NeuroBridges 2015

September 7th-9th

Salle du Conseil, Université Paris Descartes
12, rue de l'École de Médecine, 75006, Paris

Monday 7.9.15

9:00-9:15 Opening words
9:15-10:15 Opening lecture **Stanislas Dehaene** (College de France & INSERM) "Decoding the time course of conscious and non-conscious operations"

10:15-10:45 ***Coffee Break***

10:45 -11:20 **Ossama Khalaf** (EPFL, Lausanne): "In the pursuit of the fear engram: Identification of neuronal circuits underlying the treatment of anxiety disorder"
11:20-11:55 **Noam Saadon Grossman** (Hebrew University of Jerusalem, Israel): "Discontinuity of Cortical Gradients Reflects Sensory Impairment"
11:55-12:30 **Cherine Fahim** (McGill University, Canada): "Lobewise Correlates of Internalizing and Externalizing Behaviors: Categorical or Dimensional?"

12:30-14:00 ***Lunch Break***

14:00-14:35 **Maoz Shamir** (Ben-Gurion University of the Negev, Israel): "Balancing feed-forward excitation and inhibition via inhibitory spike timing dependent plasticity"
14:35-15:10 **Alessandro Barri** (Institut Pasteur, Paris): "Maximising memory storage predicts the statistics of cortical activity"

15:10-15:40 ***Coffee Break***

15:40-16:15 **Elisa Tartaglia** (Institut de la Vision, Paris): "Modulation of Network Excitability by Persistent Activity: How Working Memory Affects the Response to Incoming Stimuli"
16:15-16:50 **Noga Zaslavsky** (Hebrew University of Jerusalem, Israel): "An Information-Theoretic Approach to Learning Hierarchical Representations in Deep Neural Networks"

Dinner *(only for speakers)*

Tuesday 8.9.15

9:00-9:35 **Valerie Ego-Stengel** (UNIC, CNRS, Gif-sur-Yvette): "Neural mechanisms of Brain-Machine Interfaces"
9:35-10:10 **Amjad Abu-Rmileh** (Ben–Gurion University of the Negev, Israel): "Co-adaptive Learning in Brain Computer Interfaces"

10:10-10:40 ***Coffee Break***

10:40 -11:15 **Shimon Marom** (Technion, Israel): "Dynamics of Excitability Over Extended Time Scales"
11:15-11:50 **German Sumbre** (ENS, Paris): "Biological significance, mechanisms and development of the ongoing spontaneous activity in the zebrafish optic tectum"
11:50-12:25 **Oren Shriki** (Ben Gurion University of the Negev, Israel): "Critical dynamics in resting and evoked human brain activity"

12:25-14:00 ***Lunch Break***

14:00-14:35 **Bassam Attalah** (Champalimaud Centre for the Unknown, Portugal): "A new role of midbrain dopaminergic neurons during temporal judgments"
14:35-15:10 **Mehdi Khamassi** (Université Pierre et Marie Curie, CNRS, Paris): "Dual-system reinforcement learning and dopamine-independent Pavlovian goal-tracking behaviors"

15:10-15:40 ***Coffee Break***

15:40-16:15 **Ran Darshan** (Hebrew University of Jerusalem, Israel): "A minimal neural mechanism for explorative behaviors"
16:15-16:50 **Ahmed Moustafa** (University of Western Sydney, Australia): "The Computational and Cognitive Neuropsychology of Parkinson's Disease"

Social Event + Gala Dinner *(only for speakers)*

<u>Wednesday 9.9.15</u>

9:00-9:35 **Frédéric Chavane** (INT, CNRS, Marseille): "Motion anticipation in the primary visual cortex of the awake monkey"
9:35-10:10 **Yasmine El-Shamayleh** (University of Washington, Seattle): "Invariant visual object codes in single cortical neurons"
10:10 -10:45 **Thérèse Collins** (LPP, Université Descartes, Paris): "Corollary discharge in human superior colliculus"

