Organizing Committee:

Mickey London
Naftali Tishby
ELSC-ICNC are grateful to the Edmond J. Safra Philanthropic Foundation for its constant spiritual and financial support. We would not be where we are today – a world leader in brain research - without its generous assistance.

We would also like to thank Alice and Jack Ormut for their donation, which will support students as they complete the ICNC’s Ph.D. program. Their gift will allow future generations of brain scientists to study at the ICNC.

The partnership between the Brain Circle group of donors and the ICNC is in its fifth year. The ICNC is deeply indebted to Brain Circle members - it is their wholehearted support that allows us to carry out the mission of ELSC-ICNC.

Nilly and Vladimir Sikorsky and Gilly and Elie Zilkha have kindly donated a new neuroimaging and activation system that will allow us to study the mechanisms underlying learning processes in the nervous system in novel ways.

We would like to thank the Edmond J. Safra Philanthropic Foundation for its generous donation of a powerful computer cluster for brain simulations, which will enable the study of realistic models of large neuronal circuits in the cortex.

We are grateful to Gultin and Eric Ephrati for their donation of a new teaching facility, in memory of Eric’s parents, Odette and Maurice Ephrati. The facility includes a lecture hall, a spacious work area, and state of the art computers.

We would like to thank Michael and Morven Heller for their ongoing support of the Heller Lecture Series in Computational Neuroscience. Their generosity allows us to invite compelling, sought-after lecturers to speak at the ICNC.

We are very grateful to Mr. Eric Roland for the establishment of The Eric Roland Interdisciplinary Program for Neurodegenerative Diseases.

We are indebted to Dr. Jean-Claude Picard, Director of Association franco-israélienne pour la recherche en Neurosciences (AFIRNe) for his devoted work in support of collaborations between Hebrew University and French neuroscientists and for organizing the Israel-France Conferences on the Brain.

ELSC-ICNC’s activities are supported by generous donations and the constant involvement of the Friends of the Hebrew University in Germany, France, the Netherlands, Italy, the United Kingdom, Belgium, Canada, Switzerland, and the United States.
Sunday, February 5

11:30   Bus departing from Givat Ram Campus, main bus stop
12:15-13:15  Arrival at Ein Gedi – room allocation
13:00-13:45  Lunch

Session 1 – Language
Chair: Naftali Tishby

14:00-14:45  Danny Fox (Linguistics, HU & MIT): “From language to logic”
14:45-15:30  Yosef Grodzinsky (Linguistics, McGill University): “From language to brain”
15:30-16:00  Discussion
16:00-16:20  Coffee Break

Session 2 – Time and coding
Chair: Shay Moshel

16:20-17:00  Ben Engelhard: “Operant conditioning of a specific LFP frequency band: Relationship to Neural Synchrony”
             Advisor: Eilon Vaadia
17:00-17:40  Nori Jacoby: “Kernel information bottleneck”
             Advisors: Naftali Tishby & Merav Ahissar
17:40-19:40  Poster session (refreshments)
19:40-21:00  Dinner
21:00   Avigdor Shinan (Hebrew Literature, HU) “Folk stories in rabbinic literature”
22:00   Wine, beer & cheese
Monday, February 6
8:00-8:50  Breakfast

Session 3 – Vision
Chair: Daphna Weinshall

9:00-9:40  Elad Mezuman: “Do canonical views exist in internet image collections?”
Advisor: Yair Weiss

Session 4 – Guest Speaker

9:40-10:40  Simon Rumpel (IMP, Vienna)
"Sound encoding in the neocortex by combinations of discrete activity patterns”

10:40-11:00  Coffee Break

Session 5 – Exotic neuroscience
Chair: Benny Hochner

11:00-11:40  Guy Levy: “How octopuses coordinate their arms while crawling”
Advisor: Benny Hochner

11:40-12:20  Michael Yartsev: “Neural representation of multi-dimensional space in the Hippocampal Formation of bats”
Advisor: Nachum Ulanovsky (Weizmann Institute)

Session 6 – Guest Speaker

12:20-13:20  Rina Dechter (CS, University of California, Irvine)
“Belief networks and belief propagation; some reflections”

13:20-14:50  Lunch

Session 7 – Technology

14:50-15:40  Michal Balberg (Ornim Ltd. & ICNC Alumna)
“Interdisciplinary cerebral safety”

15:40-16:30  Danny Porath (Director of the Center of Nanotechnology HU)
“The Hebrew University Center for Nanotechnology and fantasies about the brain”

16:30-17:30  Debate: “The role of technology in the future of neuroscience”
Moderators: Yoav Livneh and Nori Jacoby

18:00-20:00  Moonlight dinner

21:00  Moonlight hike by the Marls of Masada (“Chavarei” Masada)
Tuesday, February 7

8:00-9:00  Breakfast & check-out

Session 8 – Auditory
Chair: Israel Nelken

9:00-9:40  Yael Biterman: “Relevant stimulus features for neurons in auditory cortex - experimental traces”
Advisor: Israel Nelken

9:40-10:20  Roi Kliper: “Monaural and binaural source localization using spectral dynamics of speech”
Advisors: Daphna Weinshall and Israel Nelken

10:20-10:40  Coffee Break

Session 9 – Perception
Chair: Udi Zohary

10:40-11:20  Uri Hertz: “Audiovisual integration and brain plasticity in learning a visual-to-auditory sensory substitution algorithm (SSA)”
Advisor: Amir Amedi

11:20-12:00  Michal Ramot: “Silent night? Sensory and motor aspects of spontaneous activity”
Advisor: Rafael Malach (Weizmann Institute)

12:00-12:15  Coffee Break

Session 10 – Basal Ganglia
Chair: David Hansel

12:15-12:55  Avital Adler: “Information processing in the different Basal Ganglia sub-regions”
Advisor: Hagai Bergman

12:55-13:35  Rubi Shamir: “Ventral subthalamic nucleus responds to emotional voices”
ELSC Postdoc – lab of Hagai Bergman

13:35-13:40  Farewell words

13:40-14:30  Lunch

14:45  Return to Jerusalem
LECTURES
This talk will focus on interactions between human linguistic and logical abilities. Much fruitful work in this domain assumes a cognitive system which combines linguistic primitives to form linguistic expressions (syntax). The output of syntax (a linguistic expression) then serves as input for other cognitive systems that “interpret” this output, thereby accounting for patterns of logical inference.

This talk will focus on phenomena that argue for a more intricate relationship between syntax and logic. Specifically, we will see evidence that the class of available linguistic expressions is determined in part by patterns of logical inference. In other words, we will see reasons to believe that logic affects linguistic analysis. Moreover we will see that the distribution of facts requires very specific assumptions about cognitive architecture. On the one hand, we will see that syntax must “see” the logical properties of linguistic expressions. On the other hand, however, we will see that syntax must be “blind” to non-logical aspects of meaning, aspects of meaning that must be taken into consideration in a general account of human inferential abilities. We will use these observations to motivate the postulation of an internal deductive engine, a system which is either part of syntax or works in close interaction with syntax.

The relevant observation can be used as a tool in figuring out the properties of the deductive engine (which, in turn, ought to serve as the logical building blocks of human reasoning). In doing so we will reach some surprising conclusions. First, we will conclude that the relevant logical system contains axioms that pertain to arithmetic notions. However, we will also conclude that it does not contain the discrete notion of natural number. Instead, it only has axioms that characterize dense domains. These conclusions are in line with some hypotheses in the field of mathematical cognition.
This talk describes small steps towards understanding how the human central nervous system supports the mental capacities that underlie complex linguistic behavior. These capacities inhere in our ability to combine discrete building blocks (phonemes, words, phrases) into complex, arbitrarily long linguistic expressions that we use to communicate a wide range of subtle (as well as less subtle) messages to others. These capacities – rather central to our existence as humans – also connect to other cognitive systems.

I will consider several possible approaches to the study of brain/language relations, and focus on the one I personally pursue: the localization of pieces of linguistic knowledge in specialized brain pieces. That is, I will report attempts to align well-defined, abstract syntactic operations with brain loci, or “areas”, whose borders are defined by cytoarchitectonic and receptor architectonic anatomical tools. The hope that drives this project is that a functional anatomy of language (a linguistic homunculus, if you will) would produce new insights, valuable to both theoretical linguistics and computational neuroscience.

I will illustrate the approach by reporting a series of attempts to map a central syntactic relation (called “movement”) whose result, I will argue, are of interest to linguists and neuroscientists alike. These attempts are multi-modal: they are based on deficit analyses of the linguistic abilities with brain-damaged patients, and on accounts of fMRI activation patterns in health.

Aware of the fact that many in the audience were present in a recent lecture at ELSC, I promise not to be overly repetitive, and present both theoretical considerations and results that will be new to most.
Operant conditioning of a specific LFP frequency band: Relationship to neural synchrony

Ben Engelhard

Frequency bands of LFP have been associated with a plethora of cognitive roles. In particular, various clinical disorders have been associated with abnormalities in the power of the lower gamma frequency (30-50 Hz), including ADHD, Autism, Schizophrenia, Epilepsy and others. These abnormalities are thought to reflect in turn abnormalities in the degree of neural synchronization in either a local or distributed manner. Thus, the ability to effect changes in the power of this frequency band could have important clinical implications, if said changes are accompanied by concurrent changes in the level of neural synchronization in a given locality. Further, in recent years it has been shown that a wide variety of cognitive functions incorporate changes in the power and synchronization of the lower gamma band including visual and auditory perception, memory encoding, sensory-motor integration and many others. Again, the main focus has been on these changes as relating the amount of neural synchrony which is thought to mediate processes of neural computation. The precise role of these oscillations, however, and their possible contribution to synchrony in a behavioral context remains yet unclear. It is apparent then that from a basic science perspective there is additional interest in exploring the possible role of oscillations in this frequency band in the generation of neural synchrony and their relationship to behavior.

In this study we demonstrate specific control of the power of the 30-43 Hz band of LFP in the primary motor cortex of macaques. Over the course of several sessions the monkeys learned to raise the power of this band to move a cursor on the screen and obtain a reward. The evoked activity was oscillatory in nature and band specific. It was clearly distinguishable on a single-trial basis, which permitted real time control of a brain-machine interface. This was done absent any overt movements by the monkey. The increase in the LFP band power was accompanied by a dramatic increase in the amount of neural synchrony, allowing previously uncoordinated pairs of neurons to fire together in a time-precise manner. The increased synchrony was evoked dynamically as a result of phase locking of a large number of the single units onto the LFP signal, and is a first example of volitional control of precisely timed neural activation.

Our findings have a two-fold significance: On the clinical side, they stand as an important step in the development of treatments for a wide variety of conditions in which the level of neural synchrony is impaired. From a neurophysiological perspective, we have shown a causal link between LFP oscillations, neural synchrony and behavior, which hopefully leads us towards a more complete understanding of the computational processes effected in the brain.

Advisor: Prof. Eilon Vaadia
Kernel information bottleneck

Nori Jacoby

The information bottleneck method was proposed by Tishby et. al 1999 as a general computational principle for information processing in the brain. It has been a useful tool in machine learning and data analysis, as well as in explaining neuronal activity and cognitive behavior. The idea behind this method is to extract efficient compressions - minimal sufficient statistics - of a source variable X that preserve as much information as possible on a target variable Y.

A converging iterative algorithm for solving this problem was suggested by Tishby et. al 2000, but this algorithm converges to a global optimum only for relatively small problems. However, for the special case that X and Y are jointly multivariate Gaussian a closed form global solution was obtained by Chechik and Globerson in 2005. The solution depends on the spectral properties and eigenvectors of the Canonical Correlation Analysis (CCA) matrix of X and Y, with weights that depend on the tradeoff between prediction accuracy and complexity of the compressed representation.

We will present in this talk a novel extension of the Gaussian Information Bottleneck to a much wider family of continuous cases using Vapnik's kernel trick. This has valuable practical importance, since it allows solving the information bottleneck problem for high dimensional nonlinear continuous scenarios. The result is closely connected to the well-established method called kernel-CCA and therefore can gain from numerical and theoretical technique suggested in the literature. In turns the information bottleneck approach into a practical tool and analysis technique for a wide range of neuroscience and cognitive applications.

