Max Planck Institute for Biological Cybernetics

March 22, 2018

Max Planck House Lecture Hall

Cortico-cortical connectivity: from structure to dynamic networks & control of behavior

Session 1. 9:00 – 11:30

A COMMON BLUEPRINT OF MAMMALIAN MACROSCALE CORTICAL CONNECTOMES
Alexandros Goulas, University Medical Center Hamburg-Eppendorf, Germany

CORTICO-CORTICAL CONNECTIONS: NUMBER AND DISTRIBUTION OF FIBRES, AXON DIAMETERS AND CONDUCTION VELOCITIES
Almut Schüz, Max Planck Institute for Biological Cybernetics, Tübingen, Germany

THE PARIETO-FRONTAL SYSTEM IN MONKEYS: CORTICAL AREAS, INFORMATION DOMAINS AND PROCESSING STREAMS
Roberto Caminiti, University of Rome SAPIENZA, Rome, Italy

HOW NEURONS IN THE VISUAL AND FRONTAL CORTEX INTERACT TO ENABLE VISUAL PERCEPTION AND THE EMERGENCE OF AWARENESS
Pieter Roelfsma, Netherlands Institute for Neuroscience, Amsterdam, Netherlands

Session 2. 13:00 -15:00

CORTICAL CONNECTIVITY: AXONAL TRACING, DIFFUSION MRI AND DYNAMICS
Giorgio Innocenti, Karolinska Institute, Stockholm, Sweden

TASK-RELATED EDGE DENSITY (TED) - A NEW METHOD FOR REVEALING DYNAMIC NETWORK FORMATION IN FMRI DATA OF THE HUMAN BRAIN
Gabriele Lohmann, Max Planck Institute for Biological Cybernetics, Tübingen, Germany

BRAIN-TO-BRAIN CONNECTION: JOINT-ACTION CODING IN THE PRIMATE FRONTAL CORTEX
Alexandra Battaglia-Mayer, University of Rome SAPIENZA, Rome, Italy

Abstracts

CORTICO-CORTICAL CONNECTIONS: NUMBER AND DISTRIBUTION OF FIBRES, AXON DIAMETERS AND CONDUCTION VELOCITIES

Almut Schüz, Max-Planck-Institut für biologische Kybernetik, Tübingen

The most characteristic feature of the cerebral cortex is its rich connectivity in itself, based predominantly on excitatory connections. These are comprised of short- and middle-range connections within the grey matter and long-range connections via the white matter. I will show data on the global connectivity of the mouse cortex, and then focus on the human cortical white matter. I will give an estimate of the number of fibers in the intrahemispheric bundles connecting the cortical lobes and present electron microscopic data on axonal thickness in these bundles from man and monkey. Such data are relevant for testing diffusion magnetic resonance imaging methods aiming at the investigation of white matter data in vivo, and, in particular, they are highly relevant for understanding functional interactions within the cortical network and the role of conduction times in it.

THE PARIETO-FRONTAL SYSTEM IN MONKEYS: CORTICAL AREAS, INFORMATION DOMAINS AND PROCESSING STREAMS

Roberto Caminiti, Dept. of Physiology and Pharmacology, University of Rome SAPIENZA, Rome, Italy.

The statistics of cortico-cortical connectivity between the parietal and frontal lobes, as well as that between superior and inferior parietal lobules of monkeys, shows the existence of different clusters of interconnected areas in the parieto-frontal system. The analysis of their functional properties allows the identification of at least five functional pillar domains spanning posterior parietal, anterior parietal, cingulate, frontal and prefrontal cortex. The scrutiny of inter-domain connectivity reveals different information processing streams, related to the representation of action space, reaching, grasping, oculomotor intention and visual attention, action recognition, selection of behavioral goals and strategies and estimate of the associated reward value. These streams have multiple entry nodes and outflow pathways and are all embedded within a distributed eye-hand matrix from which they can be selected by task demands.

A COMMON BLUEPRINT OF MAMMALIAN MACROSCALE CORTICAL CONNECTOMES

Alexandros Goulas, University Medical Center Hamburg-Eppendorf, Germany

The cerebral cortex of mammalian species exhibits highly intricate macroscale connectivity. Moreover, mammalian cortices differ vastly in size and phylogenetic distance. Given such complexity and pronounced species differences, it is a considerable challenge to decipher fundamental wiring principles that may underlie a common blueprint of the mammalian cortical connectome. This talk will highlight the existence of such a blueprint by analyzing extensive cytoarchitectonic and connectome data for the cerebral cortex of different mammalian species, particularly the mouse, cat, and macaque monkey. A quantitative cross-species framework is adopted and it will be shown that the cytoarchitectonic gradients of the cerebral cortex relate to fundamental features of cortico-cortical connections, that is, the existence and laminar origin of connections, as well as to the network topology of cortical areas. Thus, the cortical architecture of different mammals can be conceived as a species-specific instantiation of a common blueprint. This common blueprint is articulated in a species-specific manner that differentiates the mouse from the cat and macaque monkey cortex. The connectional blueprint potentially reflects variations of evolutionary conserved neurodevelopmental mechanisms and cellular phenomena that link the cytoarchitectonic and connectional dimensions of cortical organization and allows the extrapolation of connectional features in other mammalian cortices, such as the human cortex.