10:45-11:15 ***Coffee Break***

11:15 -11:50 **Najib Majaj** (New York University, New York): "Simple learned weighted sums of inferior temporal neuronal firing rates accurately predict human object recognition performance"
11:50-12:25 **Melodie Durnez** (L'Université Paris Descartes, Paris): "Persistent Activity as a Result of Stimulus-Driven Network-Wide Re-Organization of the Pattern of Firing Rates"

12:25-12:40 *Closing Remarks*

12:40-13:30 ***light Lunch***

Abstracts

In pursuit of the fear engram: Identification of neuronal circuits underlying the treatment of anxiety disorder

Ossama Khalaf[1]

1. Lab of Neuroepigenetics (UPGRAEFF) - Brain Mind Institute, EPFL

Fear and other anxiety disorders are extraordinarily robust and difficult to treat. Among the most effective treatments for anxiety disorders are exposure-based therapies, during which a patient is repeatedly confronted with the originally fear-eliciting stimulus in a safe environment so that the once fearful stimulus can be newly interpreted as neutral or safe. A fundamental element for successful exposure-based therapies is the reactivation/recall of the traumatic memory, which initiates a time-limited process called memory reconsolidation, during which a memory becomes susceptible to disruption.

Presently, the neuronal subpopulations underlying successful fear memory extinction remain completely unknown, which represents a big gap in memory research. Therefore, we aim to identify these neuronal subpopulations that are causally implicated in effective attenuation of remote fear memories in order to determine whether the original traumatic memory trace has been permanently modified or a new memory trace of safety has been superimposed over the original one. Using exposure-based therapy in transgenic mice, which allows for a time-limited activation of neurons upon remote memory recall, making it not only possible to visualize those neurons but also to experimentally isolate them from the rest of the neurons for further molecular investigations.

Discontinuity of Cortical Gradients Reflects Sensory Impairment

Noam Saadon-Grosman[1,2]

1. Department of Neurology, Hadassah Hebrew University Medical Center, Jerusalem 9112001, Israel.
2. Department of Medical Neurobiology, Faculty of Medicine, The Hebrew University of Jerusalem, Jerusalem 9112001, Israel.

Topographic maps are fundamental for brain organization. In the somatosensory system, whole-body sensory impairment may be reflected in cortical signal reduction and in disorganization of the somatotopic map. Yet the role of these two potential responses to somatosensory pathology is unclear. We studied whole-body cortical representations of five patients with cervical sensory Brown-Séquard syndrome (injury to one-side of the spinal cord) and five healthy controls. Brown-Séquard syndrome enabled us to compare disturbed and non-disturbed body-sides in the same subjects in response to continuous sensory stimulation using functional MRI. We quantified the spatial gradient of cortical activation and evaluate the divergence from a continuous pattern as well as the fMRI signal power. For each individual patient, gradients' continuity was disrupted in the hemisphere contralateral to the disturbed body-side at both the primary somatosensory cortex (S1) and the supplementary motor area (SMA). Gradients contralateral to the non-disturbed body-side were similar to controls. No difference was found in the fMRI signal power in both patients and controls. These results suggest that decreased sensation in Brown-Séquard patients is related to gradient discontinuity rather than signal reduction. Gra-

dient continuity may play a central role in topographical organization, and its disruption may characterize pathological signal processing.

Lobewise Correlates of Internalizing and Externalizing Behaviors: Categorical or Dimensional?

Cherine Fahim[1]

1. McGill University, Montreal, Canada

Objective

The categorical approach commonly used to study mental disorders has been criticized as too restraining and unlikely to capture the underlying neurobiology. The dimensional approach assumes that they represent extreme variants of typical behaviors along a continuum. Here, we examined the cortical morphological correlates of externalizing (EXT) and internalizing (INT) behaviors in a healthy sample of adolescent monozygotic twins, and how maternal behaviors are associated with adolescent cortical morphology.