In this talk we present the mathematical background as well as illustrative examples from the domains of visual art and music, and discuss further applications of the methods to other domains.

Advisors: Prof. Naftali Tishby & Prof. Merav Ahissar
Do canonical views exist in internet image collections?

Eldad Mezuman

Although human object recognition is supposedly robust to viewpoint, much research on human perception indicates that familiar objects have a preferred or "canonical" view. It was hypothesized by psychology researchers that this "canonical view" will be the viewpoint from which an object is most likely to be photographed but this hypothesis was never verified by analyzing statistics of real photographs. In this paper we ask: given a set of images retrieved by an image search engine for a particular object (1) is there a preferred view of the object? (2) does it correspond to the canonical view? To answer these questions we develop a simple method to extract the most likely view of an object in a photo collection. We find that indeed for most categories there exist a preferred view and that it often corresponds to the canonical view defined in psychophysical experiments.

Advisor: Prof. Yair Weiss
Sound encoding in the neocortex by combinations of discrete activity patterns in local neuronal ensembles

Simon Rumpel (IMP Vienna)

It is believed that patterns of activity are the neuronal correlate of the perception of an external stimulus, e.g. a sound. Here, we used in vivo two-photon calcium imaging to better understand how sounds are encoded at the level of local layer 2/3 ensembles in the mouse auditory cortex. We found that activity patterns are highly constrained into few discrete response modes, i.e. that a wide range of different sounds evoke the same population response pattern. Using online synthesis of sound stimuli to map the transition across response modes with fine resolution, we observed highly non-linear dynamics suggesting attractor-like competition between response modes. The combination of sounds that were associated in a specific response mode varied across local populations and was not predictable based on the population’s pure-tone frequency tuning. We used linear classifiers to test whether different pairs of sound could be discriminated on a single trial basis based on population activity. Global response patterns constructed by the combination of multiple local patterns largely outperformed local populations for the number of discriminated sound pairs, indicating that much more information is contained at the global scale. Interestingly, strong dimensionality-reduction by decomposition of single trial patterns into response modes did not lead to significant information loss. Furthermore, we found that global activity patterns in the mouse auditory cortex quantitatively predict discrimination and spontaneous categorization of sounds in behaving mice. We suggest a model of auditory cortex function in which local non-linear dynamics shape a broad basis set of spontaneous, distinct associations of stimuli that form a representation of sounds available for behavioral decisions.

Work in collaboration with Brice Bathellier, Lyubov Ushakova
How octopuses coordinate their arms while crawling

Guy Levy

Crawling is a typical way of locomotion of octopuses on the seabed or along rocks in shallow waters or outside of the water. The first stage of this study showed that octopuses use their arms while crawling with rhythmical stereotypical steps composed of anchoring some suckers to the substrate followed by arm elongation to push the body in the direction opposite to the elongating arm. Here we present a new part of the study that shows how the octopus coordinates its arms when crawling. Mature octopuses were videotaped from underneath while crawling in shallow waters and sections of interest in the video clips were stored as single images. Arms that participated in pushing and additional points of interest were labeled manually on consecutive images for the kinematic analysis of the crawling movements. The data was used to test our hypothesis suggesting that the crawling direction is a simple vectorial combination of the pushing arms and changing the direction of crawling is done by choosing a suitable set of arms rather than by rotating the body. In this part of the study we describe the arms as spreading around the body symmetrically with a $45^\circ$ angle between each adjacent couple of arms. Hence, we assume that each arm has a fixed direction of pushing by elongation relative to the body. Using this assumption together with the information regarding the identity of the pushing arms at each moment, we were able to reconstruct, in a simple toy model, the direction of crawling using only the simple vectorial combination of the participating arms. We confirm our hypothesis by showing an excellent match between the reconstructed and the actual crawling path. We suggest that as seen in other octopus movements, control simplification is achieved by using simple stereotypical movements generated at the level of the peripheral neuromuscular system of the arm (rhythmical suckers adherence and length changing) while the participating arms are coordinated by commands from the central brain.

Advisor: Prof. Benny Hochner
Neural representation of multi-dimensional space in the hippocampal formation of bats

Michael Yartsev

The hippocampus and medial entorhinal cortex (MEC), both regions in the mammalian hippocampal formation, are considered key elements in the neural circuitry underlying the representation of the space around us in the brain. The hippocampus contains 'place cells', neurons which are active when the animal passes through a particular location in the environment (the 'place field'), and the MEC contains 'grid cells', which are activated when the animal's position in space coincides with any vertex of a spatial hexagonal grid spanning the entire environment. To date, the vast majority of available electrophysiological data on how space is represented in these two interconnected brain regions was obtained from recordings in rats navigating in one- or two-dimensional environments. To extend current knowledge regarding the neural basis of spatial representation in the mammalian brain, we used a novel animal model - the Egyptian fruit bat. Here, I will describe two of my PhD research project aimed at elucidating two of the biggest mysteries regarding the neural mechanisms governing spatial representation in these two brain regions.

Project 1: What are the underlying neural mechanisms giving rise to the grid formation?

Two competing classes of theoretical models govern the field: network models, based on attractor dynamics versus oscillatory interference models, based on continuous theta-band oscillations (4–10 Hz) in single neurons. To date these models could not be dissociated experimentally, because rodent grid cells always co-exist with continuous theta oscillations. To address this, we conducted the first electrophysiological recording from the MEC of freely crawling bats. We find that, in the bat, grid cells existed in the complete absence of continuous theta oscillation and theta modulation of spiking activity which causally argues against the oscillatory interference class of models (Yartsev et al., Nature 2011).

Project 2: How is three dimensional (3-D) space represented in the neural activity of hippocampal neurons?

Much research has focused on studying the detailed properties of place cells in rodents moving in either one- or two-dimensional environments (linear tracks or open field arenas, respectively), but only few attempts have been made to study the representation of 3-D space in the mammalian hippocampus. This question is important, because both animals and humans move daily in 3-D environments; and in order to understand the role of place-cells in real-life navigation, we must record from place-cells as animals move through all three dimensions. Using a tetrode-based microdrive and a custom, lightweight multi-channel neural telemetry system, we conducted the first electrophysiological recordings from the hippocampus of a freely flying mammal, the bat. We find that all three dimensions of the available environment were represented with the same precision. Furthermore, the spatial locations and scales in which single hippocampal neurons were activated spanned the entire available environment and as a whole represented all three dimensional positions in the room. These findings argue that the mammalian hippocampus is capable of storing accurate representation of the entire three-dimensional space. Finally, although the bat’s behavior was extremely theta-oscillatory during flight (in terms of the bat’s wing-beats and echolocation), hippocampal neurons were not theta modulated, pointing to a fundamental dissociation between behavioral and neural oscillations in the mammalian hippocampus.

Advisor: Dr. Nahum Ulanovsky (Weizmann Institute)
Belief networks and belief propagation – from rumelhart to pearl to today

Rina Dechter
Donald Bren School of Information and Computer Sciences, UC Irvine

Bayesian networks have become a standard paradigm for automated reasoning under uncertainty, with numerous applications in engineering, business and the empirical sciences. They are also appealing to cognitive and neuroscientists because they provide a plausible and biologically feasible framework (e.g., distributed processing on causal representation) through which human reasoning can be explored and potentially understood.

Taking a historical perspective, I will introduce Bayesian networks, the poly-tree belief propagation algorithm and the ideas of moving from trees to loopy networks as reported by their creators. I will reflect on the current state of the art for general graphical models and highlight properties of belief propagation (e.g., convergence and accuracy) from a constraint propagation perspective.
Encoding of sounds in the early auditory system is modeled successfully based on the physiology of the cochlea and brainstem pathways. Models use short-term spectro-temporal features of the sound to describe the encoding in primary stations and to account for various perceptual capabilities. On the other end, high cortical areas have been shown to encode abstract qualities of sound. The link between early and late auditory system, and specifically the role of primary auditory cortex (A1) in hearing, is currently badly understood.

We study the transformation of low-level to high-level representations using neural recordings and computational methods. I will illustrate these with a number of examples:

1. Coding of artificial and natural sounds in human auditory cortex. Extracellular single unit recordings revealed ultra-fine frequency selectivity of neurons in artificial random contexts. The result however did not generalize to the encoding of natural stimuli, like speech and music.
2. 'Object-related potentials' in MEG study of Comodulation Masking Release (CMR). An evoked magnetic field was detected when a tone was heard as a separate object in the presence of noise but not when its detection relied on subtle changes in the timbre of the sound.
3. Responses of rat auditory cortex to classical western music. A musical piece with tight structure presented to rats, revealed neural response patterns in A1 consistent not with the short term spectral content of the sound but with the 'surprise' structure of the piece.

The evidence from these studies suggests that auditory cortex is involved both in organizing the sensory input into auditory objects and in predicting parts of the auditory input not actually encountered. Crucially, I propose to link the two tasks by identifying them: I suggest that an auditory object is instantiated by a predictive model. In support of this hypothesis, I will demonstrate the power of predictive models by a study of behavioral categorization of human voice. Predictive models based on the sound highlighted systematic differences between sounds produced by musical instruments and those produced by human voices. These differences appeared already for very short segments in agreement with psychoacoustic results obtained with the same sounds.

Advisor: Prof. Israel Nelken
Monaural and binaural source localization using spectral dynamics of speech

Roi Klipler

Following recent psycho acoustic results, showing high performance in monaural localization, we tackle the task of localizing speech signals on the horizontal plane using monaural cues. We demonstrate that monaural cues as incorporated in speech are efficiently captured by amplitude modulation spectra patterns. These patterns previously shown to be a robust representation for speech recognition can be used alongside with simple machine learning techniques to extract directionality related information and learn to discriminate and classify sound location at high resolution.

We then point out several limitations of the classic binaural model of source localization, and propose a simple and robust way of integrating information from two ears. We show that psycho acoustic results for human binaural localization performance can be reproduced by treating each ear as an independent processor and integrating the information only at the decision level.

Advisors: Prof. Daphna Weinshall and Prof. Israel Nelken
Multisensory integration is based on coupling principles which are innate, learned during development or learned in adulthood throughout our life. Sensory-substitution-algorithm (SSA), usually used as a rehabilitation tool for blind, was used here in sighted as they provides a unique opportunity to study binding of a new ‘sense’ into the well-established system. Subjects were scanned in fMRI before and after learning SSA while passively perceiving images and soundscapes (i.e. the novel auditory representation of vision). We also tested subjects in the context of a task requiring binding between the new learned ‘sense’ and vision. Both experiments demonstrate a fast and dynamic shift in sensory processing in the brain, as the information and novelty conveyed by each sensory stream changes. This shift was manifested in associative multisensory areas, including right Insula, left inferior frontal sulcus and left Supramarginal sulcus. These were accompanied with context-dependent modulation of primary sensory cortices response.

Advisor: Dr. Amir Amedi
Silent night? Sensory and motor aspects of spontaneous activity

Michal Ramot

The link between conscious awareness and perception and brain activity is one of the fundamental questions occupying neuroscientists today. It would seem that spontaneous activity, in which state the cortex remains highly active despite the lack of sensory stimulation, could provide an excellent framework for studying this question. We addressed this issue of spontaneous activity in two separate studies using very different methods. First, we used electrocorticography (ECoG) recordings from 388 electrodes from 7 patients with intractable epilepsy, who were undergoing approximately a week of invasive monitoring with implanted grids of subdural electrodes, for strictly clinical purposes. We compared sensory driven activity patterns of broadband gamma power modulations generated while awake patients watched short segments of an engaging movie with activity patterns emerging spontaneously during sleep. Our results show a highly significant (p<10^-4) similarity between sensory-driven correlation patterns and those emerging spontaneously during sleep. Moreover, this similarity was not limited to global network patterns, but rather recaptured the fine structure of correlations within sensory cortex. Our results further show a surprising significant difference between REM and NREM sleep, with reactivation being significantly stronger during NREM periods. In another study, we found that a highly significant correlation exists between the magnitude of the spontaneous BOLD fluctuations and eye movements which occur subliminally and spontaneously in the absence of any visual stimulation. Control experiments ruled out a contribution of spatial and visual attentional effects as well as smooth pursuit eye movements. These results demonstrate that spontaneous activity in the cerebral cortex is far from random. Rather it recapitulates intricate patterns of correlated activity that are generated during naturalistic sensory stimulation in the waking state, and can even drive human motor behavior.

