Mapping white matter bundle tracts and cortical myelin from multi-contrast imaging in the awake macaque monkey

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INTRODUCTION

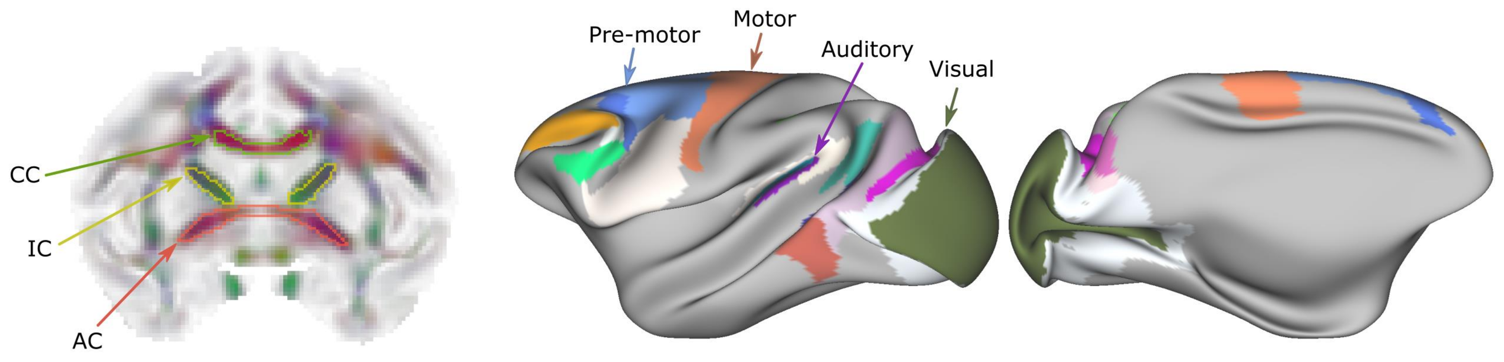
- *In-vivo* whole-brain **multi-contrast awake imaging** enables the detection of structural and functional features in brain networks without anesthesia.
- The **macaque monkey** has significantly contributed to mapping the human brain connectome by providing means to validate *in-vivo* neuroimaging microstructure and tractography measures with *ex-vivo* cytoarchitectonic and tract-tracing anatomical methods.
- Awake non-human primate imaging enables us to detect structural and functional features in brain networks in cognizant monkeys and allows for repeated measurement without anesthesia-related burden for the animal.
- ***This study demonstrates the feasibility and robustness of multi-contrast MRI acquisitions across sessions and subjects in awake macaque monkeys.***

METHODS

- Four healthy female rhesus macaques (*Macaca mulatta*) with a mean age of 3 - 4 years were scanned at a 4.7 T scanner (Bruker BioSpin) with a four-channel phased array coil using the following MR parameters