Method

Lobewise cortical morphology (i.e., cortical thickness [Cth], surface area [SA], gyrification index [GI], cortical volume [CV] and cortical complexity [CC]) was extensively assessed in 108 monozygotic twins (54 pairs: 46 boys and 62 girls, age 15 years-old), using the Civet pipeline of the Montreal Neurological Institute. EXT and INT behaviors were assessed using the computerized version of the Dominic Interactive. Maternal depressive symptoms were assessed using the Symptom Check List (SCL-90). Relationships between brain morphology, adolescent's behavior and maternal parenting during childhood were analyzed using mixed general linear models and automatic linear modeling (ALM), while controlling for sex and total brain volume.

Results

We found significant linear negative associations ($p \leq 0.05$) between (1) EXT behaviors and frontal Cth bilaterally and parietal GI bilaterally; (2) between INT behaviors and right parietal Cth, right parietal and left temporal CV. ALM analysis ($p \leq 0.01$) revealed that hemispheric thickness within twins brain morphology was most strongly associated with EXT. Conversely, maternal depressive symptoms during childhood was most strongly associated with INT.

Conclusions

Considering EXT and INT behaviors as a continuum in a healthy homogeneous adolescent twin population, our results are in line with well-established findings in clinical populations. We provided an extensive lobewise morphological assessment of two of the major mental behaviors' spectra and surmounted confounders such as sample heterogeneity, age differences, disease onset, medication, substance abuse and comorbidity. Our results may provide empirical evidence for the notion that a dimensional diagnostic approach is preferred to the categorical approach, preparing for the future inclusion of genetic, imaging, biochemical elements to psychiatric diagnoses.

Balancing feed-forward excitation and inhibition via inhibitory spike timing dependent plasticity

Maoz Shamir[1]

1. Ben Gurion University of the Negev, Israel.

It has been suggested that excitatory and inhibitory inputs to cortical cells are balanced, and that this balance is important for the highly irregular firing observed in the cortex. There are two hypotheses as to the origin of this balance. One assumes that this balance results from a stable solution of the recurrent neuronal dynamics. This hypothesis can account for a balance of steady state excitation and inhibition without fine tuning of parameters, but not for transient inputs. The second hypothesis suggests that the feed forward excitatory and inhibitory inputs to a postsynaptic cell are already balanced. This latter hypothesis can also account for the balance of transient inputs. However, it remains unclear what mechanism underlies the fine tuning required for balancing feed forward excitatory and inhibitory inputs.

Here we investigated whether inhibitory synaptic plasticity is responsible for the balance of transient feed forward excitation and inhibition. We address this issue in the framework of a model characterizing the stochastic dynamics of temporally asymmetric Hebbian spike timing dependent plasticity of feed-forward excitatory and inhibitory synaptic inputs to a single post-synaptic cell. Our analysis shows that inhibitory Hebbian plasticity generates 'negative feedback' that balances excitation and inhibition. This is in contrast with the 'positive feedback' of excitatory Hebbian synaptic plasticity.

To account for the diversity of the empirically observed STDP rules, we suggest a model in which the STDP rule is represented by two processes that occur in parallel one for potentiation and one for depression. Analysis of the STDP dynamics reveals a critical point. Below this critical point the STDP dynamics is governed by a negative feedback and the synaptic weights are characterized by a unimodal distribution. Above this point, the stability of the STDP dynamics is governed by the synaptic weight dependence of the STDP rule. In the latter case there is a different parameter with a critical value, above which, a bimodal synaptic weight distribution exists. We show that the location of these critical points depends on general properties of the temporal structure of the STDP rule and not on its fine details. These results hold for both excitatory and inhibitory synapses. The symmetry in the learning dynamics of excitatory and inhibitory synapses is discussed.

Maximizing memory storage predicts the statistics of cortical activity

Alessandro Barri[1]

1. Institut Pasteur, Paris

According to a major theory, memories are passively stored in the patterns and strengths of synaptic connections among cortical neurons, and actively recalled through self-sustained patterns of neuronal activity (induced by that synaptic structure). The recall is triggered by transient, selective external inputs. In this framework, an active memory is represented by an attractor of the collective network dynamics. Different attractors (memories) feature different spatial distributions of firing rates.