Advisor: Prof. Rafi Malach
Information processing in the different Basal Ganglia sub-regions

Avital Adler

The basal ganglia (BG) have been hypothesized to implement a reinforcement learning algorithm. However, it is not clear how information is processed along this network, thus enabling it to perform its functional role. Here we present three different encoding schemes of visual cues associated with rewarding, neutral and aversive outcomes by BG neuronal populations.

We studied the response profile and dynamical behavior of two populations of projection neurons; striatal medium spiny neurons (MSNs) and neurons in the external segment of the globus pallidus (GPe) and one neuromodulator group (striatal tonically active neurons, TANs) from behaving monkeys. MSNs and GPe neurons displayed sustained average activity to cue presentation. The population average response of MSNs was composed of three distinct response groups which were temporally differentiated and that fired in serial episodes along the trial. In the GPe, the average sustained response was composed of two response groups which were primarily differentiated by their immediate change in firing rate direction. However, unlike MSNs, neurons in both GPe response groups displayed prolonged and temporally overlapping persistent activity. Putamen TANs stereotyped response was characterized by a single transient response group. Finally, the MSN and GPe response groups reorganized at the outcome epoch, as different task events were reflected in different response groups.

Our results strengthen the functional separation between BG neuromodulators and main axis neurons. Furthermore, they reveal dynamically changing cell assemblies in the striatal network of behaving primates. Finally they support the functional convergence of the MSN response groups on to GPe cells.

Advisor: Prof. Hagai Bergman
Ventral subthalamic nucleus responds to emotional voices

Reuben R. Shamir

Emotional and behavioral changes following deep brain stimulation (DBS) were observed in Parkinson's disease (PD) patients and provide an evidence for a possible limbic function of the subthalamic nucleus (STN).

To better understand the limbic roles of the STN we have played emotional voices during microelectrode recording (MER) of 19 trajectories to the STN on 11 PD patients that underwent DBS surgery.

Here we show that the ventro-medial non-oscillatory region (VMNR) of the STN was associated with larger responses to the emotional stimulations in comparison to the dorso-lateral oscillatory region (DLOR) of the STN.

The DLOR may be favored for treatment of motor symptoms with minimal psychiatric side effects. The VMNR should be further studied and may be related to emotional symptoms of PD and to the non-motor adverse effects of STN DBS.

Work in collaboration with: Renana Eitan, Hagai Bergman, and Zvi Israel
POSTER SESSION
Effect of auditory cortex deactivation on stimulus-specific adaptation in the medial geniculate body

Flora M. Antunes

Survival depends critically on one's ability to detect and attend to rare stimuli in the environment. At the single-neuron level, the detection of rare stimuli is reflected by stimulus-specific adaptation (SSA), whereby neurons adapt to frequently occurring stimuli, but resume firing when 'surprised' by rare ones. SSA occurs in the midbrain, thalamus and auditory cortex (AC). SSA is strong in the non-lemniscal subcortical regions (Antunes et al., 2010; Malmierca et al., 2009), but the primary AC is the first lemniscal station where it is widespread and strong (Ulanovsky et al., 2003). This raised the hypothesis that SSA observed subcortically originates in the AC and is transmitted to subcortical nuclei in a top-down manner. Herein, we tested the hypothesis that SSA in thalamic neurons is inherited via corticofugal projections. We recorded the responses of 51 single neurons throughout the medial geniculate body (MGB) of the rat, before, during and after reversibly deactivating the AC by cooling (Lomber, 1999), while stimulating the animals with an oddball sequence to elicit SSA (Ulanovsky et al., 2003). Our main result is that the MGB neurons that showed SSA before AC deactivation retained significant SSA levels during deactivation. Similarly, the temporal dynamics of SSA were mostly unaffected during AC deactivation. However, other response properties of the MGB neurons changed significantly, such as: spectral response patterns, spontaneous activity, firing rate and latencies. There was a significant relationship between SSA and the changes in firing rate elicited by AC deactivation. We conclude that SSA in the MGB is not inherited from the AC, but rather, the AC modulates the responses of MGB neurons in a gain control manner. Furthermore, the AC adjusts thalamic neuronal firing depending on the level of SSA exhibited by thalamic neurons (Antunes and Malmierca, 2011).

Advisor: Prof. Israel Nelken
A neuronal decision rule for segregating auditory streams

Dana Barniv

The auditory scene is perceptually segregated into multiple elements, termed "auditory streams". This segregation is often studied using a sequence of alternating tones, which can be perceived either as one stream or as two streams. When the tones are closer in frequency or played slower, the perception tends towards one stream. Responses in primary auditory cortex are believed to represent this perceptual tendency: when the neuronal populations responding to the two tones overlap more, perception tends towards one stream. Correlation in response is therefore believed to be the decision rule underlying this perception tendency. Here, I tested this rule psychophysically. Playing the tone sequence at higher amplitude caused an increase in the tendency to perceive two streams, contrary to the prediction of the decision rule. I suggest an alternative rule, based on the difference between response profiles rather than their similarity, which yields the correct tendencies as a function of the parameters of the tone sequence. I use a neuronal model of the auditory cortex to quantitatively implement the difference rule and make predictions about segregation with varying stimulus properties.

Advisors: Prof. Eli Nelken & Prof. Misha Tsodyks
Modeling synaptic short-term plasticity:
a stochastic framework

Alessandro Barri (CNRS)

The dependence of chemical synaptic transmission on the pre-synaptic activation history - named short-term plasticity (STP) - has been implied to have an active role in information processing. This phenomenon is never detached from the elementary stochasticity of chemical synaptic transmission, suggesting that this property potentially conveys information about to the biological mechanisms underlying STP - which are as yet undetermined. However, this widely reported variability of synaptic transmission is largely disregarded in STP modeling. We present a statistically sound method which makes it possible to consider not only changes in mean responses but the dynamic evolution of the complete response distribution. This is achieved by constructing a generative model consisting of a quantal part which is provided with a refilling process as well as a dynamic probability of release. Response distributions generated by the model can then be fitted to experimental data distributions via the maximization of a likelihood criterion.

In order to benchmark the method we employed the widely used Tsodyks-Markram model (TM) to implement the dynamical part of the generative model. We then generated synthetic response trains and - by varying the degree of the responses' variability - systematically compared synaptic parameters obtained from fits with both the TM and the likelihood method. We found that the likelihood method consistently captured the value of the generative parameters better than the classical fit and that the deviation between the two methods increases with the response variability. Finally, we applied the method to real data, where we again found that the resulting fits differ significantly from the classical approach when the variability of the responses becomes important.

Work performed in the framework of the France-Israel Laboratory of Neuroscience (FILNe).

Advisor: Prof. David Hansel and Dr. Gianluigi Mongillo
Native and learned sources for expectations: comparing exogenous and endogenous shifting of attention in time

Asaf Breska

Foreknowledge of event timing facilitates response time (RT), accuracy and perceptual thresholds. The timing of an event can be expected based on task-specific arbitrary associations between it and a cue (‘high-level’ or ‘endogenous’ expectation), or based on temporal regularity in preceding stimuli (‘low-level’ or ‘exogenous’ expectation). However, the relative efficacy and interactions between these two sources of temporal expectations were not examined. To address this, we measured RT and event-related potentials in a detection task in which a visual target appeared following either short or long interval after a sequence of flickering stimuli. In alternate blocks, flicker phase (FP, exogenous cue) or sequence color (SC, endogenous cue) predicted the interval between the sequence termination and the target, with 75% validity, while the other cue dimension was non-predictive. Subjects were instructed to attend to the predictive cue dimension and respond as fast as possible to the target. Importantly, in valid FP trials the target appeared in phase with the sequence. The validity effect of the attended cue was stronger for FP than for SC. Moreover, when SC was predictive there was no validity effect in long interval, presumably due to increase in conditional probability for target occurrence as time passes (foreperiod effect). However when FP was predictive there was still a validity effect even in long interval. Finally, the contingent negative variation (CNV) preceding the target was larger when FP was predictive than when SC was predictive. Our results demonstrate the superiority of low-level (exogenous) over high-level (endogenous) temporal expectations when both sources are attended.

Advisor: Prof. Leon Y. Deouell
Neuronvisio: a graphical user interface with 3D capabilities for NEURON

Uri Cohen

The NEURON simulation environment is a common software to perform electrical simulation of neurons and neuronal networks. The classic NEURON User Interface provides some facilities to explore the model and to plot the simulation’s results. However, a real 3-Dimensions visualization is not available and there is no easy and standard way to save the results of simulations and the geometry of the model. The aim of Neuronvisio (http://mattions.github.com/neuronvisio/) is to fill this gap, offering a set of well designed python APIs and also providing a friendly User Interface to explore and interact with the model. Neuronvisio also ease access to previously published simulations by allowing users to browse NEURON models stored in ModelDB and then load them locally. The GUI facilitates the plotting of simulation results through the use of the matplotlib library. Finally the software is able to save and reload the simulations’ results using the HDF standard format.
Dynamics of reward-modulated learning rules in a visuomotor rotation task

Ran Darshan

The classical visuomotor rotation task is a good example for the remarkable ability of the brain to learn and adjust to changes in the environment. In this sensorimotor task, the subject (human or a monkey) adapts to the discrepancy between his planned reaching movement and the rotated movement he actually did. This kind of task is considered to be extremely difficult to learn in absence of visual feedback, when only a binary reward is available to the subject. Here we explore different ways to improve this learning when no visual feedback is available. To this end, we consider a simplified two-layers neural network, in which the input layer encodes the sensory information regarding target location and the output layer encodes for the planar hand movement. The connectivity matrix between these two layers is learned according to physiologically plausible reward-modulated learning rules. In this model, we investigate the dynamics of learning a rotation for one target without a visual feedback, as well as the interference and synergy in learning multiple targets. Using a combination of analytical calculations and numerical simulations, we study the convergence properties and time course of the learning. We show that the considered reward modulated algorithms are appropriate to learn the task for one or more targets. However, when the noise in the system is too small, a delayed learning effect is observed. For instance, for two targets in opposite directions, the network rapidly learns to perform well for one of them, but it takes much more time to learn the task for the second one. We also find that the total learning time varies non-monotonically as a function of the number of targets. We study in details how the tuning width of the input neurons, the targets size, the angular distance between the targets and the rotation angle affect the learning. Importantly, we find that the shape of the reward function has a critical effect on the learning dynamics. We predict that the delayed learning effect is reduced when the reward varies gradually with the error. We also make predictions regarding the way the reward can be shaped in experiments to accelerate the learning and improve the final performance.

Work performed in the framework of the France-Israel Laboratory of Neuroscience (FILNe).

Advisors: Prof. David Hansel

Work in collaboration with Dr. Arthur Leblois
Effects of sensory modality on 3-D spatial codes in bat hippocampus

Maya Geva-Sagiv

Hippocampal neural recordings are an important model system for understanding spatial cognition: The ensemble activity of hippocampal ‘place cells’ encodes the location of an animal within its environment. However, little is known on how inputs from different sensory systems affect hippocampal spatial representation.

The current project aims to dissociate the use of two long-range sensory systems – vision and echolocation – in a unique animal model, the Egyptian fruit bat. We intend to have the bats orient using vision without sonar – in a lit environment, and by sonar without vision – in the dark. Through simultaneous recordings of multiple cells in the hippocampal CA1 region of flying bats, we plan to characterize the differences in the neural codes for space of individual cells, and in the ensemble activity, based on the two sensory systems.

Preliminary results from hippocampal recordings in flying bats showed clear three-dimensional (3-D) place fields in the light, and in the dark. Some cells showed clearly reproducible 3-D place fields between two consecutive flight sessions in light conditions, suggesting that the 3-D tuning is stable – which now enables examining possible ‘remapping’ between light versus dark conditions. Some examples of recorded cells suggest that, indeed, there may be consistent remapping when switching from light to dark conditions, that reverts when switching back to the light condition. In addition to remapping of 3-D place fields, we also examined the directionality of place-cell firing, and found that some cells show clear preferences for left-right flights or for right-left flights – similar to previous reports in rats.