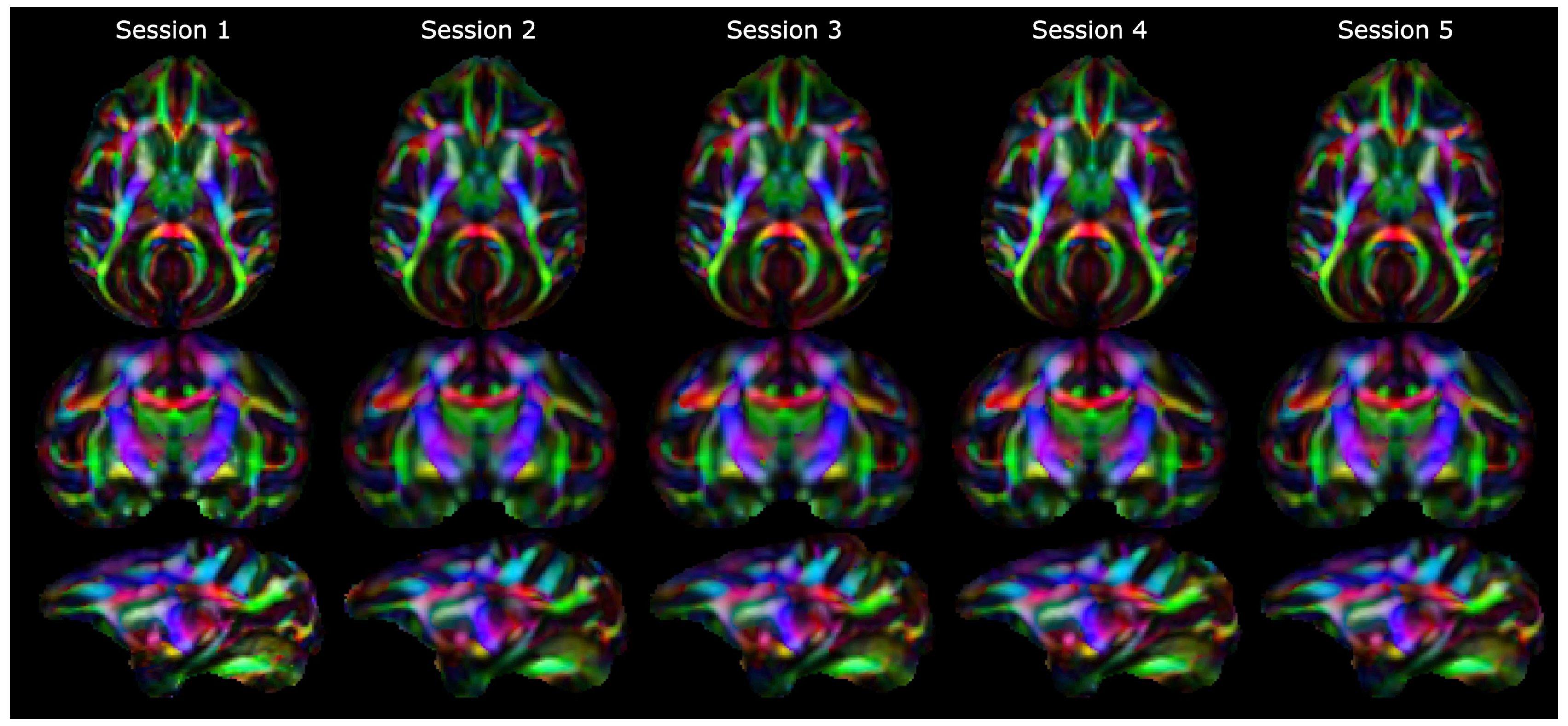
	T_1w	T_2w	Diffusion
sequence	MDEFT	RARE	SE - EPI
resolution (mm)	0.6x0.6x0.6	0.6x0.6x0.6	1x1x1
repetition time (ms)	2000	12,300	14,200
echo time (ms)	3.7	14.3	58
flip angle (deg)	30	180	90 / 180
averages	1	5	5
acquisition time (min)	8	22	75
b-values (s/mm²) / gradient directions	-	-	850 / 60

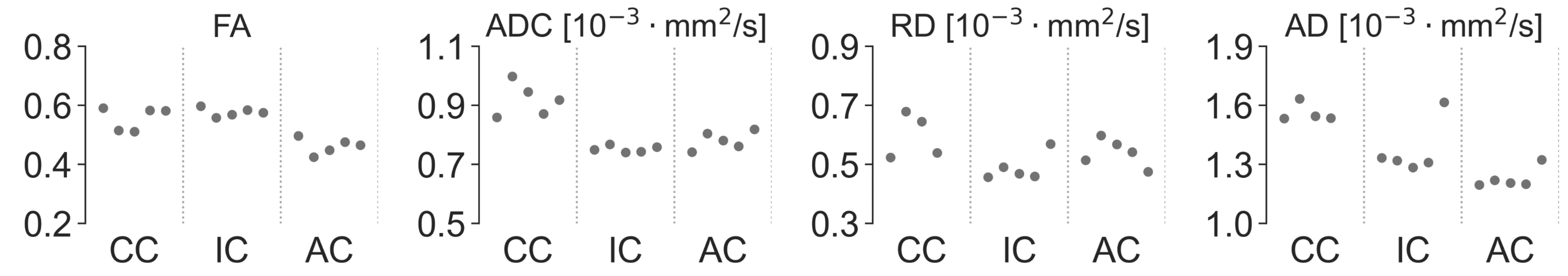
- T1-weighted (**T1w**) and T2-weighted (**T2w**) volumes were linearly registered to the corresponding contrast-specific first session volume. All in-session data were then averaged to form a contrast and subject-specific T1w and T2w volume[1].
- All diffusion-weighted imaging (**DWI**) sessions were preprocessed (denoise, eddy current correction, and motion correction) and linearly registered to create a subject average[2].
- The **subject-specific** averaged T2w, and DWI volumes were linearly registered to the individual's T1w average[1].
- Diffusion tensor maps were calculated by fitting the DTI model[2].
- The four macaques' volumes were nonlinearly aligned to form a T1w, T2w, and DWI **study average** (Average).
- T1w average was nonlinearly registered to the D99 and NMT v2 atlases to identify the ROI[3, 4].
- The **cortico-spinal tract** (CST) was mapped by selecting the motor cortex (M1) as a seed and pons as the target.
- **Cortical surfaces** were created using FreeSurfer, and maps were projected onto the surface and along with ROIs contours using AFNI/SUMA tools[5].