A rather puzzling aspect of patterns of cortical activity is their high levels of temporal irregularity and spatial inhomogeneity: Spiking is temporally irregular resembling a Poisson process, population-averaged firing rates are quite low, and distributions of single-cell firing rates are unimodal and right-skewed with a long tail.

Several mechanistic accounts have been offered to explain such a regime of activity, most notably the balance of excitation and inhibition. However, the theory of balanced networks does not explain the relationship between cortical activity and memory function.

How are the statistical features of neuronal activity in the cortex related to long-term storage? Using a combination of analytical techniques and numerical simulations, we show that, at least in a simple toy-model, those features are a natural consequence of storing a very large number of memories in a distributed neural architecture where each neuron receives a large number of connections. In particular, we show that: (i) Maximising capacity requires right-skewed long-tailed distributions of firing rates with low averages; (ii) Networks that store an extensive number of patterns that have identical average firing rates necessarily feature a balance of excitation and inhibition. Thus, a network operating in this regime necessarily produces also irregular spiking. Finally, our theory suggests that plasticity of inhibitory synapses, often neglected in theoretical studies, plays a crucial role in memory storage.

Modulation of Network Excitability by Persistent Activity: How Working Memory Affects the Response to Incoming Stimuli

Elisa Tartaglia[1]

1. Institut de la vision, Paris

Over short time periods, memories are stored by sustained patterns of spiking activity which, once initiated by the stimulus, persist over the entire retention interval. How the information stored by such persistent activity is later retrieved is presently unclear. Here we propose that, besides temporarily storing memories, persistent activity is also instrumental in their retrieval by transiently modifying the tuning properties of the underlying neuronal networks. We show that the mechanism proposed parsimoniously recapitulates the extensive experimental phenomenology on match effects observed in delayed-response tasks, where the information held in memory has to be compared with incoming, sensory-related information to act appropriately. The theory makes very specific, straightforwardly testable predictions.

An Information-Theoretic Approach to Learning Hierarchical Representations in Deep Neural Networks

Noga Zaslavsky[1]

1. Hebrew University of Jerusalem, Israel

Deep Neural Networks (DNNs) are powerful models for learning hierarchical representations of their input, and deep learning algorithms currently achieve state-of-the-art performance in a large variety of machine learning tasks. In this work we present an information-theoretic approach to analyzing DNNs, and to better understanding optimality principles that can give rise to such hierarchical representations in supervised learning. By considering a DNN as a Markov chain of representations, we naturally relate it to the information bottleneck (IB) principle, i.e. the tradeoff between compressing the input and preserving information about the label. The advantage of this approach is that it allows us to evaluate each layer in the network in terms of the mutual information between the input layer and the desired output, and to compare different networks to the optimal IB representations. The IB representations go through a sequence of structural phase transitions, and these representations define the information-theoretic limit for each layer in the network. We show that in most cases it is not possible to achieve the information-theoretic limit at all layers of the network. We then discuss possible implication for deep learning algorithms that arise from this hardness result and from finite sample generalization bounds in the IB framework.

Neural mechanisms of Brain-Machine Interfaces

Valerie Ego-Stengel[1]

1. UNIC, CNRS, Gif-sur-Yvette

Brain-machine interfaces use neuronal activity to control prostheses, with the long term goal of restoring motor abilities to impaired subjects. Operant conditioning of neuronal firing rates has been a successful strategy in the field.

Here, several neurons were recorded simultaneously in the motor cortex of head-fixed awake rats and were trained, one at a time, to modulate their firing rate up and down in order to control the position of a one-dimensional actuator carrying the reinforcement (water bottle). The goal was to displace the bottle from a remote starting position such as to bring and stabilize it in front of the mouth, allowing the rat to drink.

