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Alina Peter

Short-term memory in stimulus-specific circuits in macaque V1

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When a visual stimulus is repeated, responses are typically reduced, yet might maintain their effect through increasing synchronization. Previous work has found that many repetitions of a grating lead to increasing gamma-band synchronization. Here we show in awake macaque area V1 that both, repetition-related reductions in firing rate and increases in gamma are specific to the repeated stimulus and do not or hardly affect new stimuli. These effects show memory on the timescale of minutes of intervening stimulation. Gamma increases were also specific to the presented stimulus location. Further, repetition effects on gamma and on firing rates generalized to repetitions of natural images. Across natural images, repetition-related changes and initial response strength were positively correlated for gamma, and negatively for firing rates. These findings suggest that gamma-band synchronization subserves the adaptive processing of repeated stimulus encounters, both for generating efficient stimulus responses and possibly for memory formation.

Benjamin Stauch

Stimulus learning in human early visual cortex

Benjamin J. Stauch, Alina Peter, Heike Schuler, Pascal Fries

Stimulus repetition reduces neuronal responses in most sensory areas, while leaving perceptual fidelity intact. In macaque V1 and V4, gamma power and spike-field locking increase over high numbers of stimulus repetitions. Here we show that this gamma repetition enhancement is stimulus specific, shows short-term stimulus memory and increases the gamma-band Granger causality influence of early onto higher visual areas. In human MEG recordings, we found that stimulus-induced gamma power in early visual cortex increases with stimulus repetition. Crucially, this increase did not transfer to other stimuli, suggesting that the circuit changes were specific to the inducing stimulus. Furthermore, the increase persisted when the inducing stimulus was repeated after 25 minutes of intervening different stimuli. The increase was most pronounced in early visual areas, and entailed an increased feedforward influence onto higher areas. Our results suggest that early visual cortex gamma synchronization plays a role in adaptative neuronal processing of recurring stimuli. We propose that drive-dependent gamma phase shifting combines with spike-timing-dependent synaptic plasticity to reduce and sharpen overall responses, while maintaining the impact on higher areas and ultimately behavior.

Cem Uran

Deep neural networks reveal distinct relationships of firing and synchronization patterns to predictability in natural images

Cem Uran, Alina Peter, Andrea Lazaar, William Barnes, Johanna Klon-Lipok, Rasmus Roese, Pascal Fries, Wolf Singer, Martin Vinck

Deep neural networks for object recognition are a promising model of feedforward visual processing and can accurately predict firing-rate responses along the ventral stream. Yet, these networks are poor models of various aspects of cortical processing related to recurrent connectivity, including neuronal synchronization and the integration of sensory inputs with spatio-temporal context. We trained self-supervised, generative neural networks to predict (i.e. inpainting) small regions of natural images based on the spatial context. Using these predictions, we determined the spatial predictability of visual inputs into (macaque) V1 RFs (receptive fields), and distinguished low- from high-level predictability. Spatial predictability strongly modulated V1 activity, with distinct effects on firing rates and synchronization in gamma- (30-80Hz) and beta-bands (18-30Hz). Furthermore, firing rates, but not synchronization, were accurately predicted by deep neural networks for object recognition. Neural networks trained to specifically predict V1 gamma-band synchronization developed large, grating-like RFs in the deepest layer. These findings suggest specific roles for firing rates and synchronization in self-supervised learning of natural-image statistics.

Chao Sun

The Spatial Scale of Synaptic Protein Allocation during Homeostatic Plasticity

Chao Sun, Andreas Nold, Tatjana Tchumatchenko, Mike Heilemann, Erin M. Schuman

An individual neuron hosts up to 10,000 individual synapses that can be made stronger or weaker by local and cell-wide plasticity mechanisms- both of which require protein synthesis. To address over what spatial scale a neuron allocates synaptic resources, we quantified the distribution of newly synthesized proteins after global homeostatic upscaling using metabolic labeling and single-molecule localization (DNA-PAINT). Following upscaling, we observed a global increase in locally synthesized nascent protein in synapses and at dendrites, with a high degree of variability between individual synapses. We determined the smallest spatial scale over which nascent proteins were evenly distributed and found that it is best described by synaptic neighborhoods (~ 10 microns in length)- smaller than a dendritic branch and larger than an individual synapse. Protein allocation at the level of neighborhoods allows a neuron to balances local autonomy and global homeostasis.