In subsequent experiments, we plan to examine in detail the population dynamics of the cognitive-map buildup, when switching between sensory modalities, as well as long-term changes across days and weeks.

Advisor: Dr. Nachum Ulanovsky
Computationally efficient non-parametric inference from fMRI searchlight classification

Tal Golan

Since the early 2000s, Multi-Voxel Pattern Analysis (MVPA) has gained momentum as a powerful alternative to Region of Interest (ROI) activation analysis of fMRI. Kriegeskorte, Goebel and Bandettini (2006) suggested applying MVPA to ROIs sampled systematically by a searchlight procedure. This method enables exploratory localization of multivariate information, unconstrained by predefined ROIs. We hold that while being an attractive alternative to the prevalent mass-univariate approach to brain mapping, its adaptation by the neuroscientific community raises issues of statistical inference. Usually, the high computational cost of non-parametric testing is avoided by relying on inter-subject voxel-by-voxel agreement. We argue that this solution poses unnecessary limitations: Its power is compromised by inter-subject anatomical and functional variability, its validity is dependent on the fulfillment of random field theory assumptions and obviously it disallows any single-subject inference. We demonstrate that regularized least-squares classification (Rifkin, Yeo & Poggio, 2003) enables producing both true accuracy maps and label permuted null accuracy maps at a low computational cost. These null accuracy maps can be used to produce voxel-wise or cluster-wise statistical thresholds, which are powerful and essentially distribution free.

Advisor: Dr. Amir Amedi

Work in collaboration with Uri Hertz and Noa Zeharia
Intracellular correlates of stimulus-specific adaptation

Itai Hershenhoren

Stimulus-specific adaptation (SSA) is the reduction in response to a common stimulus which does not, or only partially, generalizes to other, even rather similar, stimuli. SSA has been studied mostly in the auditory system. It is strong and widespread in primary auditory cortex (A1) of rats, but is rather weak or absent in the main input station to A1, the ventral division of the medial geniculate body. In order to study the transformation of SSA from the input to a neuron to its output, we recorded intracellularly in A1 neurons. Recordings have been performed using sharp electrodes, and lasted for up to 780 minutes. The responses to rare sounds were recorded in a number of different contexts, including oddball sequences, Deviant-alone sequences in which most sound presentations were replaced by silence, and sequences composed of many different sounds each of which was rare. SSA was found both in subthreshold membrane potential fluctuations and in the spiking responses of A1 neurons. By comparing the responses to the same rare sounds in multiple contexts, we can show that cortical SSA cannot be fully explained by adaptation in narrow frequency channels. SSA for changes in frequency was large at frequency differences of 44%, and clearly present with tones as close to each other as 4%, near the perceptual difference limen for frequency in rats. The amount of SSA was, however, only partially correlated between the membrane potential and the spiking output. In particular, some neurons had rather weak SSA at the level of their membrane potentials, but much stronger SSA when measuring their spiking output. Such differences may indicate the presence of processing mechanisms that amplify or create SSA de-novo in primary auditory cortex.

Advisor: Prof. Israel Nelken
We measured the impact of task structure, repeated presentations and training on the magnitude of 2 basic ERP components—N1 and P2. These are the 2 salient components induced when participants are passively exposed to a series of trials, each composed of 2 tones, with 1.4 s inter-trial intervals. We found that the magnitude of P2 is larger when a repeated reference tone is presented in a fixed position, indicating fine tuning of automatic detection mechanism, which detect this repetition, even though target differs by only 4-5% from the reference. This specific memory trace is found in addition to a broader adaptation process which decreases the magnitude of both P2 and N1 to a similar extent for reference and non-reference tones (deviating by ~5%). Multi-day training increases the magnitude of P2, though the magnitude of N1 remains stable. Taken together, these findings suggest regularities embedded in series of stimuli are automatically detected by both fast and slow processes, which operate in parallel to general adaptation mechanisms. The efficiency of these mechanisms may have broad effects on cognitive skills.

Advisor: Prof. Merav Ahissar
Signal-dependent hydrolysis of phosphatidylinositol 4,5-bisphosphate without activation of phospholipase C: IMPLICATIONS ON GATING OF DROSOPHILA TRPL (TRANSIENT RECEPTOR POTENTIAL-LIKE) CHANNEL

Lev Shaya

In Drosophila, a phospholipase C (PLC)-mediated signaling cascade, couples photo-excitation of rhodopsin to the opening of the transient receptor potential (TRP) and TRP-like (TRPL) channels. A lipid product of PLC, diacylglycerol (DAG), and its metabolites, polyunsaturated fatty acids (PUFAs) may function as second messengers of channel activation. However, how can one separate between the increase in putative second messengers, change in pH, and phosphatidylinositol 4,5-bisphosphate (PI(4,5)P(2)) depletion when exploring the TRPL gating mechanism? To answer this question we co-expressed the TRPL channels together with the muscarinic (M1) receptor, enabling the openings of TRPL channels via G-protein activation of PLC. To dissect PLC activation of TRPL into its molecular components, we used a powerful method that reduced plasma membrane-associated PI(4,5)P(2) in HEK cells within seconds without activating PLC. Upon the addition of a dimerizing drug, PI(4,5)P(2) was selectively hydrolyzed in the cell membrane without producing DAG, inositol trisphosphate, or calcium signals. We show that PI(4,5)P(2) is not an inhibitor of TRPL channel activation. PI(4,5)P(2) hydrolysis combined with either acidification or application of DAG analogs failed to activate the channels, whereas PUFA did activate the channels. Moreover, a reduction in PI(4,5)P(2) levels or inhibition of DAG lipase during PLC activity suppressed the PLC-activated TRPL current. This suggests that PI(4,5)P(2) is a crucial substrate for PLC-mediated activation of the channels, whereas PUFA may function as the channel activator. Together, this study defines a narrow range of possible mechanisms for TRPL gating.

Advisor: Prof. Baruch Minke
We are interested in whether gap junction connected networks can support complex dynamics. To this end, we consider a network of neurons with gap junction connections, enhanced by additional intrinsic excitatory and global inhibitory currents. This system turns out to be equivalent to a nonlinear network with a synaptic weight matrix that has random off-diagonal elements with variance of order 1/N, and diagonal elements with variance of order 1. Such large diagonal terms make the network behave differently from the more commonly studied case where the diagonal terms make a negligible contribution.

These networks have a trivial fixed point, which does not support interesting dynamics, so we began by examining its stability. We examine the eigenvalues of the stability matrix for this trivial fixed point, which are the same as the eigenvalues of the weight matrix. These do not fall into the typical circular region of the eigenvalues of random matrices, and we discuss methods for determining the shape of this region. For appropriate coupling strength, the trivial fixed point becomes unstable. When this happens, the network exhibits long-lasting chaotic "exploratory" activity that eventually leads to a stable, nontrivial fixed point. At the fixed point, the activity or voltage value of the neurons are predominantly determined by the diagonal elements of the connectivity matrix, with the off-diagonal elements serving as a source of noise.

Simulations show that the lifetime of the transient chaotic stage grows exponentially with network size. Thus, a reasonably sized network can sustain complex activity and signal generation over large time intervals. This in turn suggests that these networks can serve as a source of internal activity for motor, learning and memory process.

Advisors: Prof. Yosef Yarom & Prof. Larry Abbott
Emotional content is a major component in music. It has long been a research topic of interest to discover the acoustic patterns in the music that carry that emotional information, and enable performers to communicate emotional messages to listeners. Previous works looked in the audio signal for local cues, most of which assume monophonic music, and their statistics over time. Here, we used generic audio features, which can be calculated for any audio signal, and focused on the progression of these features through time, investigating how informative the dynamics of the audio is for emotional content. Our data is comprised of piano and vocal improvisations of musically trained performers, instructed to convey 4 categorical emotions. We applied Dynamic Texture Mixture (DTM), which models both the instantaneous sound qualities and their dynamics, and demonstrated the strength of the model. We further showed that once taking the dynamics into account even highly reduced versions of the generic audio features carry a substantial amount of information about the emotional content. Finally, we demonstrate how interpreting the parameters of the trained models can yield interesting cognitive suggestions.

Advisor: Prof. Gert Lanckriet
Stimulus-Specific Adaptation in a Model of Primary Auditory Cortex

Tohar S. Yarden

In the primary auditory cortex (A1) of cats and rats, neurons decrease their responses to frequently-presented stimuli but not to rare stimuli. This phenomenon, called stimulus-specific adaptation (SSA), originates in the cortex and may underlie short-term sensory memory and deviance detection. To investigate possible mechanisms of SSA, we employed a neural network previously used to reproduce several other A1 response properties, including frequency tuning, forward masking, lateral inhibition, and hyper-sensitive locking suppression (Loebel et al. 2007). This network has synaptic depression, which gives rise to population spikes (PSs).

Our model exhibits SSA: rare stimuli elicit a PS but frequent stimuli do not. SSA strongly depends on stimulus and network parameters (input amplitude, inter-stimulus interval, time-constants of synapse recovery etc.) through their control of PS responses. We identified several regimes of PS generation and demarcated the regions in parameter space that allow SSA. Our results compare with experimental data and provide predictions that will be tested by electrophysiological recordings in rats.

Advisor: Prof. Israel Nelken
Sensitivity to complex statistical regularities in rat auditory cortex

Amit Yaron

Neurons in auditory cortex are sensitive to the probability of stimuli, responses to rare stimuli tending to be stronger than responses to common ones. However, whether neurons are sensitive to more complex statistical regularities, such of those needed for complex tasks like understanding language, remains to be discovered. In this study, intra- and extra-cellular recordings from the auditory cortex of halothane-anesthetized rats revealed the existence of a fine-grained analysis of the statistics of the sound sequence. Using a variation of the oddball paradigm in which the order of stimulus presentation is fixed, we found that responses were smaller than the responses to the same tones in random sequences. The size of the effect depended on the probabilities of the tones, with reduction in the responses to the common tones in fixed sequences even when the odds ratio was 1:19. We conclude that neurons in auditory cortex are sensitive to the structure of sound sequences of length 20 or more, spanning at least 6 seconds.

Advisor: Prof. Israel Nelken
Data by Itai Hershenhoren
Theory of Own and Other Mind
To which extent does the capacity to understand oneself depend on the capacity to understand the other?

Alexandra Zinck

Self-consciousness is the special capacity of being conscious of oneself as oneself with certain mental and physical states and properties. It is essentially characterized by subjective self-referential experience. I investigate to what extent a subject’s capacity to develop self-consciousness depends on the capacity to understand the mental states, especially the emotions, of others. This capacity to understand and attribute mental states (mentalizing or theory of mind (ToM)) is generally assumed to contribute to the development of self-consciousness. Empirical research suggests that the capacity to understand one’s own and others’ mental states is closely interconnected (Leslie 1987, Gopnik & Meltzoff 1994, Happé 2003). However, little is known about qualitative differences in self-consciousness that are connected to theory of (own) mind (1PP) and social understanding in general. I will examine the following hypotheses by drawing from the data of developmental and autism research:

Within a developmental framework, both, a basic pre-conceptual and a conceptual level of self-consciousness depend on the capacity of understanding others’ mental states (where I will focus on the case of understanding others’ emotions). On the non-conceptual level, understanding that others direct emotions (or other mental states) towards oneself, contributes to an emotional self-reference that is immediate and phenomenally coded and enters the non-conceptual self-representation (Reddy 2003, Sartre 1943).

On the conceptual level, impairments in the capacity of understanding other minds are followed by difficulties in conscious processing of own emotions and in ascription of emotions to others (alexithymia) (Hill 2004, Berthoz 2004) and in the communication of emotions between individuals. Research to date shows that AS is connected with reduced reports about inner states (more concrete and visual language) (Hurlburt 1994, Frith and Happé 1999) and egocentrism (Frith & de Vignemont 2005). Understanding and communication of others’ 3PP emotional evaluative and theoretical states provides important input for the conceptual level of self-representation.

I would further like to tentatively introduce the thesis that it is a second-person-perspective (2PP) that is lacking in the interactions of individuals with AS with other people and that this entails deficits in both 1PP and 3PP.