RESULTS

A: Intra-subject reproducibility

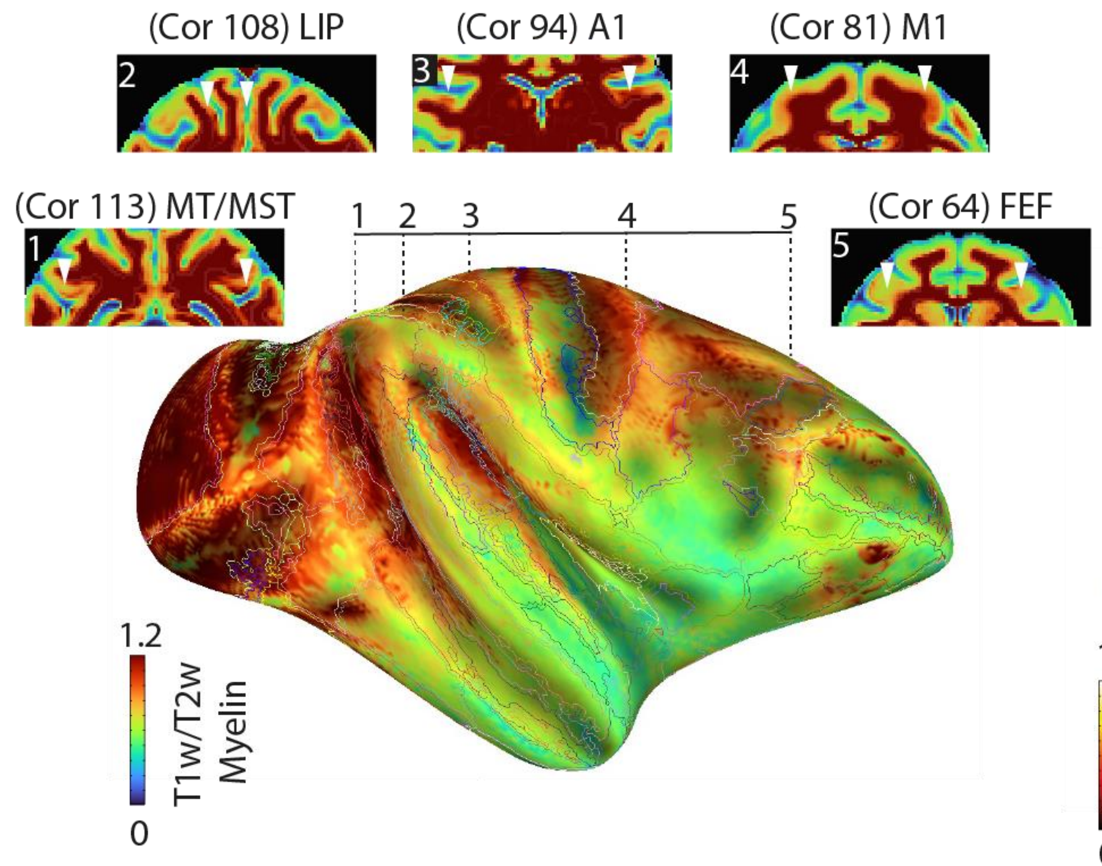


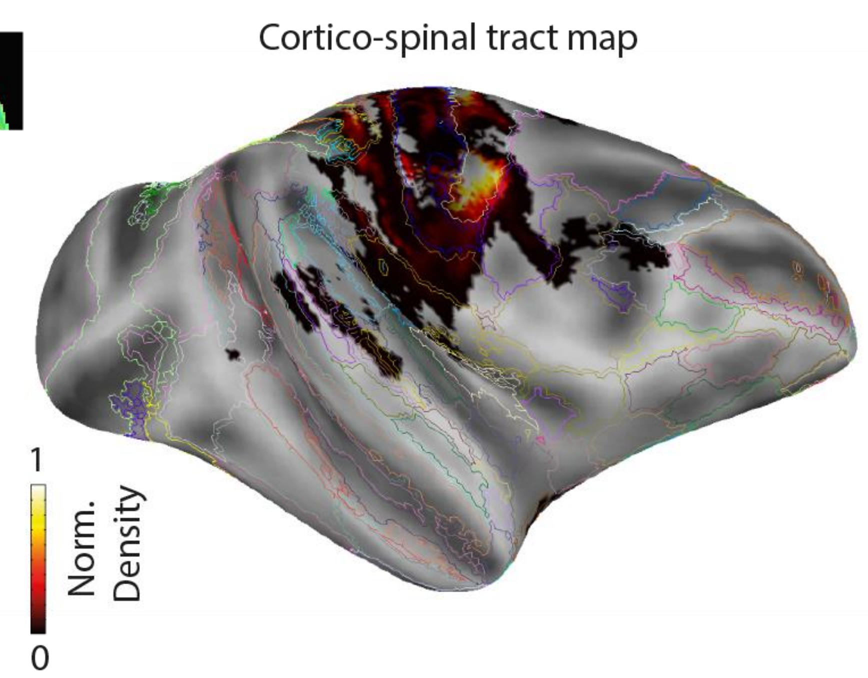


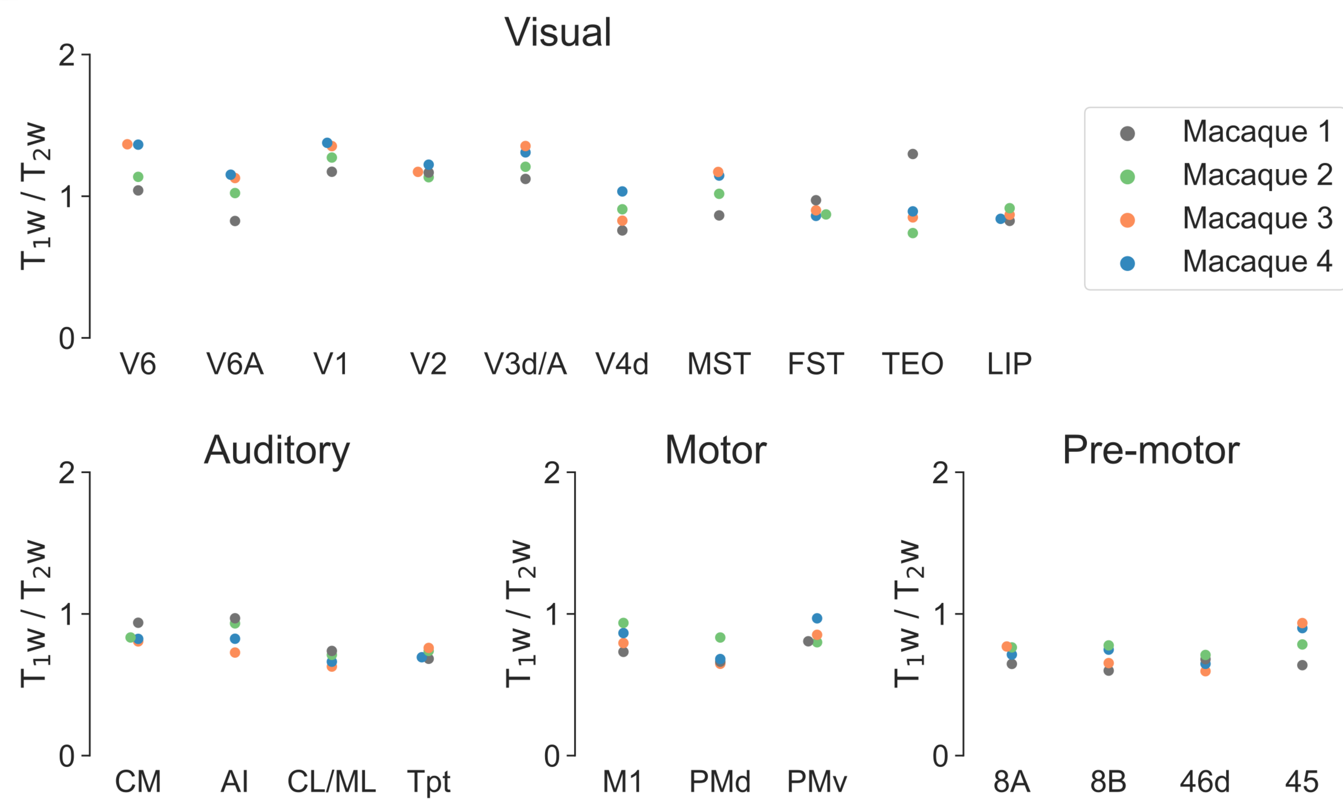
A: Intra-individual quantitative and qualitative results showed similar FA, ADC, RD, and AD values across multiple sessions.

B: Pattern of T1-T2-ratio (assumed to reflect cortical myelination) was in accordance with previous reports revealing highly myelinated areas such as visual, motor, pre-motor, and auditory cortex. High fiber densities were found in the motor cortex, along with a higher degree of myelination.