Chitaranjan Mahapatra

Quantitative studies of autonomic nervous system activities in urinary bladder smooth muscle cells towards bladder overactivities

Chitaranjan Mahapatra

The urinary incontinence (UI) is defined as the involuntary loss of urine and associated with the enhanced spontaneous contractions of the detrusor smooth muscle (DSM). The spontaneously evoked action potentials (sAPs) in DSM cells initiate and modulate these contractions. The DSM is strongly innervated, connecting approximately 16000 afferent and efferent axons from ganglion neurons. It generates sAPs due to the stochastic nature of purinergic neurotransmitter release from the parasympathetic nerve. This study aims to understand the putative relationship between the fluctuating ion channel conductances and the stochastic release of ATP in generating sAPs. The neurotransmitter current was considered as an independent excitatory conductance in the model. The point-conductance is incorporated into a single DSM cell model based on a single cylindrical compartment. The elicited AP consists of an after depolarization and afterhyperpolarization phase. The AP peak amplitude and duration are about 5 mV and 40 ms respectively. The membrane resting potential is held at – 50 mV with a 3 mV of fluctuation. The stochastic depolarization up to 20 mV activates the T-type Ca2+ channel first and then the L-type Ca2+ channel to generate an action potential. The T-type Ca2+ channel blocker can be used as a new pharmacological target for UI.

Dumitru Ciolac

Gender-specific signatures of hippocampal networks and regional integrity in multiple sclerosis

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Introduction: The hippocampus is recognized as an early target of multiple sclerosis (MS) and besides focal neuroinflammatory damage, network disruption is thought to account for cognitive deficits in MS. Given the sex-related vulnerability to cognitive decline in MS, sex-driven differences in hippocampal networks and regional integrity can be hypothesized.

Methods: A cohort of 476 MS patients (age 35±10 years, 337 females, disease duration 16±14 months) and 110 healthy subjects (HS, 34±15 years, 54 females) were imaged on a 3T MRI scanner at baseline and after 2 years. Volumes of hippocampal subfields were quantified and fed into the reconstruction of single-subject networks and analyzed within the graph theoretical framework. Sex-related differences in network and subfield properties were evaluated with linear mixed-effects models, adjusted for age, center and total hippocampal volume; p-values are reported after Bonferroni correction for multiple comparisons.

Results: At baseline, both female and male patients displayed higher clustering ($p<0.05$) compared to HS. Female patients had higher clustering ($p<0.05$) but equally efficient network organization (local and global efficiency, $p>0.05$) compared to male patients. At follow-ups, independently of sex, patients had increased modularity, clustering and global efficiency, however, with higher values in female patients (all $p<0.05$). Both female and male patients had lower volumes in almost all subfields compared to HS. Female patients had smaller parasubiculum and presubiculum but larger molecular layer as compared to male patients. Over time, female patients had more widespread regional volumetric reduction compared to male patients. Cognitive performance was positively associated with clustering ($r=0.27$, $p<0.01$), local ($r=0.25$, $p<0.01$) and global efficiency ($r=0.24$, $p<0.01$) only in female but not in male patients.

Conclusion: Our findings suggest a more clustered and modular network architecture in female patients despite a more extensive local atrophy over time. The stronger association of cognitive performance with intrinsic hippocampal connectivity may explain cognitive reserve in female patients.

Gabriel González-Escamilla

Connectome underpinnings of centromedian nucleus of the thalamus deep brain stimulation in generalized pharmacoresistant epilepsy

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Deep brain stimulation (DBS) is effective for the treatment of neuropsychiatric disorders and first promising results have been achieved to reduce seizure severity and frequency in pharmacoresistant epilepsies through thalamic DBS.

While targeted local neuromodulation is achieved through DBS, a shift of neural activity in the epileptogenic network is a prerequisite for an effective clinical response. Here, preoperative imaging and connectomic analysis were applied to dissect targeted networks and model therapeutic responses to thalamic DBS.

Here, we make use of long-term clinical and imaging data (2-11 years) from patients with generalized pharmacoresistant epilepsy that underwent centromedian (CM) DBS (N = 10, mean age at surgery = 30.8±5.9 years, 4 female) and modelled the volume of tissue activated (VTA), which were included as seeds to reconstruct the targeted network from diffusion and functional connectome data. We further evaluated the association between the targeted networks and the clinical outcome of CM-DBS. Significant seizure frequency reduction (>50%) after CM-DBS was shown in 90% of the patients. The optimal clinical response was associated with the DBS location site and the streamlines connecting VTAs with a distinctive network conformed by the sensorimotor and supplementary motor cortices, cerebellum/brainstem, as well as the frontal cortex. The same network was robustly depicted using both structural and functional connectivity data. Fibers within the cerebellum/brainstem, highly overlapping with the reticular system, were most tightly associated with the optimal DBS outcome. Our results show that the outcome of CM-DBS in generalized pharmacoresistant epilepsy is highly dependent on the individual connectivity profile of the electrode location site and the targeted network, including the cerebello-thalamo-cortical regions. The proposed framework could be implemented in future studies to refine stereotactic implantation sites or the parameters for targeted neuromodulation.

