Layer-dependent orientational structure in primary human somatosensory (S1) and motor cortices (M1)

Christoph Wolfram Ulrich Leuze, Alfred Anwander, Pierre-Louis Bazin, Till Riffert, Stefan Geyer, Robert Turner

Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

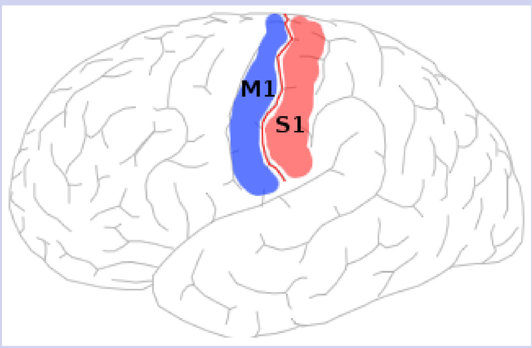
leuze@cbs.mpg.de

MAX-PLANCK-GESELLSCHAFT

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

Introduction

- **The preferred diffusion direction in the cortex is radial for most parts of the brain [1].**
- **However, in several previous studies mainly tangential diffusion was reported in the primary somatosensory cortex [2,3].**
- **We examined these results by performing high-spatial high-angular resolution diffusion weighted imaging in human cadaver brain samples.**



The primary motor cortex (M1) and the primary somatosensory cortex (S1) covering the precentral gyrus and postcentral gyrus around the central sulcus

Methods

- All experiments were performed on a 9.4T micro-imaging system (Bruker Avance 400, Micro 2.5 gradient system, Bruker, Germany) using a 25 mm inner diameter birdcage coil (Bruker, Germany).
- Scans were performed on excised blocks of formalin-fixed human cadaver brain (1.5x1.5x1cm) containing part of the motor and somatosensory cortices (post mortem interval before fixation = 5h-28h, obtained with informed consent, Netherlands Brain Bank, Amsterdam). The samples were fixed in 4% formalin and immersed in phosphate buffered saline (PBS) at least 2 weeks before scanning.
- Sequence protocol: Pulsed-gradient spin-echo (PGSE) sequence (TE=26 ms, TR=1600-3000 ms, b=1569-2808 s/mm2, Δ=13.96-14.56 ms, 60-228 diffusion directions + 5-11 b=0 s/mm², spatial resolution: 242 µm isotropic, 7-15 adjacent slices)
- Data evaluation performed with FSL-DTIFIT for calculation of diffusion tensor, FSL-bedpostx for estimation of ball & 2 stick model, MIPAV (NIH, Bethesda, USA) for calculation of the surface normal, MRTRIX for estimation of the fibre orientation distribution function (ODF) [4] and MATLAB for calculation of the radiality index. ODF peak extraction was performed according to [5].

