Neuroanatomy for Neuroimagers: Bringing a systems-level perspective to neuroimaging analyses

Mac Shine Organizer
The University of Sydney
Sydney, NSW
Australia

Symposium
The human brain is comprised of numerous circuits and systems that together interact to form the basis of cognitive function. While we have a variety of techniques to measure these patterns of organization, an appreciation of the basic neuroanatomical principles that together form the central nervous system is critical for understanding the complex patterns that we observe in our neuroimaging data. This workshop will introduce attendees to the basic organizational structure of the human brain. We will present neuroanatomical principles at both the systems and circuit level. Upon completion, attendees will have obtained a better understanding of the functional organization of the human brain, how it has been shaped over evolutionary time, and how the different neuroimaging signals from their experiments may relate to the underlying neuroanatomy. The flexibility of this topic means that attendees will develop insight into how to interpret diverse kinds of neuroimaging data, ranging from non-invasive structural and functional MRI or M/EEG in humans, to tract-tracing, at the systems and circuit level.

Objective
- An understanding of the neuroanatomy of functional systems across the cerebral cortex, basal ganglia, cerebellum, and brainstem.
- An understanding of different anatomical features that influence brain function, including cortical microstructure, connectivity, and neurochemical systems.
- How to incorporate evolutionary and neuroethological principles into the interpretation of neuroimaging findings.

Target Audience
This session targets attendees who are familiar with basic neuroimaging techniques, but are interested to learn more about the brain anatomy they encounter in their research. The session content aims to provide a basic introduction to various systems-level topics in neuroanatomy, with specific focus on anatomical themes that are relevant to the interpretation of neuroimaging findings.

Presentations

Shaping Brain Gradients: From phylogeny to social interaction
The current COVID-19 crisis, leading to increased social disconnection and need for social cohesion, highlights the importance of social skills to enhance human cooperation on a community level, as well as to overcome loneliness and social isolation at the level of the individual. However, to what extent social skills are embedded in human cortical organization, and whether this organization can change when nurturing social skills is incompletely understood. In the current session we will on the one hand discuss how evolutionary and genetic factors shape cortical organization and how this organisation may enable abstract cognitive and affective functions such as Theory of Mind and compassion. Then, we will shift gears and focus on how the intrinsic organization of the human brain may alter following social mental training. Throughout the session we will highlight both methods and application, and open up discussion for new questions, challenges, and research avenues. We hope that this broad approach underscores the intrinsic connection between human brain organization and human social behaviors.

Presenter
Sofie Valk, Max Planck Institute for Human and Cognitive Brain Sciences Liepzig, Germany

Principles of Cortical Microstructure

Cortical microstructure is fundamental to understanding brain function. In this session, we will explore the principles of cortical microstructure, discuss the supporting evidence, address caveats and identify their reflection in in vivo neuroimaging. Beginning with an introduction to cytoarchitecture, we will extend from the characterisation of individual cortical areas to variations across large-scale gradients. We will dismantle the relationship of cytoarchitecture to connectivity, based on principles such as the structural model and the laminar origin of projections. This will build towards a fuller understanding of the canonical microcircuit and why this is now a popular basis for in silico models of the brain. Throughout the session we will also discuss how microscale cortical features are resolved with macroscale or quantitative MRI. Together, these key topics will enhance the attendees' understanding of the functional correlates of cortical microstructure.

Presenter

Casey Paquola, MNI Montreal, Quebec, Canada

Imaging the Human Cerebellum: Challenges and recent advances

The cerebellum is a brain structure that has historically been relegated to the supplementary materials of scientific papers, removed from the field of view of neuroimaging studies, and excluded from major functional atlases of the human brain. However, the past three decades of functional neuroimaging has provided a number of important insights into the anatomy and function of the cerebellum, with a particular emphasis on a cerebellar involvement in cognition. The cerebellum is unlike the cerebral cortex in terms of both anatomy and physiology. It is a tightly folded, three-layered structure that comprises approximately 80% of all the neurons in the human brain. In conducting neuroimaging studies of the cerebellum, it is important to understand these differences and to appreciate how they introduce novel challenges in analysing fMRI and MRI data. In this symposium, we will explore these challenges in depth and talk about some recent advances. For example, we will discuss how different neuronal processes are reflected in the cerebellar BOLD signal compared to the neocortex and how our interpretation of fMRI data could be altered as a result. We will also focus on physiological artifacts that plague the cerebellum and discuss methods that account for this large proportion of explainable variance. Finally, we will turn our attention to anatomical localization, and examine different approaches that have been adopted to deal with variability and bias in reconstructing the cerebellar cortex in individuals. We hope that this discussion will encourage the interested neuroimager to consider the cerebellum in future studies and to adopt best-practices in analysing these data.

Presenter

Maedbh King, The University of California Berkeley Berkeley, CA, United States

Basal Ganglia – anatomy, function and their integration with the cortex

Due to pathologies such as stroke or degenerative diseases and their most salient symptoms, the basal ganglia have historically been regarded to play an exclusive role in motor function of the brain. Specifically, they were thought to be involved in an action selection process, where the most sensible action plans arising in the cortex are selected and set into motion by muscular activity via the brainstem and spinal cord. Recent evidence has challenged this view, suggesting that the basal ganglia are now increasingly considered to play a role in holistic brain function – including associative and limbic processing. Pathologies that are typically associated with the basal ganglia are movement disorders such as Parkinson's Disease, Essential Tremor and Dystonia, as well as Huntington's and Tourette's Disease. Specific alterations in basal ganglia circuitry are used to explain symptoms found in those diseases. When adopting a more holistic view, symptoms from the motor domain can be explained in diseases with an associative or affective focus. For instance, apathy – the lack of interest or enthusiasm sometimes found in patients suffering from Depression – can be explained with a model similar to akinesia – the lack of movement – when transferring models of pathology from the motor to the affective domains of basal ganglia – cortex interactions. In this talk, I will shed light on such models – the basal ganglia cortical loops covering almost all domains of human brain function. I will discuss the anatomy and function of the basal ganglia, their interactions with the cortex and methods that are involved in studying their structure and function (such as ultra-highfield MRI, MEG, EEG and LFP recordings).

Presenter

Andreas Horn, Charité – Universitätsmedizin Berlin, Germany