Advisors: Prof. Oron Shagrir & Prof. Uta Frith
Learning good image priors is of utmost importance for the study of vision, computer vision and image processing applications. Learning priors and optimizing over whole images can lead to tremendous computational challenges. In contrast, when we work with small image patches, it is possible to learn priors and perform patch restoration very efficiently. This raises three questions - do priors that give high likelihood to the data also lead to good performance in restoration? Can we use such patch based priors to restore a full image? Can we learn better patch priors? In this work we answer these questions. We compare the likelihood of several patch models and show that priors that give high likelihood to data perform better in patch restoration. Motivated by this result, we propose a generic framework which allows for whole image restoration using any patch based prior for which a MAP (or approximate MAP) estimate can be calculated. We show how to derive an appropriate cost function, how to optimize it and how to use it to restore whole images. Finally, we present a generic, surprisingly simple Gaussian Mixture prior, learned from a set of natural images. When used with the proposed framework, this Gaussian Mixture Model outperforms all other generic prior methods for image denoising, deblurring and inpainting.

Advisor: Prof. Yair Weiss
Sunday, February 5

11:30   Bus departing from Givat Ram Campus, main bus stop
12:15-13:15  Arrival at Ein Gedi – room allocation
13:00-13:45  Lunch

Session 1 – Language
Chair: Naftali Tishby

14:00-14:45  Danny Fox (Linguistics, HU & MIT): “From language to logic”
14:45-15:30  Yosef Grodzinsky (Linguistics, McGill University): “From language to brain”
15:30-16:00  Discussion
16:00-16:20  Coffee Break

Session 2 – Time and coding
Chair: Shay Moshel

16:20-17:00  Ben Engelhard: “Operant conditioning of a specific LFP frequency band: Relationship to Neural Synchrony”
             Advisor: Eilon Vaadia
17:00-17:40  Nori Jacoby: “Kernel information bottleneck”
             Advisors: Naftali Tishby & Merav Ahissar
17:40-19:40  Poster session (refreshments)
19:40-21:00  Dinner
21:00   Avigdor Shinan (Hebrew Literature, HU) “Folk stories in rabbinic literature”
22:00   Wine, beer & cheese
Monday, February 6
8:00-8:50 Breakfast

**Session 3 – Vision**
Chair: Daphna Weinshall

9:00-9:40 Elad Mezuman: “Do canonical views exist in internet image collections?”
Advisor: Yair Weiss

**Session 4 – Guest Speaker**
9:40-10:40 Simon Rumpel (IMP, Vienna)
“Sound encoding in the neocortex by combinations of discrete activity patterns”

10:40-11:00 Coffee Break

**Session 5 – Exotic neuroscience**
Chair: Benny Hochner

11:00-11:40 Guy Levy: “How octopuses coordinate their arms while crawling”
Advisor: Benny Hochner

11:40-12:20 Michael Yartsev: “Neural representation of multi-dimensional space in the Hippocampal Formation of bats”
Advisor: Nachum Ulanovsky (Weizmann Institute)

**Session 6 – Guest Speaker**
12:20-13:20 Rina Dechter (CS, University of California, Irvine)
“Belief networks and belief propagation; some reflections”

13:20-14:50 Lunch

**Session 7 – Technology**
14:50-15:40 Michal Balberg (Ornim Ltd. & ICNC Alumna)
“Interdisciplinary cerebral safety”

15:40-16:30 Danny Porath (Director of the Center of Nanotechnology HU)
“The Hebrew University Center for Nanotechnology and fantasies about the brain”

16:30-17:30 Debate: “The role of technology in the future of neuroscience”
Moderators: Yoav Livneh and Nori Jacoby

18:00-20:00 Moonlight dinner

21:00 Moonlight hike by the Marls of Masada (“Chavarei” Masada)
Tuesday, February 7

8:00-9:00  Breakfast & check-out

Session 8 – Auditory
Chair: Israel Nelken

9:00-9:40  Yael Biterman: “Relevant stimulus features for neurons in auditory cortex - experimental traces”
Advisor: Israel Nelken

9:40-10:20  Roi Kliper: “Monaural and binaural source localization using spectral dynamics of speech”
Advisors: Daphna Weinshall and Israel Nelken

10:20-10:40  Coffee Break

Session 9 – Perception
Chair: Udi Zohary

10:40-11:20  Uri Hertz: “Audiovisual integration and brain plasticity in learning a visual-to-auditory sensory substitution algorithm (SSA)”
Advisor: Amir Amedi

11:20-12:00  Michal Ramot: “Silent night? Sensory and motor aspects of spontaneous activity”
Advisor: Rafael Malach (Weizmann Institute)

12:00-12:15  Coffee Break

Session 10 – Basal Ganglia
Chair: David Hansel

12:15-12:55  Avital Adler: “Information processing in the different Basal Ganglia sub-regions”
Advisor: Hagai Bergman

12:55-13:35  Rubi Shamir: “Ventral subthalamic nucleus responds to emotional voices”
ELSC Postdoc – lab of Hagai Bergman

13:35-13:40  Farewell words

13:40-14:30  Lunch

14:45  Return to Jerusalem
LECTURES
This talk will focus on interactions between human linguistic and logical abilities. Much fruitful work in this domain assumes a cognitive system which combines linguistic primitives to form linguistic expressions (syntax). The output of syntax (a linguistic expression) then serves as input for other cognitive systems that “interpret” this output, thereby accounting for patterns of logical inference.

This talk will focus on phenomena that argue for a more intricate relationship between syntax and logic. Specifically, we will see evidence that the class of available linguistic expressions is determined in part by patterns of logical inference. In other words, we will see reasons to believe that logic affects linguistic analysis. Moreover we will see that the distribution of facts requires very specific assumptions about cognitive architecture. On the one hand, we will see that syntax must “see” the logical properties of linguistic expressions. On the other hand, however, we will see that syntax must be “blind” to non-logical aspects of meaning, aspects of meaning that must be taken into consideration in a general account of human inferential abilities. We will use these observations to motivate the postulation of an internal deductive engine, a system which is either part of syntax or works in close interaction with syntax.

The relevant observation can be used as a tool in figuring out the properties of the deductive engine (which, in turn, ought to serve as the logical building blocks of human reasoning). In doing so we will reach some surprising conclusions. First, we will conclude that the relevant logical system contains axioms that pertain to arithmetic notions. However, we will also conclude that it does not contain the discrete notion of natural number. Instead, it only has axioms that characterize dense domains. These conclusions are in line with some hypotheses in the field of mathematical cognition.
This talk describes small steps towards understanding how the human central nervous system supports the mental capacities that underlie complex linguistic behavior. These capacities inhere in our ability to combine discrete building blocks (phonemes, words, phrases) into complex, arbitrarily long linguistic expressions that we use to communicate a wide range of subtle (as well as less subtle) messages to others. These capacities – rather central to our existence as humans – also connect to other cognitive systems.

I will consider several possible approaches to the study of brain/language relations, and focus on the one I personally pursue: the localization of pieces of linguistic knowledge in specialized brain pieces. That is, I will report attempts to align well-defined, abstract syntactic operations with brain loci, or “areas”, whose borders are defined by cytoarchitectonic and receptor architectonic anatomical tools. The hope that drives this project is that a functional anatomy of language (a linguistic homunculus, if you will) would produce new insights, valuable to both theoretical linguistics and computational neuroscience.

I will illustrate the approach by reporting a series of attempts to map a central syntactic relation (called “movement”) whose result, I will argue, are of interest to linguists and neuroscientists alike. These attempts are multi-modal: they are based on deficit analyses of the linguistic abilities with brain-damaged patients, and on accounts of fMRI activation patterns in health.

Aware of the fact that many in the audience were present in a recent lecture at ELSC, I promise not to be overly repetitive, and present both theoretical considerations and results that will be new to most.
Operant conditioning of a specific
LFP frequency band:
Relationship to neural synchrony

Ben Engelhard

Frequency bands of LFP have been associated with a plethora of cognitive roles. In particular, various clinical disorders have been associated with abnormalities in the power of the lower gamma frequency (30-50 Hz), including ADHD, Autism, Schizophrenia, Epilepsy and others. These abnormalities are thought to reflect in turn abnormalities in the degree of neural synchronization in either a local or distributed manner. Thus, the ability to effect changes in the power of this frequency band could have important clinical implications, if said changes are accompanied by concurrent changes in the level of neural synchronization in a given locality. Further, in recent years it has been shown that a wide variety of cognitive functions incorporate changes in the power and synchronization of the lower gamma band including visual and auditory perception, memory encoding, sensory-motor integration and many others. Again, the main focus has been on these changes as relating the amount of neural synchrony which is thought to mediate processes of neural computation. The precise role of these oscillations, however, and their possible contribution to synchrony in a behavioral context remains yet unclear. It is apparent then that from a basic science perspective there is additional interest in exploring the possible role of oscillations in this frequency band in the generation of neural synchrony and their relationship to behavior.

In this study we demonstrate specific control of the power of the 30-43 Hz band of LFP in the primary motor cortex of macaques. Over the course of several sessions the monkeys learned to raise the power of this band to move a cursor on the screen and obtain a reward. The evoked activity was oscillatory in nature and band specific. It was clearly distinguishable on a single-trial basis, which permitted real time control of a brain-machine interface. This was done absent any overt movements by the monkey. The increase in the LFP band power was accompanied by a dramatic increase in the amount of neural synchrony, allowing previously uncoordinated pairs of neurons to fire together in a time-precise manner. The increased synchrony was evoked dynamically as a result of phase locking of a large number of the single units onto the LFP signal, and is a first example of volitional control of precisely timed neural activation.

Our findings have a two-fold significance: On the clinical side, they stand as an important step in the development of treatments for a wide variety of conditions in which the level of neural synchrony is impaired. From a neurophysiological perspective, we have shown a causal link between LFP oscillations, neural synchrony and behavior, which hopefully leads us towards a more complete understanding of the computational processes effected in the brain.

Advisor: Prof. Eilon Vaadia
Kernel information bottleneck

Nori Jacoby

The information bottleneck method was proposed by Tishby et. al 1999 as a general computational principle for information processing in the brain. It has been a useful tool in machine learning and data analysis, as well as in explaining neuronal activity and cognitive behavior. The idea behind this method is to extract efficient compressions - minimal sufficient statistics - of a source variable X that preserve as much information as possible on a target variable Y.

A converging iterative algorithm for solving this problem was suggested by Tishby et. al 2000, but this algorithm converges to a global optimum only for relatively small problems. However, for the special case that X and Y are jointly multivariate Gaussian a closed form global solution was obtained by Chechik and Globerson in 2005. The solution depends on the spectral properties and eigenvectors of the Canonical Correlation Analysis (CCA) matrix of X and Y, with weights that depend on the tradeoff between prediction accuracy and complexity of the compressed representation.

We will present in this talk a novel extension of the Gaussian Information Bottleneck to a much wider family of continuous cases using Vapnik's kernel trick. This has valuable practical importance, since it allows solving the information bottleneck problem for high dimensional nonlinear continuous scenarios. The result is closely connected to the well-established method called kernel-CCA and therefore can gain from numerical and theoretical technique suggested in the literature. In turns the information bottleneck approach into a practical tool and analysis technique for a wide range of neuroscience and cognitive applications.

In this talk we present the mathematical background as well as illustrative examples from the domains of visual art and music, and discuss further applications of the methods to other domains.

Advisors: Prof. Naftali Tishby & Prof. Merav Ahissar
Do canonical views exist in internet image collections?

Eldad Mezuman

Although human object recognition is supposedly robust to viewpoint, much research on human perception indicates that familiar objects have a preferred or "canonical" view. It was hypothesized by psychology researchers that this "canonical view" will be the viewpoint from which an object is most likely to be photographed but this hypothesis was never verified by analyzing statistics of real photographs. In this paper we ask: given a set of images retrieved by an image search engine for a particular object (1) is there a preferred view of the object? (2) does it correspond to the canonical view? To answer these questions we develop a simple method to extract the most likely view of an object in a photo collection. We find that indeed for most categories there exist a preferred view and that it often corresponds to the canonical view defined in psychophysical experiments.

