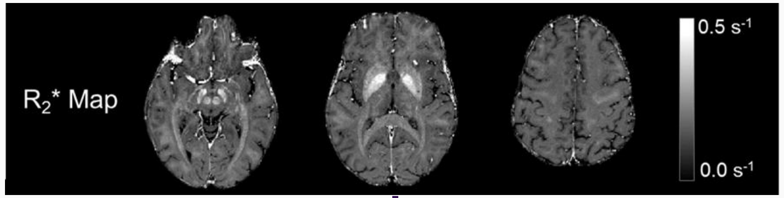


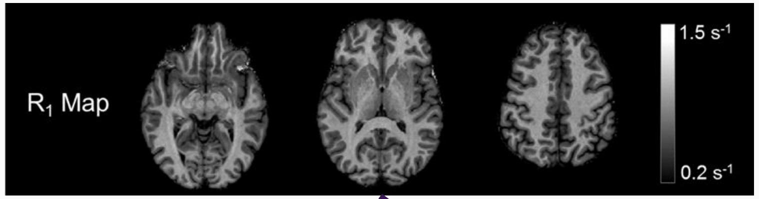
Rate of apparent age-related atrophy depends on image weighting!

Interpreting Morphological Differences

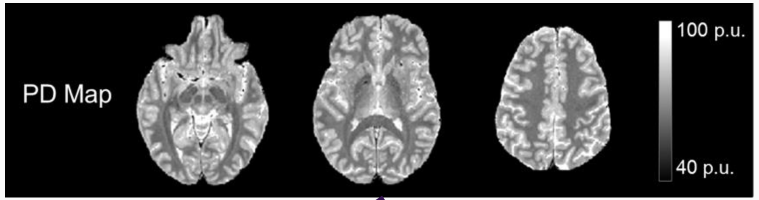
Effective Transverse Relaxation Rate

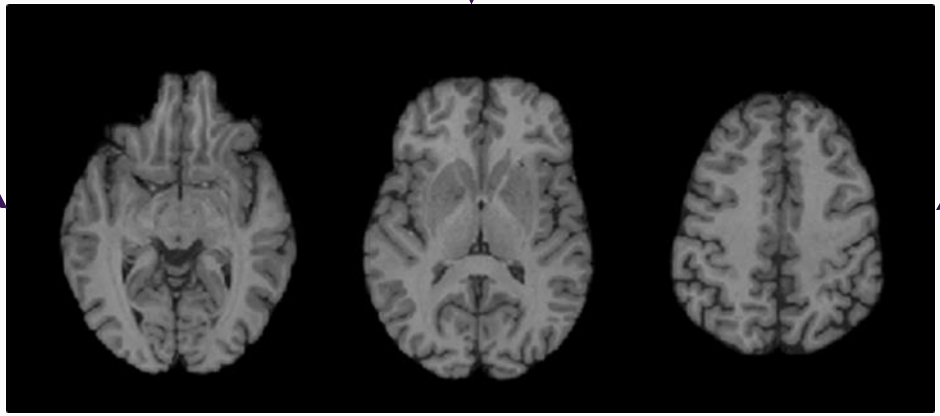


Longitudinal Relaxation Rate



Proton Density

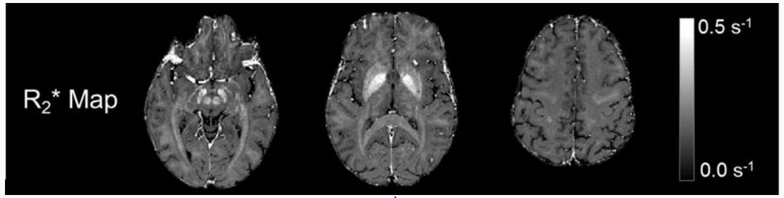




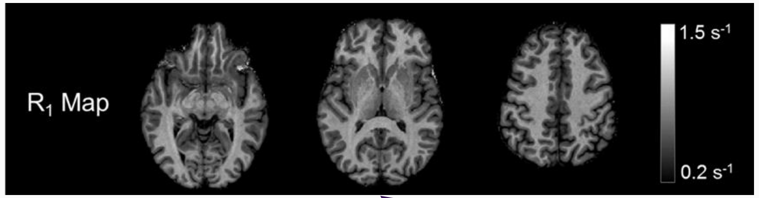
SI_{MPRAGE}(Sequence Parameters, Hardware, Physical MRI Properties)

