Advanced techniques for functional and structural neuroimaging of the cerebellum

Wietske van der Zwaag Organizer
Spinoza Centre for Neuroimaging
Amsterdam
Netherlands

Recent years have seen a resurgent interest in the human cerebellum, a brain structure challenging to image but essential to human cognition. Improved data quality and advanced analysis techniques now allow neuroscientists to better understand the many functions of this highly folded brain structure. This is an important development, as the cerebellum contributes to mental function across a wide range of domains, including motor control, cognition, language, and emotion. Disruption of cerebellar function has been implicated as a risk factor for many neuropsychiatric disorders. In this course, we will cover the current state of the art of cerebellar imaging, starting from the choice of structural and functional acquisition protocols, analysis pipelines, atlas normalization, and visualization techniques. We will do so in a short series of six different lectures, 2 of which will include hands-on interactive demonstrations of the software packages Nighres and SUIT.

Objective

Learning objectives will be to (1) know what can be achieved in terms of cerebellar image contrasts, both functionally and structurally and (2) how to go about analysing this data. To help achieve these goals, an application-oriented lecture is also included.

Target Audience

We welcome all neuroscientists interested in whole-brain studies, as well as those interested specifically in the cerebellum.

Presentations

High resolution and high SNR in the little brain

The fine structure of the cerebellum necessitates high spatial resolution, which in turn limits the available signal to noise ratio in cerebellar MRI. This lecture will discuss the possibilities of improving on that SNR and spatial resolution, specifically in the cerebellum. The use of ultra-high field, dielectric pads, multi-channel transmit and local coils will be discussed in such a way that the audience should be able to make an informed choice on how to

use these in their own experiments. The audience response system will be used to increase audience participation.

Presenter

Wietske van der Zwaag, Spinoza Centre for Neuroimaging Amsterdam
Netherlands

Structural connectivity of the cerebellum

Ex-vivo and ultra-high field in-vivo imaging has been pushing the envelope on our understanding of intrinsic cerebellar connectivity in humans. This lecture will present and discuss current advances in performing structural connectivity in the human cerebellum with diffusion MRI. It will also critically assess the methodological limitations of diffusion tractography within the tightly packed volume of the cerebellum, and include discussion on how potential multi-synaptic connectivity to and from the cerebral cortex may (or may not) be identified.

Presenter

Christopher Steele, Concordia University Montreal, Quebec
Canada

Cerebellar sub-voxel microstructure

Besides its use in tractography, diffusion MRI also gives insight into cell structure. With its high neuronal density and a distinct macro- and microstructure the cerebellum is intriguing for new diffusion weighted imaging techniques. Oscillating gradient spin echo (OGSE) enables ultra short diffusion times that separate the neuron rich granular layer from the mainly dendritic molecular layer of the cerebellar cortex. Multidimensional diffusion encoding (MDE) is another technique that can isolate variance from anisotropy in heterogenic tissue and enable the estimation of the microscopic fractional anisotropy. Our experimental framework incorporates spectrally tuned gradient trajectories that combine the contrasts of OGSE and MDE. This enables data driven and model free separation of cerebellar structures. Finally, diffusion weighted spectroscopy (DWS) measure mobility of cell type specific metabolites which gives an additional specificity to the geometry of the intracellular spaces of neurons and glial cells.

Presenter

Henrik Lundell, Danish Research Centre for Magnetic Resonance Copenhagen, NN
Denmark

Functional segmentation and atlases for the human cerebellum

This lecture will cover recent developments in the SUIT toolbox for analysis of cerebellar imaging data, including isolation, group normalisation, and surface-based visualization. Traditionally, neuroimaging results have been summarized in terms of the 10 cerebellar lobules. However, new task-based functional atlases of the cerebellum now show that these anatomical boundaries do not corresponding to functional subdivisions – and instead suggest alternative ways to subdivide the cerebellar functionally. The presentation will include hands-on demonstration of analysis tools and online atlasses.

Presenter

Joern Diedrichsen, the University of Western Ontario London, Western Ontario
Canada

Cerebellar segmentation and cortical mapping

The cerebellar cortex is a tightly folded structure tucked under the cerebrum. While obtaining a complete cortical map is still beyond the capabilities of modern MRI, the geometry of the lobules can already be captured. This lecture will present a processing pipeline for estimating the cortical surface of the cerebellum from high resolution MRI with the open source Nighres toolbox. Cortical surface inflation, mapping, and partial volume correction via depth modeling will also be covered. The methods will be demonstrated on open data during the presentation.

Presenter

Pierre Louis Bazin, University of Amsterdam Amsterdam, NH
Netherlands

The role of the cerebellum in language and neurodevelopmental disorders

In humans, the cerebellum constitutes 10% of the total volume of the brain. Though historically considered a motor structure, the vast majority of the cerebellum is functionally and anatomically connected to associated cortices. Neuroimaging research shows that the cerebellum is consistently active during cognitive tasks. This lecture will present research on cerebellar contributions to complex cognition including language processing and discuss how cerebellar dysfunction may be associated with neurodevelopmental disorders.

Presenter

Anila D'Mello, MIT Boston, MA
United States