Advisor: Prof. Yair Weiss
Sound encoding in the neocortex by combinations of discrete activity patterns in local neuronal ensembles

Simon Rumpel (IMP Vienna)

It is believed that patterns of activity are the neuronal correlate of the perception of an external stimulus, e.g. a sound. Here, we used *in vivo* two-photon calcium imaging to better understand how sounds are encoded at the level of local layer 2/3 ensembles in the mouse auditory cortex. We found that activity patterns are highly constrained into few discrete response modes, i.e. that a wide range of different sounds evoke the same population response pattern. Using online synthesis of sound stimuli to map the transition across response modes with fine resolution, we observed highly non-linear dynamics suggesting attractor-like competition between response modes. The combination of sounds that were associated in a specific response mode varied across local populations and was not predictable based on the population’s pure-tone frequency tuning. We used linear classifiers to test whether different pairs of sound could be discriminated on a single trial basis based on population activity. Global response patterns constructed by the combination of multiple local patterns largely out-performed local populations for the number of discriminated sound pairs, indicating that much more information is contained at the global scale. Interestingly, strong dimensionality-reduction by decomposition of single trial patterns into response modes did not lead to significant information loss. Furthermore, we found that global activity patterns in the mouse auditory cortex quantitatively predict discrimination and spontaneous categorization of sounds in behaving mice. We suggest a model of auditory cortex function in which local non-linear dynamics shape a broad basis set of spontaneous, distinct associations of stimuli that form a representation of sounds available for behavioral decisions.

Work in collaboration with Brice Bathellier, Lyubov Ushakova
How octopuses coordinate their arms while crawling

Guy Levy

Crawling is a typical way of locomotion of octopuses on the seabed or along rocks in shallow
waters or outside of the water. The first stage of this study showed that octopuses use their
arms while crawling with rhythmical stereotypical steps composed of anchoring some suckers
to the substrate followed by arm elongation to push the body in the direction opposite to the
elongating arm. Here we present a new part of the study that shows how the octopus
coordinates its arms when crawling. Mature octopuses were videotaped from underneath
while crawling in shallow waters and sections of interest in the video clips were stored as single
images. Arms that participated in pushing and additional points of interest were labeled
manually on consecutive images for the kinematic analysis of the crawling movements. The
data was used to test our hypothesis suggesting that the crawling direction is a simple vectorial
combination of the pushing arms and changing the direction of crawling is done by choosing a
suitable set of arms rather than by rotating the body. In this part of the study we describe the
arms as spreading around the body symmetrically with a $45^\circ$ angle between each adjacent
couple of arms. Hence, we assume that each arm has a fixed direction of pushing by elongation
relative to the body. Using this assumption together with the information regarding the identity
of the pushing arms at each moment, we were able to reconstruct, in a simple toy model, the
direction of crawling using only the simple vectorial combination of the participating arms. We
confirm our hypothesis by showing an excellent match between the reconstructed and the
actual crawling path. We suggest that as seen in other octopus movements, control
simplification is achieved by using simple stereotypical movements generated at the level of the
peripheral neuromuscular system of the arm (rhythmical suckers adherence and length
changing) while the participating arms are coordinated by commands from the central brain.

Advisor: Prof. Benny Hochner
Neural representation of multi-dimensional space in the hippocampal formation of bats

Michael Yartsev

The hippocampus and medial entorhinal cortex (MEC), both regions in the mammalian hippocampal formation, are considered key elements in the neural circuitry underlying the representation of the space around us in the brain. The hippocampus contains 'place cells', neurons which are active when the animal passes through a particular location in the environment (the 'place field'), and the MEC contains 'grid cells', which are activated when the animal's position in space coincides with any vertex of a spatial hexagonal grid spanning the entire environment. To date, the vast majority of available electrophysiological data on how space is represented in these two interconnected brain regions was obtained from recordings in rats navigating in one- or two-dimensional environments. To extend current knowledge regarding the neural basis of spatial representation in the mammalian brain, we used a novel animal model - the Egyptian fruit bat. Here, I will describe two of my PhD research project aimed at elucidating two of the biggest mysteries regarding the neural mechanisms governing spatial representation in these two brain regions.

Project 1: What are the underlying neural mechanisms giving rise to the grid formation?

Two competing classes of theoretical models govern the field: network models, based on attractor dynamics versus oscillatory interference models, based on continuous theta-band oscillations (4–10 Hz) in single neurons. To date these models could not be dissociated experimentally, because rodent grid cells always co-exist with continuous theta oscillations. To address this, we conducted the first electrophysiological recording from the MEC of freely crawling bats. We find that, in the bat, grid cells existed in the complete absence of continuous theta oscillation and theta modulation of spiking activity which causally argues against the oscillatory interference class of models (Yartsev et al., Nature 2011).

Project 2: How is three dimensional (3-D) space represented in the neural activity of hippocampal neurons?

Much research has focused on studying the detailed properties of place cells in rodents moving in either one- or two-dimensional environments (linear tracks or open field arenas, respectively), but only few attempts have been made to study the representation of 3-D space in the mammalian hippocampus. This question is important, because both animals and humans move daily in 3-D environments; and in order to understand the role of place-cells in real-life navigation, we must record from place-cells as animals move through all three dimensions. Using a tetrode-based microdrive and a custom, lightweight multi-channel neural telemetry system, we conducted the first electrophysiological recordings from the hippocampus of a freely flying mammal, the bat. We find that all three dimensions of the available environment were represented with the same precision. Furthermore, the spatial locations and scales in which single hippocampal neurons were activated spanned the entire available environment and as a whole represented all three dimensional positions in the room. These findings argue that the mammalian hippocampus is capable of storing accurate representation of the entire three-dimensional space. Finally, although the bat’s behavior was extremely theta-oscillatory during flight (in terms of the bat’s wing-beats and echolocation), hippocampal neurons were not theta modulated, pointing to a fundamental dissociation between behavioral and neural oscillations in the mammalian hippocampus.

Advisor: Dr. Nahum Ulanovsky (Weizmann Institute)
Belief networks and belief propagation – from rumelhart to pearl to today

Rina Dechter
Donald Bren School of Information and Computer Sciences, UC Irvine

Bayesian networks have become a standard paradigm for automated reasoning under uncertainty, with numerous applications in engineering, business and the empirical sciences. They are also appealing to cognitive and neuroscientists because they provide a plausible and biologically feasible framework (e.g., distributed processing on causal representation) through which human reasoning can be explored and potentially understood.

Taking a historical perspective, I will introduce Bayesian networks, the poly-tree belief propagation algorithm and the ideas of moving from trees to loopy networks as reported by their creators. I will reflect on the current state of the art for general graphical models and highlight properties of belief propagation (e.g., convergence and accuracy) from a constraint propagation perspective.
Relevant stimulus features for neurons in auditory cortex - experimental traces

Yael Bitterman

Encoding of sounds in the early auditory system is modeled successfully based on the physiology of the cochlea and brainstem pathways. Models use short-term spectro-temporal features of the sound to describe the encoding in primary stations and to account for various perceptual capabilities. On the other end, high cortical areas have been shown to encode abstract qualities of sound. The link between early and late auditory system, and specifically the role of primary auditory cortex (A1) in hearing, is currently badly understood.

We study the transformation of low-level to high-level representations using neural recordings and computational methods. I will illustrate these with a number of examples:

1. Coding of artificial and natural sounds in human auditory cortex. Extracellular single unit recordings revealed ultra-fine frequency selectivity of neurons in artificial random contexts. The result however did not generalize to the encoding of natural stimuli, like speech and music.
2. 'Object-related potentials' in MEG study of Comodulation Masking Release (CMR). An evoked magnetic field was detected when a tone was heard as a separate object in the presence of noise but not when its detection relied on subtle changes in the timbre of the sound.
3. Responses of rat auditory cortex to classical western music. A musical piece with tight structure presented to rats, revealed neural response patterns in A1 consistent not with the short term spectral content of the sound but with the 'surprise' structure of the piece.

The evidence from these studies suggests that auditory cortex is involved both in organizing the sensory input into auditory objects and in predicting parts of the auditory input not actually encountered. Crucially, I propose to link the two tasks by identifying them: I suggest that an auditory object is instantiated by a predictive model. In support of this hypothesis, I will demonstrate the power of predictive models by a study of behavioral categorization of human voice. Predictive models based on the sound highlighted systematic differences between sounds produced by musical instruments and those produced by human voices. These differences appeared already for very short segments in agreement with psychoacoustic results obtained with the same sounds.

Advisor: Prof. Israel Nelken
Monaural and binaural source localization using spectral dynamics of speech

Roi Klipler

Following recent psychoacoustic results, showing high performance in monaural localization, we tackle the task of localizing speech signals on the horizontal plane using monaural cues. We demonstrate that monaural cues as incorporated in speech are efficiently captured by amplitude modulation spectra patterns. These patterns previously shown to be a robust representation for speech recognition can be used alongside with simple machine learning techniques to extract directionality related information and learn to discriminate and classify sound location at high resolution.

We then point out several limitations of the classic binaural model of source localization, and propose a simple and robust way of integrating information from two ears. We show that psychoacoustic results for human binaural localization performance can be reproduced by treating each ear as an independent processor and integrating the information only at the decision level.

Advisors: Prof. Daphna Weinshall and Prof. Israel Nelken
Audiovisual integration and brain plasticity in learning a visual-to-auditory sensory substitution algorithm (SSA)

Uri Hertz

Multisensory integration is based on coupling principles which are innate, learned during development or learned in adulthood throughout our life. Sensory-substitution-algorithm (SSA), usually used as a rehabilitation tool for blind, was used here in sighted as they provides a unique opportunity to study binding of a new ‘sense’ into the well-established system. Subjects were scanned in fMRI before and after learning SSA while passively perceiving images and soundscapes (i.e. the novel auditory representation of vision). We also tested subjects in the context of a task requiring binding between the new learned ‘sense’ and vision. Both experiments demonstrate a fast and dynamic shift in sensory processing in the brain, as the information and novelty conveyed by each sensory stream changes. This shift was manifested in associative multisensory areas, including right Insula, left inferior frontal sulcus and left Supr marginal sulcus. These were accompanied with context- dependent modulation of primary sensory cortices response.

Advisor: Dr. Amir Amedi
Silent night? Sensory and motor aspects of spontaneous activity

Michal Ramot

The link between conscious awareness and perception and brain activity is one of the fundamental questions occupying neuroscientists today. It would seem that spontaneous activity, in which state the cortex remains highly active despite the lack of sensory stimulation, could provide an excellent framework for studying this question. We addressed this issue of spontaneous activity in two separate studies using very different methods. First, we used electrocorticography (ECoG) recordings from 388 electrodes from 7 patients with intractable epilepsy, who were undergoing approximately a week of invasive monitoring with implanted grids of subdural electrodes, for strictly clinical purposes. We compared sensory driven activity patterns of broadband gamma power modulations generated while awake patients watched short segments of an engaging movie with activity patterns emerging spontaneously during sleep. Our results show a highly significant \( p<10^{-4} \) similarity between sensory-driven correlation patterns and those emerging spontaneously during sleep. Moreover, this similarity was not limited to global network patterns, but rather recaptured the fine structure of correlations within sensory cortex. Our results further show a surprising significant difference between REM and NREM sleep, with reactivation being significantly stronger during NREM periods. In another study, we found that a highly significant correlation exists between the magnitude of the spontaneous BOLD fluctuations and eye movements which occur subliminally and \textit{spontaneously} in the absence of any visual stimulation. Control experiments ruled out a contribution of spatial and visual attentional effects as well as smooth pursuit eye movements. These results demonstrate that spontaneous activity in the cerebral cortex is far from random. Rather it recapitulates intricate patterns of correlated activity that are generated during naturalistic sensory stimulation in the waking state, and can even drive human motor behavior.

Advisor: Prof. Rafi Malach
Information processing in the different Basal Ganglia sub-regions

Avital Adler

The basal ganglia (BG) have been hypothesized to implement a reinforcement learning algorithm. However, it is not clear how information is processed along this network, thus enabling it to perform its functional role. Here we present three different encoding schemes of visual cues associated with rewarding, neutral and aversive outcomes by BG neuronal populations.