In the first phase of the experiment, the bottle could only move in one direction and its displacement was controlled by the increase in firing rate above a preset threshold. Most neurons submitted to this conditioning successfully increased their activity during trials after several learning sessions. Once trained, the neuron chosen to control the operant behavior reacted consistently more rapidly than the other simultaneously recorded neurons after trial onset. We observed also that the firing rate variability increased in an anticipatory way before trial onset, specifically for the neurons that could be conditioned successfully. Interestingly, this effect was observed only in the initial phases of the conditioning and disappeared once the training was complete.

In the second phase of the experiment, neurons were allowed to modulate their firing rate up or down, and consequently the rate changes were used to control both the direction and displacement speed of the water. The bottle could thus move bilaterally, and the goal was to maintain the bottle in the drinking zone. All conditioned neurons adapted their firing rate to the instantaneous bottle position so that the drinking time was increased relative to chance. The mean firing rate averaged over all bottle trajectories depended on position, so that the mouth position operated as an attractor, at least for the bottle starting side. Again, the conditioned neuron reacted on average faster than the other simultaneously recorded neurons and led to a better bottle control than if trajectories were simulated using the activity of simultaneously recorded neurons.

Overall, our results demonstrate that conditioning single neurons in rat motor cortex is a suitable approach to control a prosthesis in real-time, and that these neurons occupy a lead position after learning, acting as "master" neurons in the network.

Co-adaptive Learning in Brain Computer Interfaces

Amjad Abu-Rmileh[1]

1. Department of Brain and Cognitive Sciences, Ben-Gurion University, Israel

A Brain Computer Interface (BCI) enables direct control of brain activity over external devices, such as robots. Motor imagery (MI) based BCI detects changes in brain activity associated with imaginary limbs movements, such as tapping with the right or left hand. MI based BCIs require training, during which the user gradually learns how to control the relevant patterns of brain activity with the help of feedback. Additionally, it is common to use machine learning techniques to improve BCI performance and adapt the decoding algorithm to the user's brain. Therefore, the brain and the BCI need to "collaborate" in order to constantly improve performance. To study the role of co-adaptive learning in a BCI paradigm and the time scales involved, we investigated the performance of subjects in a cued MI task over 6 consecutive days. One group performs the BCI task using a fixed readout algorithm based on MI data from day 1. For the other group, the readout algorithm frequently adapts, in a closed-loop manner, based on brain activity patterns during the experiment days.

Preliminary results with the first group showed that, in general, the performance of the fixed readout algorithm decreases, probably due to variations in brain activity from day to day. Reanalysis of the same data by artificially adapting the readout algorithm suggested that continuous update of the readout algorithm will improve the BCI performance. Results from the second group supported the idea that machine adaptation would positively affect the BCI performance.

In the next phase of the experiment, we will investigate several factors that may improve the performance of the co-adaptive system, such as: adapting the classifier to subject specific features (e.g. individualized frequency bands), modifying the rate of classifier adaptation, and increasing the duration of the training.

Dynamics of Excitability Over Extended Time Scales

Shimon Marom[1]

1. Technion, Israel

Statistics of single neuron responsiveness amid repeated stimuli are broadly distributed. Underlying biophysical mechanisms will be described. Theoretical, methodological, and functional implications will be discussed.

Biological significance, mechanisms and development of the ongoing spontaneous activity in the zebrafish optic tectum

German Sumbre[1]

1. ENS, Paris

Spontaneous neuronal activity is spatiotemporally structured, influencing brain computations. Nevertheless, the neuronal interactions underlying these spontaneous activity patterns, and their biological relevance, remain elusive. Here, we addressed these questions using two-photon calcium imaging of intact zebrafish larvae to monitor the neuron-to-neuron spontaneous activity fine structure in the tectum, a region involved in visual spatial detection. Spontaneous activity was organized in topographically compact assemblies, grouping functionally similar neurons rather than merely neighboring ones, reflecting the tectal retinotopic map despite being independent of retinal drive. Assemblies represent all-or-none-like sub-networks shaped by competitive dynamics, mechanisms advantageous for visual detection in noisy natural environments. Notably, assemblies were tuned to the same angular sizes and spatial positions as prey-detection performance in behavioral assays, and their spontaneous activation predicted directional tail movements. Therefore, structured spontaneous activity represents "preferred" network states, tuned to behaviorally relevant features, emerging from the circuit's intrinsic non-linear dynamics, adapted for its functional role.