Results

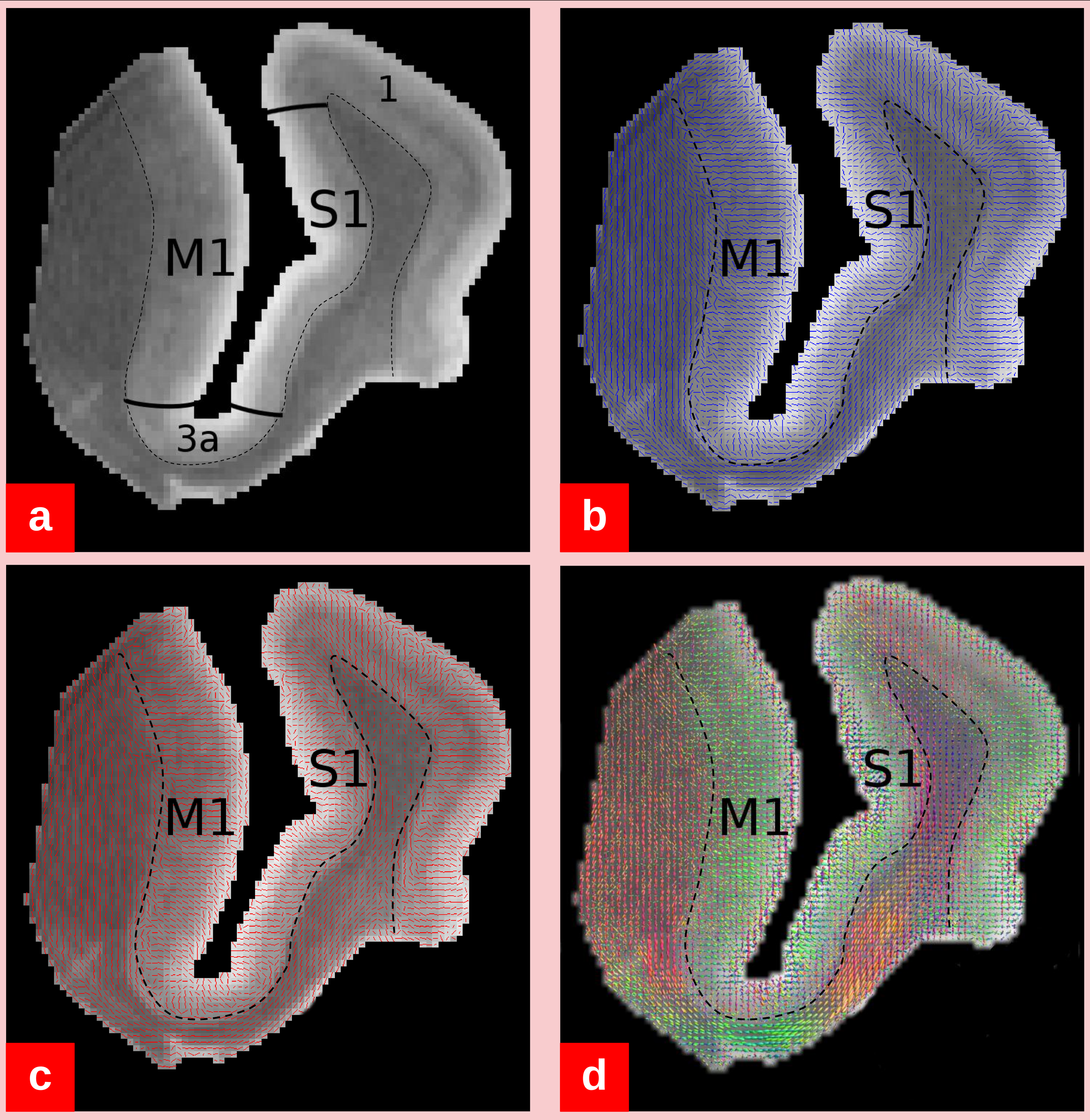


Fig.1: **(a)** A formalin-fixed piece of human cadaver brain containing part of the primary motor- (M1) and somatosensory (S1) cortex.
The area boundaries were chosen based on the anatomical location of these areas with respect to the central sulcus.
(b) The **principal eigenvector** of the diffusion tensor shows a mainly radial diffusion direction in both M1 and S1 → **M1 radial & S1 radial**
(c) The **first stick of the ball & 2 stick model** also shows a mainly radial diffusion direction in both M1 and S1 → **M1 radial & S1 radial**
(d) The **ODF** of the fibres shows a high number of crossing radial and tangential peaks
→ **M1 radial with high number of crossing tangential peaks**
S1 radial with high number of crossing tangential peaks
Stronger fibre crossings could be observed near the WM and near the cortical surface.