We studied the response profile and dynamical behavior of two populations of projection neurons; striatal medium spiny neurons (MSNs) and neurons in the external segment of the globus pallidus (GPe) and one neuromodulator group (striatal tonically active neurons, TANs) from behaving monkeys. MSNs and GPe neurons displayed sustained average activity to cue presentation. The population average response of MSNs was composed of three distinct response groups which were temporally differentiated and that fired in serial episodes along the trial. In the GPe, the average sustained response was composed of two response groups which were primarily differentiated by their immediate change in firing rate direction. However, unlike MSNs, neurons in both GPe response groups displayed prolonged and temporally overlapping persistent activity. Putamen TANs stereotyped response was characterized by a single transient response group. Finally, the MSN and GPe response groups reorganized at the outcome epoch, as different task events were reflected in different response groups.

Our results strengthen the functional separation between BG neuromodulators and main axis neurons. Furthermore, they reveal dynamically changing cell assemblies in the striatal network of behaving primates. Finally they support the functional convergence of the MSN response groups on to GPe cells.

Advisor: Prof. Hagai Bergman
Ventral subthalamic nucleus responds to emotional voices

Reuben R. Shamir

Emotional and behavioral changes following deep brain stimulation (DBS) were observed in Parkinson's disease (PD) patients and provide an evidence for a possible limbic function of the subthalamic nucleus (STN).

To better understand the limbic roles of the STN we have played emotional voices during microelectrode recording (MER) of 19 trajectories to the STN on 11 PD patients that underwent DBS surgery.

Here we show that the ventro-medial non-oscillatory region (VMNR) of the STN was associated with larger responses to the emotional stimulations in comparison to the dorso-lateral oscillatory region (DLOR) of the STN.

The DLOR may be favored for treatment of motor symptoms with minimal psychiatric side effects. The VMNR should be further studied and may be related to emotional symptoms of PD and to the non-motor adverse effects of STN DBS.

Work in collaboration with: Renana Eitan, Hagai Bergman, and Zvi Israel
POSTER SESSION
Survival depends critically on one's ability to detect and attend to rare stimuli in the environment. At the single-neuron level, the detection of rare stimuli is reflected by stimulus-specific adaptation (SSA), whereby neurons adapt to frequently occurring stimuli, but resume firing when 'surprised' by rare ones. SSA occurs in the midbrain, thalamus and auditory cortex (AC). SSA is strong in the non-lemniscal subcortical regions (Antunes et al., 2010; Malmierca et al., 2009), but the primary AC is the first lemniscal station where it is widespread and strong (Ulanovsky et al., 2003). This raised the hypothesis that SSA observed subcortically originates in the AC and is transmitted to subcortical nuclei in a top-down manner. Herein, we tested the hypothesis that SSA in thalamic neurons is inherited via corticofugal projections. We recorded the responses of 51 single neurons throughout the medial geniculate body (MGB) of the rat, before, during and after reversibly deactivating the AC by cooling (Lomber, 1999), while stimulating the animals with an oddball sequence to elicit SSA (Ulanovsky et al., 2003). Our main result is that the MGB neurons that showed SSA before AC deactivation retained significant SSA levels during deactivation. Similarly, the temporal dynamics of SSA were mostly unaffected during AC deactivation. However, other response properties of the MGB neurons changed significantly, such as: spectral response patterns, spontaneous activity, firing rate and latencies. There was a significant relationship between SSA and the changes in firing rate elicited by AC deactivation. We conclude that SSA in the MGB is not inherited from the AC, but rather, the AC modulates the responses of MGB neurons in a gain control manner. Furthermore, the AC adjusts thalamic neuronal firing depending on the level of SSA exhibited by thalamic neurons (Antunes and Malmierca, 2011).
A neuronal decision rule for segregating auditory streams

Dana Barniv

The auditory scene is perceptually segregated into multiple elements, termed "auditory streams". This segregation is often studied using a sequence of alternating tones, which can be perceived either as one stream or as two streams. When the tones are closer in frequency or played slower, the perception tends towards one stream. Responses in primary auditory cortex are believed to represent this perceptual tendency: when the neuronal populations responding to the two tones overlap more, perception tends towards one stream. Correlation in response is therefore believed to be the decision rule underlying this perception tendency. Here, I tested this rule psychophysically. Playing the tone sequence at higher amplitude caused an increase in the tendency to perceive two streams, contrary to the prediction of the decision rule. I suggest an alternative rule, based on the difference between response profiles rather than their similarity, which yields the correct tendencies as a function of the parameters of the tone sequence. I use a neuronal model of the auditory cortex to quantitatively implement the difference rule and make predictions about segregation with varying stimulus properties.

Advisors: Prof. Eli Nelken & Prof. Misha Tsodyks
Modeling synaptic short-term plasticity: a stochastic framework

Alessandro Barri (CNRS)

The dependence of chemical synaptic transmission on the pre-synaptic activation history - named short-term plasticity (STP) - has been implied to have an active role in information processing. This phenomenon is never detached from the elementary stochasticity of chemical synaptic transmission, suggesting that this property potentially conveys information about to the biological mechanisms underlying STP - which are as yet undetermined. However, this widely reported variability of synaptic transmission is largely disregarded in STP modeling. We present a statistically sound method which makes it possible to consider not only changes in mean responses but the dynamic evolution of the complete response distribution. This is achieved by constructing a generative model consisting of a quantal part which is provided with a refilling process as well as a dynamic probability of release. Response distributions generated by the model can then be fitted to experimental data distributions via the maximization of a likelihood criterion.

In order to benchmark the method we employed the widely used Tsodyks-Markram model (TM) to implement the dynamical part of the generative model. We then generated synthetic response trains and - by varying the degree of the responses' variability - systematically compared synaptic parameters obtained from fits with both the TM and the likelihood method. We found that the likelihood method consistently captured the value of the generative parameters better than the classical fit and that the deviation between the two methods increases with the response variability. Finally, we applied the method to real data, where we again found that the resulting fits differ significantly from the classical approach when the variability of the responses becomes important.

Work performed in the framework of the France-Israel Laboratory of Neuroscience (FILNe).

Advisor: Prof. David Hansel and Dr. Gianluigi Mongillo
Native and learned sources for expectations: comparing exogenous and endogenous shifting of attention in time

Asaf Breska

Foreknowledge of event timing facilitates response time (RT), accuracy and perceptual thresholds. The timing of an event can be expected based on task-specific arbitrary associations between it and a cue ('high-level' or ‘endogenous’ expectation), or based on temporal regularity in preceding stimuli ('low-level' or ‘exogenous’ expectation). However, the relative efficacy and interactions between these two sources of temporal expectations were not examined. To address this, we measured RT and event-related potentials in a detection task in which a visual target appeared following either short or long interval after a sequence of flickering stimuli. In alternate blocks, flicker phase (FP, exogenous cue) or sequence color (SC, endogenous cue) predicted the interval between the sequence termination and the target, with 75% validity, while the other cue dimension was non predictive. Subjects were instructed to attend to the predictive cue dimension and respond as fast as possible to the target. Importantly, in valid FP trials the target appeared in phase with the sequence. The validity effect of the attended cue was stronger for FP than for SC. Moreover, when SC was predictive there was no validity effect in long interval, presumably due to increase in conditional probability for target occurrence as time passes (foreperiod effect). However when FP was predictive there was still a validity effect even in long interval. Finally, the contingent negative variation (CNV) preceding the target was larger when FP was predictive than when SC was predictive. Our results demonstrate the superiority of low-level (exogenous) over high-level (endogenous) temporal expectations when both sources are attended.

Adviser: Prof. Leon Y. Deouell
Neuronvisio: a graphical user interface with 3D capabilities for NEURON

Uri Cohen

The NEURON simulation environment is a common software to perform electrical simulation of neurons and neuronal networks. The classic NEURON User Interface provides some facilities to explore the model and to plot the simulation’s results. However, a real 3-Dimensions visualization is not available and there is no easy and standard way to save the results of simulations and the geometry of the model. The aim of Neuronvisio (http://mattions.github.com/neuronvisio/) is to fill this gap, offering a set of well designed python APIs and also providing a friendly User Interface to explore and interact with the model. Neuronvisio also ease access to previously published simulations by allowing users to browse NEURON models stored in ModelDB and then load them locally. The GUI facilitates the plotting of simulation results through the use of the matplotlib library. Finally the software is able to save and reload the simulations’ results using the HDF standard format.
Dynamics of reward-modulated learning rules in a visuomotor rotation task

Ran Darshan

The classical visuomotor rotation task is a good example for the remarkable ability of the brain to learn and adjust to changes in the environment. In this sensorimotor task, the subject (human or a monkey) adapts to the discrepancy between his planned reaching movement and the rotated movement he actually did. This kind of task is considered to be extremely difficult to learn in absence of visual feedback, when only a binary reward is available to the subject. Here we explore different ways to improve this learning when no visual feedback is available. To this end, we consider a simplified two-layers neural network, in which the input layer encodes the sensory information regarding target location and the output layer encodes for the planar hand movement. The connectivity matrix between these two layers is learned according to physiologically plausible reward-modulated learning rules. In this model, we investigate the dynamics of learning a rotation for one target without a visual feedback, as well as the interference and synergy in learning multiple targets. Using a combination of analytical calculations and numerical simulations, we study the convergence properties and time course of the learning. We show that the considered reward modulated algorithms are appropriate to learn the task for one or more targets. However, when the noise in the system is too small, a delayed learning effect is observed. For instance, for two targets in opposite directions, the network rapidly learns to perform well for one of them, but it takes much more time to learn the task for the second one. We also find that the total learning time varies non-monotonically as a function of the number of targets. We study in details how the tuning width of the input neurons, the targets size, the angular distance between the targets and the rotation angle affect the learning. Importantly, we find that the shape of the reward function has a critical effect on the learning dynamics. We predict that the delayed learning effect is reduced when the reward varies gradually with the error. We also make predictions regarding the way the reward can be shaped in experiments to accelerate the learning and improve the final performance.

Work performed in the framework of the France-Israel Laboratory of Neuroscience (FILNe).

Advisors: Prof. David Hansel

Work in collaboration with Dr. Arthur Leblois
Effects of sensory modality on 3-D spatial codes in bat hippocampus

Maya Geva-Sagiv

Hippocampal neural recordings are an important model system for understanding spatial cognition: The ensemble activity of hippocampal ‘place cells’ encodes the location of an animal within its environment. However, little is known on how inputs from different sensory systems affect hippocampal spatial representation.

The current project aims to dissociate the use of two long-range sensory systems – vision and echolocation – in a unique animal model, the Egyptian fruit bat. We intend to have the bats orient using vision without sonar – in a lit environment, and by sonar without vision – in the dark. Through simultaneous recordings of multiple cells in the hippocampal CA1 region of flying bats, we plan to characterize the differences in the neural codes for space of individual cells, and in the ensemble activity, based on the two sensory systems.

Preliminary results from hippocampal recordings in flying bats showed clear three-dimensional (3-D) place fields in the light, and in the dark. Some cells showed clearly reproducible 3-D place fields between two consecutive flight sessions in light conditions, suggesting that the 3-D tuning is stable – which now enables examining possible ‘remapping’ between light versus dark conditions. Some examples of recorded cells suggest that, indeed, there may be consistent remapping when switching from light to dark conditions, that reverts when switching back to the light condition. In addition to remapping of 3-D place fields, we also examined the directionality of place-cell firing, and found that some cells show clear preferences for left-right flights or for right-left flights – similar to previous reports in rats.

In subsequent experiments, we plan to examine in detail the population dynamics of the cognitive-map buildup, when switching between sensory modalities, as well as long-term changes across days and weeks.

Advisor: Dr. Nachum Ulanovsky
Since the early 2000s, Multi-Voxel Pattern Analysis (MVPA) has gained momentum as a powerful alternative to Region of Interest (ROI) activation analysis of fMRI. Kriegeskorte, Goebel and Bandettini (2006) suggested applying MVPA to ROIs sampled systematically by a searchlight procedure. This method enables exploratory localization of multivariate information, unconstrained by predefined ROIs. We hold that while being an attractive alternative to the prevalent mass-univariate approach to brain mapping, its adaptation by the neuroscientific community raises issues of statistical inference. Usually, the high computational cost of non-parametric testing is avoided by relying on inter-subject voxel-by-voxel agreement. We argue that this solution poses unnecessary limitations: Its power is compromised by inter-subject anatomical and functional variability, its validity is dependent on the fulfillment of random field theory assumptions and obviously it disallows any single-subject inference. We demonstrate that regularized least-squares classification (Rifkin, Yeo & Poggio, 2003) enables producing both true accuracy maps and label permuted null accuracy maps at a low computational cost. These null accuracy maps can be used to produce voxel-wise or cluster-wise statistical thresholds, which are powerful and essentially distribution free.