BRAIN-TO-BRAIN CONNECTION: JOINT-ACTION CODING IN THE PRIMATE FRONTAL CORTEX

Alexandra Battaglia-Mayer, Dipartimento di Fisiologia e Farmacologia, SAPIENZA - Università di Roma

Daily life often requires motor coordination with another partner. We recorded cell activity from premotor cortex of two monkeys performing in a 'solo' and in a ‘joint-action' condition. We found that, in addition to classical action-related 'solo' cells, firing similarly when the same action was performed in either conditions, a population of ‘joint-action cells’ encoded not only the own action, but also that of the partner better than the solo cells, and also signaled the social motor error, i.e the difference between the motor output of the interacting monkeys. Action observation-related activity did not improve the representational power of joint-action cells. When monkeys coordinated their action with a computer, the accuracy of joint-action cells to discriminate between solo and joint-action performance decreased significantly.

HOW NEURONS IN THE VISUAL AND FRONTAL CORTEX INTERACT TO ENABLE VISUAL PERCEPTION AND THE EMERGENCE OF AWARENESS

Pieter Roelfsma, Netherlands Institute for Neuroscience, Amsterdam, Netherlands

Most theories hold that early visual cortex is responsible for the local analysis of simple features while cognitive processes take place in higher areas of the parietal and frontal cortex. However, these theories are not undisputed because there are findings that implicate early visual cortex in visual cognition - in tasks where subjects reason about what they see. Are these cognitive effects in early visual cortex an epiphenomenon or are they functionally relevant for these mental operations? I will discuss new evidence supporting the hypothesis that the modulation of activity in early visual areas has a causal role in cognition. The modulatory influences allow the early visual cortex to act as a multiscale cognitive blackboard for read and write operations by higher visual areas, which can thereby efficiently exchange information. I will next address how a conscious experience can emerge. Along the cortical hierarchy, a progressively larger proportion of cells modulate their spiking activity according to the subject’s perceptual state, and the global workspace theory holds that stimuli only reach awareness as soon as they induce a special, “ignited” state in frontal cortex. We compared activity propagation from lower to higher cortical areas between perceived and identical non-perceived stimuli in V1, V4 and the dorsolateral prefrontal cortex of macaque monkeys. The animals carried out a task in which they reported the presence of a low-contrast stimulus with an eye movement. We found that low contrast stimuli that reached awareness elicited a stronger initial feedforward response at all these levels of the cortical hierarchy than stimuli that remained subliminal. Stimuli that reached awareness elicited a characteristic, “ignited” state. We could predict whether a weak stimulus reaches awareness based on the pre-stimulus brain state. Our findings provide new insights into the conditions that permit visual stimuli to enter into consciousness.

CORTICAL CONNECTIVITY: AXONAL TRACING, DIFFUSION MRI AND DYNAMICS

Giorgio M Innocenti, Karolinska Institute, Stockholm, Sweden and EPFL, Lausanne, Switzerland

One of the strongest, time-honored structural-functional relations in the neurosciences is that between axon diameter and conduction velocity of action potentials established by Hursch (1939) in a foundational study, supervised by Gasser, Grundfest and Lorente de No, at Rockefeller University. This relation was an essential building block in Erlanger and Gasser’s structural/functional classification of peripheral nerve fibers leading to the attribution of Nobel Prize to Gasser in 1945. Over the last few years the analysis of axon diameters and conduction velocities was extended to the central nervous system using a combination of histological techniques coupled to the computation of axonal conduction velocities and axonally generated conduction delays. The overall picture is that the brain consists of axonal pathways conducting at different velocities and generating different conduction delays between brain sites. Diffusion MRI is overcoming severe obstacles to provide a reliable picture of brain connections, including estimates of axon diameters. A bewildering dynamic view of brain function is emerging where axons become the agent of fundamental computations particulalrly in the temporal domain. These studies of axons have prompted some functional interpretations although other aspects, raise open questions.

TASK-RELATED EDGE DENSITY (TED) - A NEW METHOD FOR REVEALING DYNAMIC NETWORK FORMATION IN FMRI DATA OF THE HUMAN BRAIN

Gabriele Lohmann, Max Planck Institute for Biological Cybernetics, Tübingen, Germany

In this talk, I will present a new data analysis algorithm that is designed to identify time series of voxels in an fMRI image that collectively synchronize in response to a task. At the heart of our approach is the concept of spatially localized and task-induced edge density motivating us to call this algorithm "TED" (Task-induced Edge Density). In short, TED identifies edges in a brain network that differentially respond in unison to a task onset and that occur in dense packs of edges with similar characteristics. We show first results of TED applied to fMRI data acquired at 9.4 Tesla which revealed widespread task-related brain activation that evaded detection using traditional approaches.

Contact Information

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