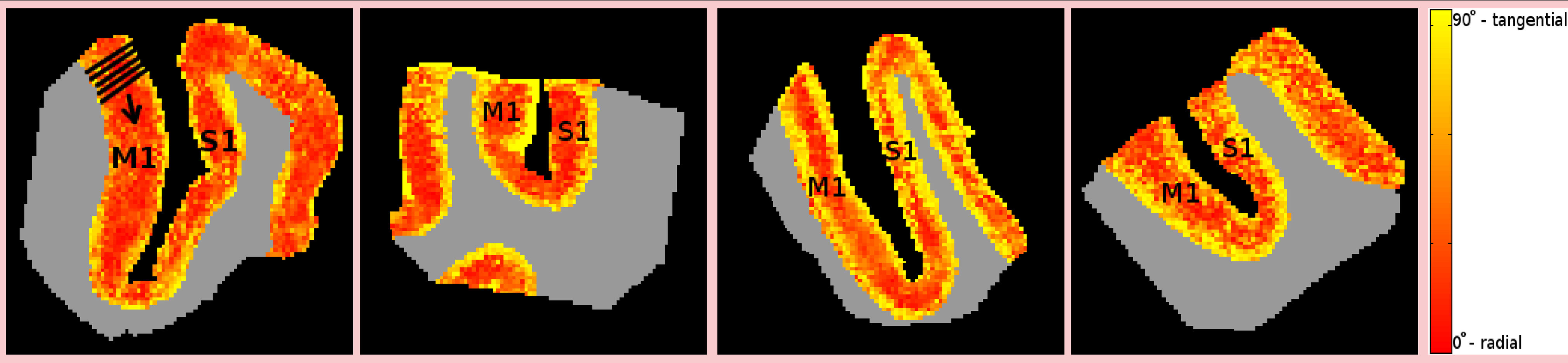
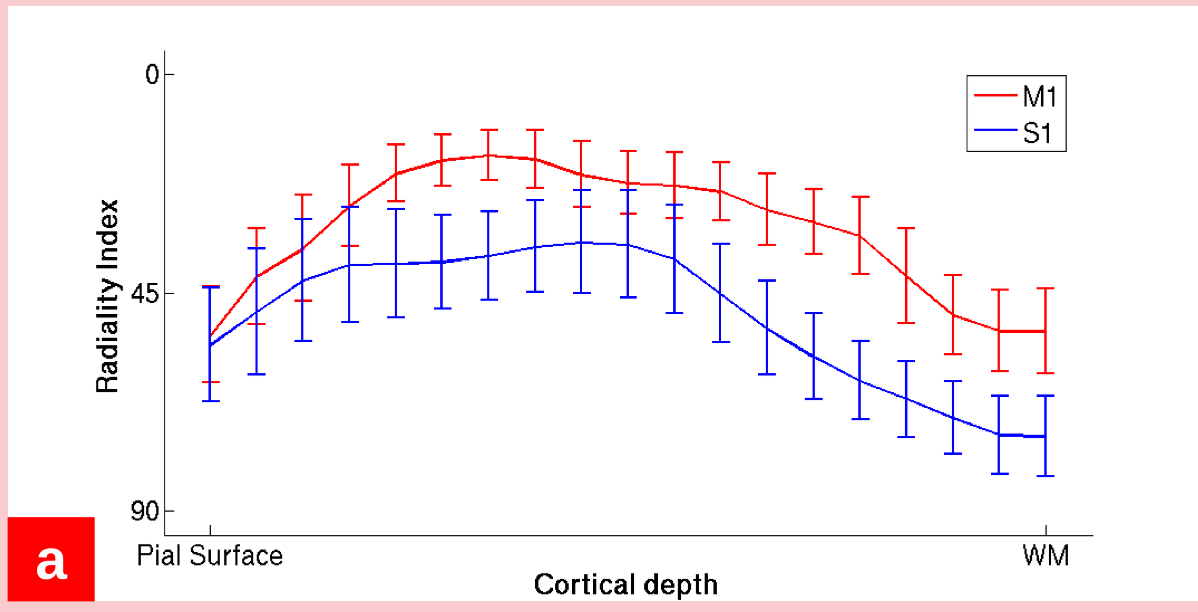


Fig.2: Four different brain samples showing the **Radiality Index (RI)** inside M1 and S1 cortex The radiality index (RI) is the angle between the principal eigenvector of the diffusion tensor and the surface normal.
M1 mainly radial with tangential diffusion near the cortical surface and the WM boundary.
S1 also mainly radial with tangential diffusion near the cortical surface and the WM boundary.
The volumes of this tangential component are almost equal in M1 and S1. However, the volume ratio of the radial component is much higher in M1.
Profiles for Fig.3 were taken along the lines in the left image covering both M1 and S1.