Advisor: Dr. Amir Amedi

Work in collaboration with Uri Hertz and Noa Zeharia
Intracellular correlates of stimulus-specific adaptation

Itai Hershenhoren

Stimulus-specific adaptation (SSA) is the reduction in response to a common stimulus which does not, or only partially, generalizes to other, even rather similar, stimuli. SSA has been studied mostly in the auditory system. It is strong and widespread in primary auditory cortex (A1) of rats, but is rather weak or absent in the main input station to A1, the ventral division of the medial geniculate body. In order to study the transformation of SSA from the input to a neuron to its output, we recorded intracellularly in A1 neurons. Recordings have been performed using sharp electrodes, and lasted for up to 780 minutes. The responses to rare sounds were recorded in a number of different contexts, including oddball sequences, Deviant-alone sequences in which most sound presentations were replaced by silence, and sequences composed of many different sounds each of which was rare. SSA was found both in subthreshold membrane potential fluctuations and in the spiking responses of A1 neurons. By comparing the responses to the same rare sounds in multiple contexts, we can show that cortical SSA cannot be fully explained by adaptation in narrow frequency channels. SSA for changes in frequency was large at frequency differences of 44%, and clearly present with tones as close to each other as 4%, near the perceptual difference limen for frequency in rats. The amount of SSA was, however, only partially correlated between the membrane potential and the spiking output. In particular, some neurons had rather weak SSA at the level of their membrane potentials, but much stronger SSA when measuring their spiking output. Such differences may indicate the presence of processing mechanisms that amplify or create SSA de novo in primary auditory cortex.

Advisor: Prof. Israel Nelken
We measured the impact of task structure, repeated presentations and training on the magnitude of 2 basic ERP components – N1 and P2. These are the 2 salient components induced when participants are passively exposed to a series of trials, each composed of 2 tones, with 1.4 s inter-trial intervals. We found that the magnitude of P2 is larger when a repeated reference tone is presented in a fixed position, indicating fine tuning of automatic detection mechanism, which detect this repetition, even though target differs by only 4-5% from the reference. This specific memory trace is found in addition to a broader adaptation process which decreases the magnitude of both P2 and N1 to a similar extent for reference and non reference tones (deviating by ~5%). Multi-day training increases the magnitude of P2, though the magnitude of N1 remains stable. Taken together, these findings suggest regularities embedded in series of stimuli are automatically detected by both fast and slow processes, which operate in parallel to general adaptation mechanisms. The efficiency of these mechanisms may have broad effects on cognitive skills.
Signal-dependent hydrolysis of phosphatidylinositol 4,5-bisphosphate without activation of phospholipase C: IMPLICATIONS ON GATING OF DROSOPHILA TRPL (TRANSIENT RECEPTOR POTENTIAL-LIKE) CHANNEL

Lev Shaya

In Drosophila, a phospholipase C (PLC)-mediated signaling cascade, couples photo-excitation of rhodopsin to the opening of the transient receptor potential (TRP) and TRP-like (TRPL) channels. A lipid product of PLC, diacylglycerol (DAG), and its metabolites, polyunsaturated fatty acids (PUFAs) may function as second messengers of channel activation. However, how can one separate between the increase in putative second messengers, change in pH, and phosphatidylinositol 4,5-bisphosphate (PI(4,5)P(2)) depletion when exploring the TRPL gating mechanism? To answer this question we co-expressed the TRPL channels together with the muscarinic (M1) receptor, enabling the openings of TRPL channels via G-protein activation of PLC. To dissect PLC activation of TRPL into its molecular components, we used a powerful method that reduced plasma membrane-associated PI(4,5)P(2) in HEK cells within seconds without activating PLC. Upon the addition of a dimerizing drug, PI(4,5)P(2) was selectively hydrolyzed in the cell membrane without producing DAG, inositol trisphosphate, or calcium signals. We show that PI(4,5)P(2) is not an inhibitor of TRPL channel activation. PI(4,5)P(2) hydrolysis combined with either acidification or application of DAG analogs failed to activate the channels, whereas PUFA did activate the channels. Moreover, a reduction in PI(4,5)P(2) levels or inhibition of DAG lipase during PLC activity suppressed the PLC-activated TRPL current. This suggests that PI(4,5)P(2) is a crucial substrate for PLC-mediated activation of the channels, whereas PUFA may function as the channel activator. Together, this study defines a narrow range of possible mechanisms for TRPL gating.

Advisor: Prof. Baruch Minke
Dynamics of Gap Junctions Inspired Networks

Merav Stern

We are interested in whether gap junction connected networks can support complex dynamics. To this end, we consider a network of neurons with gap junction connections, enhanced by additional intrinsic excitatory and global inhibitory currents. This system turns out to be equivalent to a nonlinear network with a synaptic weight matrix that has random off-diagonal elements with variance of order 1/N, and diagonal elements with variance of order 1. Such large diagonal terms make the network behave differently from the more commonly studied case where the diagonal terms make a negligible contribution.

These networks have a trivial fixed point, which does not support interesting dynamics, so we began by examining its stability. We examine the eigenvalues of the stability matrix for this trivial fixed point, which are the same as the eigenvalues of the weight matrix. These do not fall into the typical circular region of the eigenvalues of random matrices, and we discuss methods for determining the shape of this region. For appropriate coupling strength, the trivial fixed point becomes unstable. When this happens, the network exhibits long-lasting chaotic "exploratory" activity that eventually leads to a stable, nontrivial fixed point. At the fixed point, the activity or voltage value of the neurons are predominantly determined by the diagonal elements of the connectivity matrix, with the off-diagonal elements serving as a source of noise.

Simulations show that the lifetime of the transient chaotic stage grows exponentially with network size. Thus, a reasonably sized network can sustain complex activity and signal generation over large time intervals. This in turn suggests that these networks can serve as a source of internal activity for motor, learning and memory process.

Advisors: Prof. Yosef Yarom & Prof. Larry Abbott
Emotional content is a major component in music. It has long been a research topic of interest to discover the acoustic patterns in the music that carry that emotional information, and enable performers to communicate emotional messages to listeners. Previous works looked in the audio signal for local cues, most of which assume monophonic music, and their statistics over time. Here, we used generic audio features, which can be calculated for any audio signal, and focused on the progression of these features through time, investigating how informative the dynamics of the audio is for emotional content. Our data is comprised of piano and vocal improvisations of musically trained performers, instructed to convey 4 categorical emotions. We applied Dynamic Texture Mixture (DTM), which models both the instantaneous sound qualities and their dynamics, and demonstrated the strength of the model. We further showed that once taking the dynamics into account even highly reduced versions of the generic audio features carry a substantial amount of information about the emotional content. Finally, we demonstrate how interpreting the parameters of the trained models can yield interesting cognitive suggestions.

**Advisor: Prof. Gert Lanckriet**
Stimulus-Specific Adaptation in a Model of Primary Auditory Cortex

Tohar S. Yarden

In the primary auditory cortex (A1) of cats and rats, neurons decrease their responses to frequently-presented stimuli but not to rare stimuli. This phenomenon, called stimulus-specific adaptation (SSA), originates in the cortex and may underlie short-term sensory memory and deviance detection. To investigate possible mechanisms of SSA, we employed a neural network previously used to reproduce several other A1 response properties, including frequency tuning, forward masking, lateral inhibition, and hyper-sensitive locking suppression (Loebel et al. 2007). This network has synaptic depression, which gives rise to population spikes (PSs).

Our model exhibits SSA: rare stimuli elicit a PS but frequent stimuli do not. SSA strongly depends on stimulus and network parameters (input amplitude, inter-stimulus interval, time-constants of synapse recovery etc.) through their control of PS responses. We identified several regimes of PS generation and demarcated the regions in parameter space that allow SSA. Our results compare with experimental data and provide predictions that will be tested by electrophysiological recordings in rats.

Advisor: Prof. Israel Nelken
Sensitivity to complex statistical regularities in rat auditory cortex

Amit Yaron

Neurons in auditory cortex are sensitive to the probability of stimuli, responses to rare stimuli tending to be stronger than responses to common ones. However, whether neurons are sensitive to more complex statistical regularities, such of those needed for complex tasks like understanding language, remains to be discovered. In this study, intra- and extra-cellular recordings from the auditory cortex of halothane-anesthetized rats revealed the existence of a fine-grained analysis of the statistics of the sound sequence. Using a variation of the oddball paradigm in which the order of stimulus presentation is fixed, we found that responses were smaller than the responses to the same tones in random sequences.

The size of the effect depended on the probabilities of the tones, with reduction in the responses to the common tones in fixed sequences even when the odds ratio was 1:19. We conclude that neurons in auditory cortex are sensitive to the structure of sound sequences of length 20 or more, spanning at least 6 seconds.

Advisor: Prof. Israel Nelken
Data by Itai Hershenhoren
Theory of Own and Other Mind
To which extent does the capacity to understand oneself depend on the capacity to understand the other?

Alexandra Zinck

Self-consciousness is the special capacity of being conscious of oneself as oneself with certain mental and physical states and properties. It is essentially characterized by subjective self-referential experience. I investigate to what extent a subject’s capacity to develop self-consciousness depends on the capacity to understand the mental states, especially the emotions, of others. This capacity to understand and attribute mental states (mentalizing or theory of mind (ToM)) is generally assumed to contribute to the development of self-consciousness. Empirical research suggests that the capacity to understand one’s own and others’ mental states is closely interconnected (Leslie 1987, Gopnik & Meltzoff 1994, Happé 2003). However, little is known about qualitative differences in self-consciousness that are connected to theory of (own) mind (1PP) and social understanding in general. I will examine the following hypotheses by drawing from the data of developmental and autism research:

Within a developmental framework, both, a basic pre-conceptual and a conceptual level of self-consciousness depend on the capacity of understanding others’ mental states (where I will focus on the case of understanding others’ emotions). On the non-conceptual level, understanding that others direct emotions (or other mental states) towards oneself, contributes to an emotional self-reference that is immediate and phenomenally coded and enters the non-conceptual self-representation (Reddy 2003, Sartre 1943).

On the conceptual level, impairments in the capacity of understanding other minds are followed by difficulties in conscious processing of own emotions and in ascription of emotions to others (alexithymia) (Hill 2004, Berthoz 2004) and in the communication of emotions between individuals. Research to date shows that AS is connected with reduced reports about inner states (more concrete and visual language) (Hurlburt 1994, Frith and Happé 1999) and egocentrism (Frith & de Vignemont 2005). Understanding and communication of others’ 3PP emotional evaluative and theoretical states provides important input for the conceptual level of self-representation.

I would further like to tentatively introduce the thesis that it is a second-person-perspective (2PP) that is lacking in the interactions of individuals with AS with other people and that this entails deficits in both 1PP and 3PP.

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From learning models of natural image patches to whole image restoration

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Learning good image priors is of utmost importance for the study of vision, computer vision and image processing applications. Learning priors and optimizing over whole images can lead to tremendous computational challenges. In contrast, when we work with small image patches, it is possible to learn priors and perform patch restoration very efficiently. This raises three questions - do priors that give high likelihood to the data also lead to good performance in restoration? Can we use such patch based priors to restore a full image? Can we learn better patch priors? In this work we answer these questions. We compare the likelihood of several patch models and show that priors that give high likelihood to data perform better in patch restoration. Motivated by this result, we propose a generic framework which allows for whole image restoration using any patch based prior for which a MAP (or approximate MAP) estimate can be calculated. We show how to derive an appropriate cost function, how to optimize it and how to use it to restore whole images. Finally, we present a generic, surprisingly simple Gaussian Mixture prior, learned from a set of natural images. When used with the proposed framework, this Gaussian Mixture Model outperforms all other generic prior methods for image denoising, deblurring and inpainting.

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