Gavin Brelstaff

Mutual causation between body and brain

Gavin Brelstaff, Alexandra Brelstaff

Mutual Causation has received relatively little attention since Lois Frankel's analysis demoted it as practical possibility. Indeed its absence is implicit in the increasing application of Structural Causal Models to represent causal relations between conscious perceptive states, brain states and report states - as exemplified in the account of Gustav Bernroider. Nevertheless, Penny et al have explored whether brain activity might be driven by master-slave or mutual entrainment mechanisms - adopting Dynamic Causal Modelling between networks of weakly coupled oscillators - whereby dynamic phase changes may indicate causal reversals. Might such a network extend to peripheral sites so that a mutual causal oscillation between body and brain process becomes conceivable? This would reflect Damasio's "resonant loop between body states and brain states" and lays the empirical path along which sentience can lead to knowledge rather than being a superfluous appendage.

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Mathias Voigt

Intracolumnar effects of intracortical microstimulation in the primary auditory cortex

Mathias B. Voigt, Andrej Kral

Electrical stimulation is one of the oldest causal approaches in neuroscience. Especially stimulation inside the cortical tissue, intracortical microstimulation (ICMS), has been used extensively in associating neuronal populations with brain functions and is the method of choice for current developments in clinical neuroprostheses. However, the influence of various stimulus parameters on the elicited neuronal activation and the extent of the stimulation is still under discussion. Here, we

report about the results of experiments, in which we combined ICMS with concurrent recordings of population activity on a single shank, in vivo. Using linear multi-electrode arrays, spanning all cortical layers, we could gather information on the intracolumnar effects of ICMS at the point of stimulation. We electrically stimulated the primary auditory cortex of guinea pigs under ketamine/xylazin or isoflurane anesthesia. Stimulation consisted of biphasic, monopolar single current pulses of both leading-phase polarities (cathodic and anodic) and acoustic clicks as physiological control stimuli. The elicited cortical response was determined by concurrently recording broadband potentials from the remaining electrodes of the stimulated array.
Above an intensity threshold, ICMS reliably evoked a stereotypical cortical response in the stimulated column. Below this threshold, the neuronal response was dependent on the depth of stimulation below the pia. The best match of the electrically elicited response profile to physiological responses was achieved with stimulation of the thalamo-recipient layer IV.
Time-frequency analyses revealed a strong propensity of low-current single ICMS pulses to elicit early, evoked response components but failure to elicit long-latency, induced components on their own. However, the long-latency induced component of the response to a concurrent acoustic stimulus was found to be selectively enhanced. Additionally, a phase-based excitability analysis documented that the neuronal activity elicited by ICMS can be integrated into ongoing cortical activity in the same way as the activity elicited by a physiological stimulus.

Muthuraman Muthuraman

Cross-frequency coupling between gamma oscillations and deep brain stimulation frequency in cortico-subcortical networks in Parkinson's disease patients

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The disruption of pathologically enhanced beta oscillations is considered one of the key mechanisms mediating the clinical effects of deep brain stimulation on motor symptoms in Parkinson's disease. However, a specific modulation of other distinct physiological or pathological oscillatory activities could also play an important role in symptom control and motor function recovery during deep brain stimulation. Finely tuned gamma oscillations have been suggested to be prokinetic in nature, facilitating the preferential processing of physiological neural activity. In this study, we postulate that clinically effective high-frequency stimulation of the subthalamic nucleus imposes cross-frequency interactions with gamma oscillations in a cortico-subcortical network of interconnected regions and normalises the balance between beta and gamma oscillations. To this end we acquired resting state high-density (256 channels) electro-encephalography from 31 patients with Parkinson's disease who underwent deep brain stimulation to compare spectral power and power-to-power cross-frequency coupling using a beamformer algorithm for coherent sources. To show that modulations exclusively relate to stimulation frequencies that alleviate motor symptoms, two clinically ineffective frequencies were tested as control conditions.
We observed a robust reduction of beta and increase of gamma power, attested in the regions of a cortical and sub-cortical network. Additionally, we found a clear cross-frequency coupling of narrowband gamma frequencies to the stimulation frequency in all of these nodes which negatively correlated with motor impairment. Furthermore, deep brain stimulation at clinically ineffective frequencies did not alter the source power spectra or cross-frequency coupling in any region. These findings demonstrate that clinically effective deep brain stimulation of the subthalamic nucleus differentially modifies different oscillatory activities in a wide-spread network of cortical and subcortical regions. Particularly the cross frequency interactions between finely tuned gamma oscillations and the stimulation frequency may suggest an entrainment mechanism that could promote dynamic neural processing underlying motor symptom alleviation.