Interpreting Morphological Differences

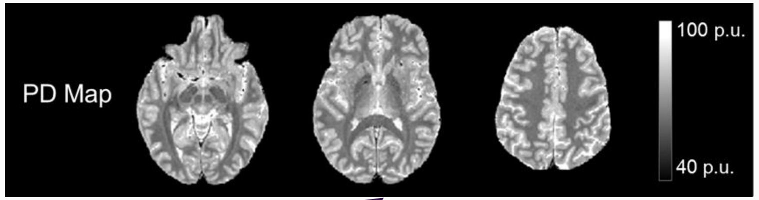
Effective Transverse Relaxation Rate

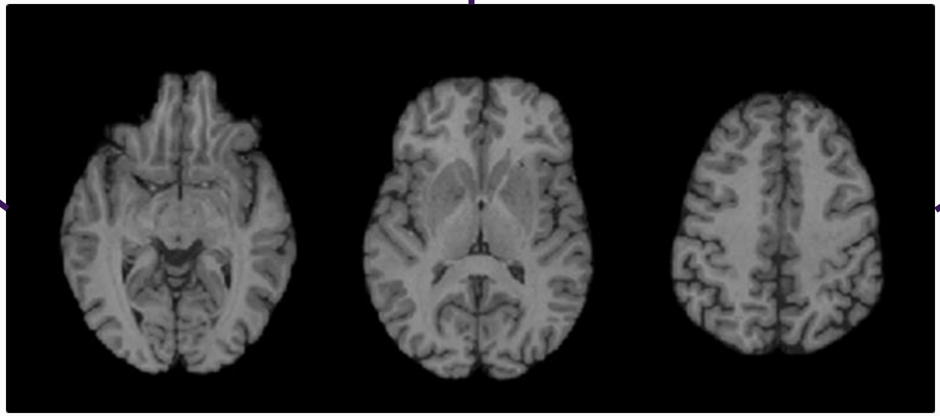


Longitudinal Relaxation Rate



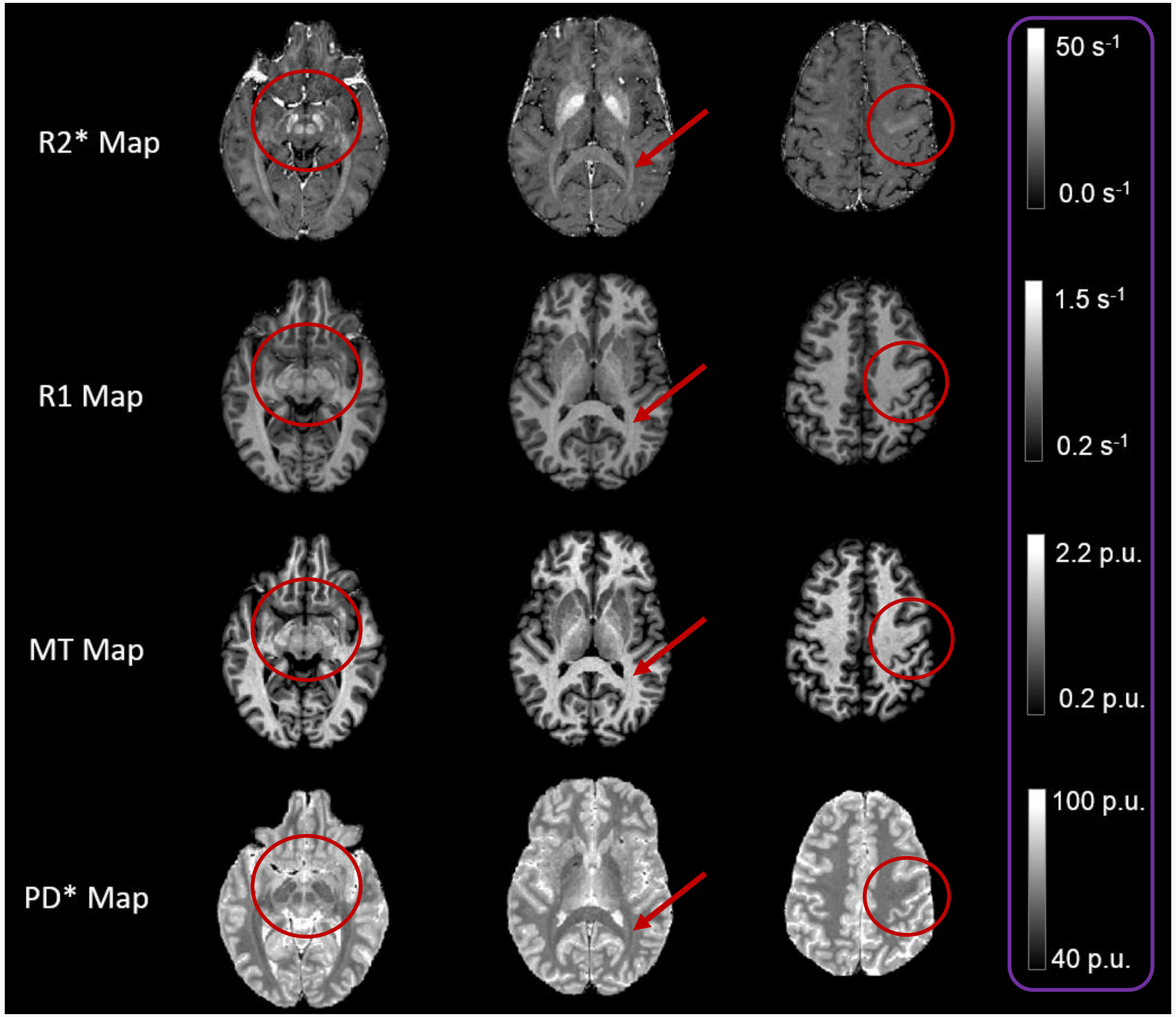
Proton Density





$$SI_{\mathrm{MPRAGE}}(\text{Sequence Parameters, Hardware, }\underline{\text{Physical MRI Properties}})$$

Quantitative MRI



Want to learn more?

SPM

Special Interest Workshop on "Quantitative MRI"

Methods Section

OXFORD

Cerebral Cortex, 2023, 33, 2823–2837
https://doi.org/10.1093/cercor/bhac244
Advance access publication date 2 July 2022
Original Article

Fast and functionally specific cortical thickness changes induced by visual stimulation

Natalia Zaretskaya[1,2,*], Erik Fink[1], Ana Arsenovic[1,2], Anja Ischebeck[1,2]

[1]Department of Cognitive Psychology and Neuroscience, Institute of Psychology, University of Graz, Universitaetsplatz 2, 8010 Graz, Austria,
[2]BioTechMed-Graz, Mozartgasse 12, 8010 Graz, Austria

MRI data acquisition

Experiments were performed on a 3 T whole-body MRI scanner (Magnetom Vida, Siemens Healthineers, Erlangen, Germany) with a 64-channel Head/Neck coil (Siemens Healthineers, Erlangen, Germany). The acquisition parameters for each of the protocols are listed in Table 1.

Table 1. Protocol overview.

Protocol type	MPRAGE (fMRI analysis)	2D GE-EPI
Isotropic voxel size (mm)	1	3
TR (ms)	2,530	3,220
TE (ms)	3.88	32
TI (ms)	1,200	n/a
flip angle	7°	82°
Matrix	256 × 256	76 × 76
~~Slices~~	176	46
PE	A>>P	A>>P
Acceleration	GRAPPA 2	None
Duration (min)	6:03	8:22
Partial Fourier	Off	Off
Bandwidth (Hz/pixel)	190	1,828

TR, repetition time; TE, time to echo; TI, inversion time.

Thank you! Any Questions?