Critical dynamics in resting and evoked human brain activity

Oren Shriki[1]

1. Department of Cognitive and Brain Sciences, Ben-Gurion University, Beer Sheva, Israel

In recent years, several experimental studies suggested that the cortex at resting-state operates at proximity to critical dynamics. These dynamics allow neuronal activity to propagate over long distances without premature termination or explosive growth and reflect a subtle balance of excitatory and inhibitory forces. An important manifestation of critical dynamics are cascades of activity across many spatial scales, termed neuronal avalanches. The talk will describe our studies using EEG (Electroencephalography) and MEG (Magnetoencephalography) to probe for critical dynamics in the human brain, at both resting-state and evoked activity. We found that the recorded cortical activity is critical and organizes as neuronal avalanches at both resting-state and stimulus-evoked activities. Such critical, scale-free dynamics have been shown to optimize information processing, implying that the human brain attains an optimal dynamical regime for information processing both at rest and when evoked by stimuli.

A new role of midbrain dopaminergic neurons during temporal judgments

Bassam Attalah[1]

1. Champalimaud Centre for the Unknown, Portugal

Encoding the passage of time is critical to behavior and cognition. Although classically referenced as key structures for reward based decision making and motor behavior, the basal ganglia are critical for

encoding time on the scale of seconds. Yet, little is known about how distinct components of basal ganglia circuit contribute to the encoding of time. Here we probe the role of a critical component of the basal ganglia, midbrain dopaminergic (DAergic) neurons. We both measured and manipulated the activity of DAergic neurons in animals performing a temporal discrimination task. In this task, animals learned to judge the delay between two tones as shorter or longer than a 1.5s boundary, reporting their judgements by entering one of two nose ports in order to earn a reward. To characterise the response properties of midbrain DAergic neurons during this task, we expressed GCaMP6f specifically in these neurons and recorded bulk fluorescence signals in awake, behaving mice. We observed large phasic responses tied to various task events, such as delay onset, delay offset and reward delivery. Notably, the amplitude of the response to delay offset was larger when stimuli were judged as short than when they were judged as long, regardless of whether the subsequent choice was correct. This suggests that short temporal judgements are correlated with higher midbrain DAergic activity. To test whether this relationship is causal, we photo-activated these neurons using channelrhodopsin-2 during task performance. This manipulation resulted in a horizontal shift in the psychometric curve towards shorter choices. Our results suggest that activating midbrain DAergic neurons slows the animal's internal representation of elapsed time, supporting a novel and non-classical role for midbrain DAergic neurons in time encoding.

Dual-system reinforcement learning and dopamine-independent Pavlovian goal-tracking behaviors

Mehdi Khamassi[1]

1. Université Pierre et Marie Curie, CNRS, Paris

The model-free reinforcement learning (RL) framework (i.e. learning stimulus-response associations without trying to build an internal model of the world), and in particular Temporal-Difference learning algorithms, have been successfully applied to Neuroscience since about 20 years. They can account for dopamine reward prediction error signals in simple Pavlovian and instrumental single-step decision-making tasks. However, more complex multi-step tasks (i.e. requiring a sequence of actions before getting a reward) employed both in Neuroscience and Robotics illustrate their computational limitations.

