Educational Symposium:

Mechanisms of longitudinal relaxation in the human brain

When: 11.04.2019 9:00 am - 4:00 pm

Where: Library Seminar Room, MPI CBS Leipzig

Scope:

The longitudinal relaxation time of water protons (T1) is a sensitive biomarker for brain tissue composition reflecting local macromolecular and iron content. T1-contrast in the brain is widely applied for anatomical imaging, brain segmentation, cortical parcellation and as a biomarker for myelination. However, the relaxation mechanisms in the brain tissue are far from fully understood and no generative models of the underlying processes so far exist. This limits interpretation and specificity of T1-based myelination biomarkers. This workshop will bring together experts in quantitative MRI of the brain and provide an overview of current models of myelin- and iron-induced longitudinal relaxation in the human brain. The target audience are scientists, PhD students and postdocs working in the field of quantitative MRI and microstructural imaging of the human brain.

Program:

9:00 am - 9:50 am

- Harald Möller, NMR Group, MPI CBS, Leipzig

  Exchanging water compartments in brain tissue and their impact on proton spin relaxation

  In the confined environment between adjacent myelin membrane layers, water protons experience frequent interactions with non-aqueous components. This accelerates relaxation and induces magnetization transfer (MT) between water and macromolecular protons. For a quantitative analysis, models of varying complexity have been developed. Relatively comprehensive is a model that considers water in an intra-axonal, an extra-axonal and a myelin compartment as well as corresponding macromolecular pools with magnetization transfer and inter-compartmental water exchange as coupling pathways. However, it is far too complex for practical MRI applications, and simpler models are typically used to appreciate the role of myelin for proton relaxation. We will discuss some more frequently employed models in the context of T1, T2, T2* and MT experiments, underlying simplifications and potential limitations.

9:50 am - 10:40 am

- Gunther Helms, Lund University, Sweden
  T1 and MT: The basis of structural MRI
  T1 relaxation in brain tissue is governed by cross-relaxation and/or exchange with macro-molecules. The same processes are probed by magnetization transfer (MT) techniques. Modeling is facilitated since the coupled Bloch-McConnell equations can be solved in closed form. Solutions come in many formulations (and approximations) but rarely yield physical insight or “feel” for the underlying phenomena.

10:40 am - 11:00 am Coffee break

11:00 am -11:50 am

- Aviv Mezer, Hebrew University of Jerusalem, Israel
  Disentangling the T1 dependencies on water fraction and molecular composition of brain tissue
  Quantitative MRI (qMRI) parameters such as T1 provide physical parametric measurements crucial for clinical and scientific studies. However, an important challenge in applying qMRI measurements is their biological specificity, as they change in response to both molecular composition and water

content. I will discuss an approach that disentangles these two important biological quantities and allows for decoding of the molecular composition from the qMRI signal. I will demonstrate that this approach can reveal the molecular composition of lipid samples. Furthermore, we identify region-specific molecular signatures in the human brain that have been validated against histological measurements. Last, we exploit our method to reveal region-specific molecular changes in the aging human brain. I suggest that the ability to disentangle molecular signatures from water-related changes opens the door to a quantitative and specific characterization of the human brain.

11:50 am - 12:30 pm

- Kerrin Pine, Department of Neurophysics, MPI CBS, Leipzig
  Measuring T1 in the brain: potentials, challenges and acquisitional biases
  Quantitative relaxometry of a human brain provides unique insight into the tissue microstructural properties. However, high resolution accurate quantitative measurements of longitudinal relaxation in vivo within feasible scanning time are challenging.
  I will describe approaches for T1 mapping starting with classical methods such as inversion recovery and Look-Locker methods, followed by more recent developments including DESPOT1, MP2RAGE, multi-parametric mapping and balanced steady state free precession. The basic principles behind each method, their advantages for neuroscience applications, challenges and experimental biases will be discussed.

12:30 pm - 2:00 pm Lunch break

2:00 pm -2:30 pm

- Risto A. Kauppinen, University of Bristol, United Kingdom
  Angular Dependency of T1 in White Matter at 3T: Potential Mechanisms?
  T1 in brain parenchyma is influenced by physico-chemical factors, such as water, myelin and iron content. We recently observed that T1 is longest in white matter (WM) voxels with fractional anisotropy (FA)>0.3 when the fibre-to-field angle (θ_{FB}) was ~55°. i.e. close to the magic angle. M0 (a proxy of proton density) vs FA plots of WM also peaked close to θ_{FB} of 55°, indicating that the apparent T1 relaxation anisotropy may be mediated by MRI visibility of proton species, i.e. through a non-anisotropic mechanism. These data, as supported by recent studies, indicate that θ_{FB} may be a novel source of T1 contrast in WM pointing to an effect of microstructure on T1 in WM. Our pilot data from a cohort of 40 healthy participants indicate that the θ_{FB} effect on WM T1 decrease with age. Our findings link WM microstructure and T1 relaxation implicating that neurobiological value of relaxometric MRI may be richer than previously thought.

2:30 am - 3:00 pm

- Evgeniya Kirilina, Department of Neurophysics, MPI CBS, Leipzig
  Iron induced longitudinal relaxation in the human brain
  Iron is indispensible for brain function and might be important contributor to several neurodegenerative diseases. It is present in form of isolated, as supraparamagentic inclusions in protein ferritin or in ferromagnetic inclusions. MRI provides a valuable tool for in vivo iron quantification due to the interaction of paramagnetic iron with water proton spins. Impact of iron on MR parameters has to be considered for design of MR-basted myelin biomarkers, due to the co-localisation of iron and myelin in the brain. In my talk I will summarize current knowledge on mechanisms of iron-induced relaxation for different iron species. Particularly the contribution of supraparamagnetic and paramagnetic iron to longitudinal relaxation time T1 and implication of quantitative MRI will be discussed.

3:00 pm - 4:00 pm

- *Panel discussion, moderated by Nikolaus Weiskopf (all speakers)*

6:30 pm Symposium's Dinner at the restaurant "Bayerischer Bahnhof"