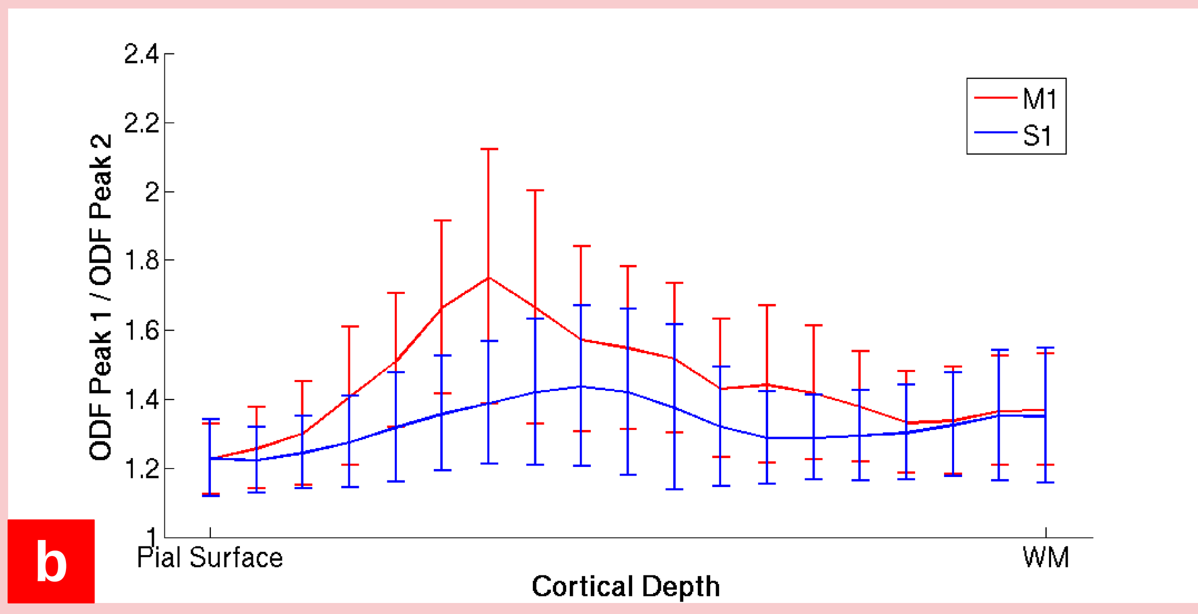


Fig.3: **(a) Cortical profiles of the Radiality index** extending from the WM to the cortical surface. The means were taken over all profiles in both M1 and S1 of the sample from Fig.1. Radiality is slightly higher inside M1 and the peak with high radiality appears broader than in S1.
(b) Cortical profiles of the ODF ratio (OR = ODF peak 1/ODF Peak 2) extending from the WM to the cortical surface. The means were taken over all profiles in both M1 and S1 of the sample from Fig.1.
In both M1 and S1 **the OR is decreasing towards the WM and the cortical surface**, representing the crossing of radial fibres with tangential fibre pathways in these areas.
The OR is higher in parts of M1 indicating the stronger Radiality in the middle layers of the cortex.

Discussion

- According to our results from formalin-fixed human cadaver brain **the main diffusion direction in both M1 and S1 appear to be radial.**
- The **Radiality index is slightly higher in M1** which may be explained by its dominant radial cyto- and myeloarchitecture.
- Radiality is changing throughout the cortical depth with a **lower radiality** in both M1 and S1 **near the WM and the cortical surface.**
- The ODF ratio showed that this **decrease in radiality can be explained by** the **crossing** of radial **fibres** with tangential fibre pathways near the surface and near the WM.

Acknowledgements

The authors would like to thank Prof. Dr. Jürgen Haase from the faculty of physics and geosciences at the University of Leipzig for his support and for providing access to the Bruker Scanner.

References

[1] R. Heidemann et al., MRM, 64:9-14 (2010)
[2] A. Anwander et al., Proc.- ISMRM, 109 (2010)
[3] J. McNab et al., Proc.- ISMRM, 412 (2011)
[4] J.D. Tournier et al., Neuroimage, 35: 1459-1472 (2007)
[5] T. Riffert et al., Proc.- ESMRMB, 329 (2011)

Info

 # 893
Tuesday
June 12
13:30 -15:30