In parallel, the last 10 years have seen a growing interest in computational models for the coordination of different types of learning algorithms, e.g. model-free and model-based RL. Such a coordination enables to explain more diverse behaviors (namely goal-directed and habitual behaviors). I'll show here that it can also well account for inter-individual differences during Pavlovian autoshaping experiments in rats, where subgroups of individuals have been categorized as sign- and goal-trackers. In particular, the model can explain why the learning process in some individuals (goal-trackers, hypothesized to rely more on their internal model of the consequences of their actions on the environment) is not dependent on dopamine while it is in others, as shown experimentally by the absence of dopamine reward prediction error signals in these animals and by the sparing of learning by pharmacological injections of dopamine antagonist. The computational model led to a series of experimental predictions that could be tested to further validate/refute it. Finally, if the time allows for it, I'll show some applications of this framework to Robotics with the aim of getting new insights on the dynamics of learning in more realistic, noisy, embodied situations.

A minimal neural mechanism for explorative behaviors

Ran Darshan[1]

1. Hebrew University of Jerusalem , Israel

Motor behavior appears to be disorganized during early stages of development and is thought to be initially purely explorative. According to current theories, such exploration is essential for learning sensorimotor transformations. We combine data analysis and modeling to study the central neuronal mechanism that underlies explorative behaviors, focusing on babbling-like behaviors in human and non-human vocal learners. We quantify the temporal structure of babbling in four vocal learners with different levels of complexity in their adult vocalizations: zebra finches, swamp sparrows, canaries and human babies. We show that: 1) In all these learners, gesture duration distributions during early babbling are well fitted by a decaying exponential (in line with previous reports in zebra finches; Aronov et al., 2008) ; 2) interspecies differences in the temporal features of early babbling are to a large extent accounted for by time rescaling. These findings point to the existence of a central mechanism underlying explorative behavior which is common to all these learners and therefore robust with respect to anatomical and physiological differences between individuals and species. We investigate possible mechanisms for motor exploration in a theoretical model of the neuronal circuit that activates the effectors producing babbling in songbirds. It comprises a premotor and a motor network representing the avian cortical-like areas LMAN and RA, each consisting of a large number of excitatory and inhibitory spiking neurons. The premotor network projects to the motor network which in turn activates a small number of effectors as is the case in songbird anatomy. We argue that requiring the circuit to autonomously and robustly generate random activation of the effectors constrains its architecture and dynamics strongly. We show that this implies that: 1) the premotor as well as the motor area are recurrent networks operating in a regime where excitation and inhibition are balanced and 2) the feedforward projections from the former to the latter and then to the effectors are topographic. Under these conditions, the motor network exhibits temporally irregular firing with substantial correlations between neurons that activate the same effector. Importantly, correlations emerge from the recurrent dynamics of the circuit without any fine- tuning of parameters. When connected to a non linear model of a syrinx, the circuit generates explorative behavior with statistics similar to those exhibited in the data. Finally, we validate our theory by testing its predictions regarding the spatiotemporal patterns of activity in LMAN and RA in neuronal recordings in singing finches.

The computational and cognitive neuropsychology of Parkinson's disease

Ahmed Moustafa[1]

1. The University of Western Sydney , Australia

Parkinson's disease (PD) is most commonly viewed as a motor disorder associated with reduced levels of dopamine in the basal ganglia and prefrontal cortex. Over the last two decades, research has shown that PD is also associated with cognitive and psychiatric deficits. Specifically, my research (along with research from other labs) has shown that PD patients show impairment performing attentional, working memory, and feedback learning tasks. PD patients are prescribed dopaminergic medications to ameliorate their motor symptoms. In this talk, I will present empirical and computational research findings on the effects of PD and dopaminergic medications on cognitive and motor processes. I will also present new results (and a computational model) on the behavioral basis of the occurrence of "impulse control disorders" (Piray et al., 2014) and "gait problems" (Muralidharan et al., 2014) in a subset of PD patients. I will also present data on a new computational model of Deep Brain Stimulation (DBS) (Mandali et al., 2015).