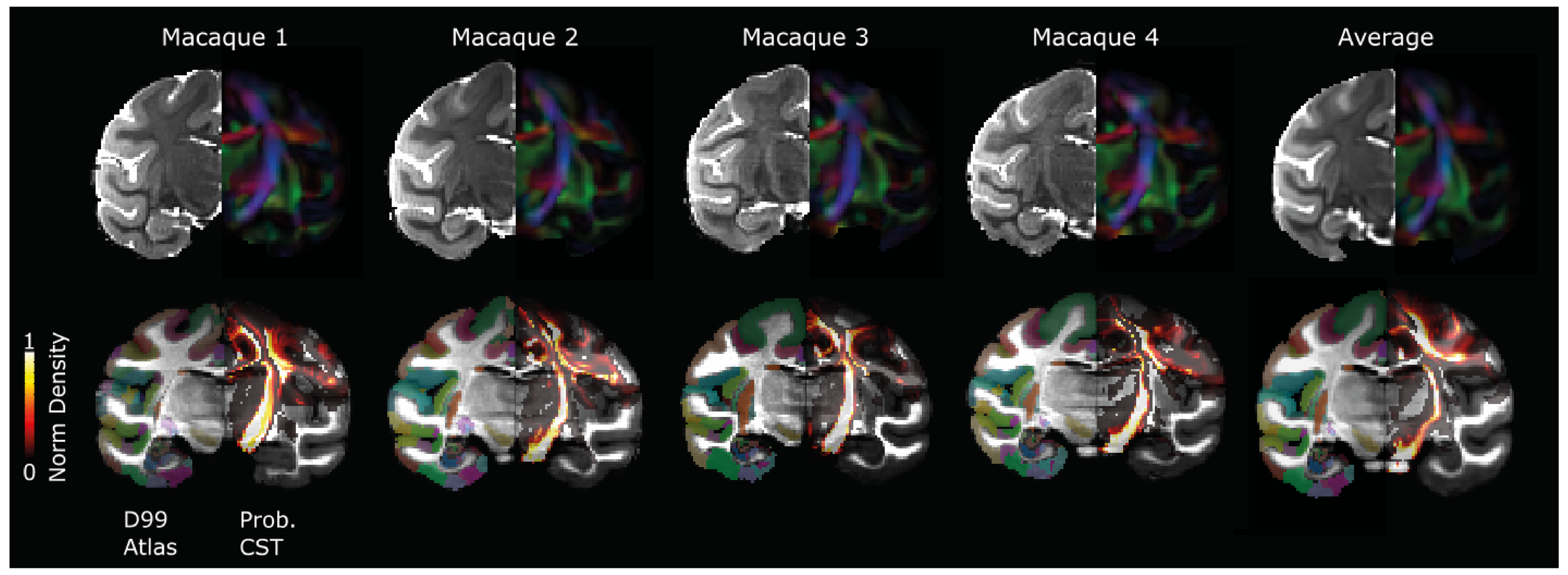
B: Cortical myelination (T1w/T2w)

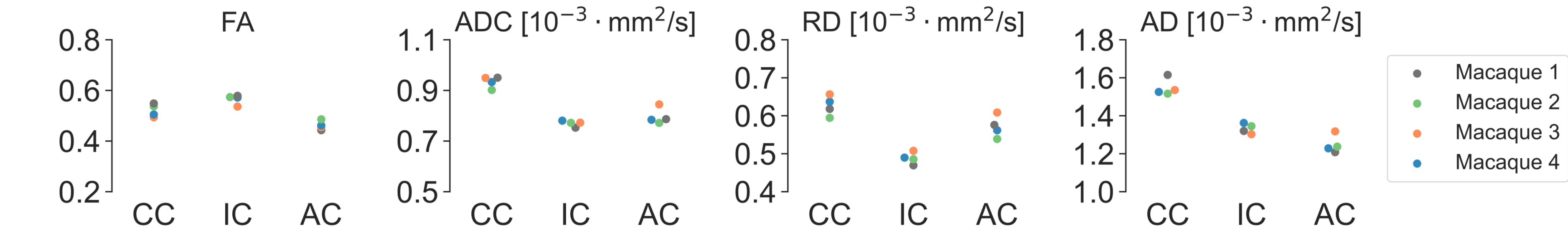






C: Inter-subject variability





C: Comparisons across the subjects revealed similar FA, ADC, RD, and AD values.

CONCLUSION

- This study shows the feasibility of obtaining multiple MRI contrasts across sessions and subjects of awake macaque monkeys.
- The achieved quality was auspicious and sufficient to reveal cortical myelination and tissue microstructural features, including white matter fiber bundles.
- Tractography results ensured the robustness of detecting white matter fiber bundles.

References

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