Oleg Soloviov

TOWARDS THE GENERAL BRAIN ACTIVITY THEORY (JBT): PROCESSING INFORMATION IN NEURONAL NETWORKS BY MEANS OF TWO FORMS OF CAUSALITY

Oleg Soloviov

Abstract. All neuroelectrical, neurochemical, neuromolecular, ionic, etc. processes expressed in physical quantities, are considered, by default, to realize biologically and/or socially expedient information functions. However, scientific experience claims that physical processes 'are indifferent' to a person's biological or/and social existence (Soloviov, 2019). Thus, we are faced with an intriguing question: what makes the neural networks of the brain integrate information (Tononi) biologically and/or socially expediently.

The Fig.1 in a high generalized way symbolizes the physical structure of the neural networks of the brain, which provide the information operations of accumulation and integration of information by means of mental phenomena.

I insist that subjective value (realized in the limbic region) directs all information processes in the neural networks of the brain to biological (later in evolution, social) expediency. I insist that the perception of information in the human brain occurs by means of subjective value. I insist that the integration of information is determined by means of subjective value. I insist that even the storing information in the brain is controlled by means of subjective value.

Further, we will take into account that physical causality presupposes the direction of the cause from the outside towards the body. However, in the case of the brain, the opposite determination may be observed. Here we are talking about the formation of informationally well-endowed motor acts in the brain on the basis of integrated information. Subjective value turns out to be an "indetermined" factor of choice of needed for organization of behavior information inside the continuum of information fixed in the brain (Soloviov, 2019).

Thus, the factor of subjective value, operating with information accumulated in the brain, turns out to be a fundamental mechanism for the implementation of causality from within of high level living systems.

Key words: subjective value, from within causality, informationally well-endowed motor act.

Rishabh Chakrabarty

Neural Decoding is all you need.

Rishabh Chakrabarty

Simone Russo

Cortical lesions induce local and distant electrophysiological sleep-like dynamics: an intracranial study in humans

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Focal brain injury can disrupt neural activity beyond the site of neuronal loss, involving a larger network of connected brain areas. This network effect, known as 'diaschisis', has profound clinical implications but lacks a clear electrophysiological correlate. Here, we study the local and large-scale effects of lesions induced by radiofrequency thermocoagulation, performed for epilepsy treatment, on stereo-electroencephalographic intracerebral activity in 21 patients. By taking advantage of controlled anatomical lesions, standardized baseline conditions, effective connectivity measures, and high-resolution intracerebral recordings, we show that a key electrophysiological component of diaschisis is the generation of sleep-like slow waves within the awake brain. These slow waves can extend well beyond the structural lesion, specifically involve connected areas and resemble the neuronal events observed during natural sleep. Accounting for the pathological intrusion of sleep-like dynamics within the awake brain will be essential for shaping the outcome and rehabilitation of focal and multi-focal brain injury.

Zachary Ip

Cortical stroke disrupts hippocampal activity and cortico-hippocampal communication

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Middle cerebral artery (MCA) stroke is the most common stroke in humans, and often leads to impaired cognition and memory. The hippocampus is highly involved in memory function, however hippocampal blood flow is not supplied by the MCA, and MCA stroke does not compromise the structural integrity of the hippocampus. Here we investigate chronic electrophysiological changes to cortico-hippocampal networks following experimental MCA occlusion in rats. We recorded local field potentials simultaneously from cortex and hippocampus two weeks and one month following stroke. We analyzed signal power, brain state, phase-amplitude coupling, and sharp wave associated ripples to assess hippocampal function and cortico-hippocampal communication. Our results show disrupted communication between the sensorimotor cortex and hippocampus, and reduced hippocampal activity following stroke. This suggests that the neural activity underlying cognitive function following stroke can be characterized by these chronic changes in electrophysiology, establishing hippocampal biomarkers of stroke for potential targeted therapies.