Motion anticipation in the primary visual cortex of the awake monkey

Frédéric Chavane[1]

1. INT, CNRS, Marseille

Visual motion integration is traditionally viewed as a cascade of hierarchical processing steps identified using local stationary inputs. However naturalistic inputs are intrinsically dynamical. Objects moving along smooth trajectories generate sequences of spatio-temporally coherent feed-forward inputs that shall interact with spreads of activity within and between cortical retinotopic maps. In awake monkeys, we investigated how these nested propagations shape the cortical mapping of a motion trajectory. We show that, as early as in the primary visual cortex, spiking responses of neurons gradually anticipate the arrival of a moving bar into their receptive field. By dissecting the spatio-temporal mesoscopic dynamics using multi-electrode arrays LFPs and voltage-sensitive dye imaging, we demonstrate that such anticipatory signal results from the convergent interplay of intra- and inter-cortical inputs propagating information faster than the feed-forward sequence. Thus, lateral propagation is able to drive retinotopic networks ahead of feed-forward incoming events, implementing a spatiotemporal predictive computation.

Invariant object codes in single cortical neurons

Yasmine El-Shamayleh[1]

1. University of Washington

Size-invariant object recognition – the ability to recognize objects across transformations of image scale – is a fundamental property of biological and artificial visual systems. To investigate its basis in the primate cerebral cortex, we measured single neuronal responses to scaled stimuli in visual area V4, a cornerstone of the object processing pathway. Leveraging a successful quantitative model of contour-based object representation that makes specific predictions for how neuronal selectivity may depend on stimulus scale, we asked whether V4 neurons changed their preferences for object contour features across scale transformations (a size-dependent code) or maintained them (a size-invariant code). Most V4 neurons signaled their preferred contour features in a size-invariant manner, revealing a more versatile representation than predicted by the model. Our results advocate a revision of our encoding model and endorse V4 as a plausible foundation for behaviorally-relevant object codes in high-level visual cortex.

Corollary discharge in human superior colliculus

Thérèse Collins[1]

1. Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS

Saccades are thought to result from population activity in the deep layers of the superior colliculus. Saccade metrics (direction, amplitude) depend on the location of activity within the SC, that contains a map of the visuo-motor world. The collicular map is distorted with foveal magnification and increasingly larger and positively-skewed movement fields towards the representation of the periphery. The size of the neuronal population active just before a saccade is in turn roughly constant, whatever the saccade metrics (McIlwain, 1975). The hallmarks of saccadic behavior are predicted by such a coding scheme: larger saccadic scatter and greater undershoot with increasing amplitude (Vitu 2013). It is possible to transform visual space into collicular coordinates (Ottes et al, 1986). Using the double-step task to measure saccades that depend on a corollary discharge (CD), it is possible to determine how CD variability changes with amplitude. Transforming this variability from visual to collicular coordinates may shed light on the origin of the CD signal used in the double-step task.

Simple learned weighted sums of inferior temporal neuronal firing rates accurately predict human object recognition performance

Najib Majaj[1]

1. New York University, New York , United States

To go beyond qualitative models of the biological substrate of object recognition, we ask: can ventral stream neuronal responses accurately account for core object recognition performance? We measured human performance in 64 object recognition tests using thousands of challenging images that explore shape similarity and identity preserving object variation. We then used multi-electrode arrays to measure neuronal population responses to those same images in visual areas V4 and IT of monkeys, and we simulated V1 population responses. We tested many candidate linking hypotheses—each postulating how ventral stream neuronal responses underlie object recognition behavior. Specifically, for each hypothesis we computed the predicted performance on the 64 tests and compared it to the measured pattern of human performance. All tested hypotheses based on low and mid-level visually-evoked activity (pixels, V1, and V4) were very poor predictors of human behavioral pattern. However, simple distributed, learned, weighted sums of mean IT firing rates exactly predicted the behavioral pattern. More elaborate linking hypotheses relying on IT trial-by-trial correlational structure, finer IT temporal codes, or ones that strictly respect the known spatial sub-structures of IT (“face patches”) did not improve predictive power. While these results do not reject those more elaborate hypotheses, they suggest a simple, sufficient quantitative model: each object recognition task is learned from the spatially distributed mean firing rates (100 ms) of ~60,000 IT neurons, and is executed as a simple weighted sum of those firing rates.