Organizing Committee:

Livia de Hoz
Amir Globerson
Robert Guetig
Naftali Tishby
ACKNOWLEDGEMENTS

We are grateful to the Edmond J. Safra Philanthropic Foundation for its constant spiritual and financial support. The ICNC would not be where it is 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 fourth year. The ICNC is deeply indebted to Brain Circle members - it is their wholehearted support that allows us to carry out the mission of the 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 Gullin 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.

The 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, January 16

11:00  Bus leaving from Givat Ram Campus (main bus stop)

12:15-13:15  Arrival at Ein Gedi – room allocation

13:00-13:45  Lunch

Session 1 – Cognitive models
Chair-person: Merav Ahissar

14:00-14:40  Nori Jacoby
“Perception action model of sensory motor synchronization”
Advisor: Naftali Tishby & Merav Ahissar

14:40-15:20  Itamar Lerner
“Semantic priming in schizophrenia: an attractor network model with attractor instability”
Advisors: Shlomo Bentin & Oren Shriki

15:20-15:40  Coffee Break

Session 2 – Keynote talk
15:40-16:40  Jason Kerr (MPI for Biological Cybernetics, Tübingen)
“As nature intended: Imaging cortical neuronal populations in the freely moving animal”

16:40-17:00  Discussion
Moderator Israel Nelken

17:30-19:30  Poster session

19:30-21:00  Dinner

21:00  Ariel Rubinstein (Tel Aviv University and NYU)
“A personal journey in the wonderland of Neuro-Economics”

22:00  Wine, beer & cheese
Monday, January 17th
8:00-8:50 Breakfast

Session 3 – Sensorimotor functions
Chair-person: Yifat Prut

9:00-9:40 Hagai Lalazar
“Sensorimotor processing in the primary motor cortex during reaching movements: Searching for a new theory”
Advisor: Eilon Vaadia

9:40-10:20 Michal Eisenberg
“Visual and Motor Representations in the Primary Motor Cortex”
Advisor: Ehud Zohary

10:20-10:50 Coffee Break

Session 4 – Keynote talk
10:50-11:50 Carl Petersen (EPFL, Lausanne)
“Synaptic mechanisms of sensory perception”

11:50-12:10 Discussion
Moderator Eli Nelken

12:10-16:30 Light lunch & hike

Session 5 – Information flow in neural networks
Chair-person: Robert Guetig

17:30-18:10 Tim Vogels (EPFL, Lausanne)
“Controlling information flow in neuronal networks by means of detailed balance”

18:30-20:30 Dinner

20:30 David Grossman, discussion with Udi Zohary

22:00 DJ & drinks
Tuesday, January 18th

8:00-9:00  Breakfast & checking out

Session 6 – Cortical source localization
Chair-person: Leo Joskowicz

9:00-9:40  Alon Keren
“EEG and MEG source localization by incorporating temporal constraints”
Advisor: Leon Deouell

9:40-10:20  Ruby Shamir
“Trajectory planning method for reduced patient risk in image-guided neurosurgery” *(Eric Roland Lecture)*
ELSC Post-doc – lab of Hagai Bergman

10:20-10:40  Coffee Break

Session 7 – Molecular Biology & Electrophysiology
Chair-person: Yonatan Loewenstein

10:40-11:20  Amit Berson
“Alzheimer’s disease-associated hnRNP A/B loss promotes neurodegeneration” *(Eric Roland Lecture)*
Advisor: Hermona Soreq

11:20-12:00  Asaf Gal
“Dynamics of single neuron excitability over extended timescale”
Advisors: Shimon Marom & Naftali Tishbyy

12:00-12:15  Coffee Break

Session 8 – Statistical models of natural images
Chair-person: Amir Globerson

12:15-12:55  Daniel Zoran
“The "tree-dependent components" of natural scenes are edge filters”
Advisor: Yair Weiss

12:55-13:00  Farewell words

13:10-14:00  Lunch

14:15  Return to Jerusalem
LECTURES
Sensory motor synchronization (SMS) experiments in the form of tapping along with a metronome are an important case study of the interaction between action and perception. The challenge of modeling SMS is to accurately predict the action (the next tap) from the perceptual information (recent stimuli and responses) available to the brain.

The Perception Action Loop framework (PAL) developed by Tishby and others (Tishby & Polani 2011) is a framework that enables mathematical modeling of the entire action perception model. This framework describes the "action" taken by the subject as a solution to an information theory problem in which the subject is trying to optimize a goal function ("reward") based on predictions of the stimuli. The formalism highlights information and prediction as key-elements in understanding the Perception Action cycle.

We administered a simple tapping paradigm - each block of the experiment included a single type of perturbation: either using the typical step change, where the tempo of stimuli alternates between two fixed values (2-tempo conditions), or using random step changes (roving condition), where the tempo changes to a new fixed value every random number of beats.

The main experimental findings are that, the asynchrony one beat after the perturbation is non-linearly dependent on the perturbation size and is similar in the 2 tempi and the roving conditions. This is surprising because it means that the fact that the next tempo was less predicted on the random condition did not significantly affect the performance implying that information about potential step changes is not utilized.

We will show preliminary results, based on a simplified version of the PAL framework that predicts the main experimental findings better than four other linear models from the literature (Michon 1967; Hary & Moore, 1985; Mates 1994; Schulze et. al. 2005). The ability to explain novel conditions without introducing novel parameters suggests that the PAL model is a promising framework for understanding sensory-motor loops.

Advisor: Naftali Tishby & Merav Ahissar
Schizophrenia, one of the most debilitating mental illnesses, is frequently accompanied by thought disorders. One of the most common thought disorders is loosening of associations: The inability of patients to maintain the relevant topic of conversation and their tendency to repeatedly switch topics, one after the other, sometimes based on a sporadic word from the previous sentence. Abnormal associativity has often been studied in schizophrenics using the semantic priming paradigm. This paradigm allows measuring how the processing of one written word (called the 'target') is influenced by a previous exposure to a semantically related word (the 'prime'). Schizophrenics, compared to control participants, exhibit an augmented priming effect when the Stimulus Onset Asynchrony (SOA) between prime and target is short, and a reduced priming effect when the SOA is long. In addition, schizophrenics show a significant priming effect for pairs related through a mediating association (such as 'wedding'-‘finger’, mediated by ‘ring’) while control subjects often do not exhibit such priming. I present an attractor neural network model with synaptic adaptation mechanisms that account for these results. Based on a previous hypothesis (Rolls et al., 2008), I suggest that attractor instability (possibly stemming from NMDA deficiencies, known to occur in schizophrenia) can lead to the full spectrum of priming effects in schizophrenics and can also be linked to other symptoms of the disease such as patients' difficulty in using context. Finally, I show how the model can be linked to a previous model of semantic priming in schizophrenics and controls which was not based on attractor networks.

Advisors: Shlomo Bentin & Oren Shriki
As nature intended: Imaging cortical neuronal populations in the freely moving animal

Jason Kerr

MPI for Biological Cybernetics, Tübingen

While the neuronal basis of certain behaviors and sensory modalities can be studied under anesthesia or head-fixation, the full gamut of neural activity and its functions is accessible only in awake unrestrained animal. In addition, as neurons do not work in isolation, but are embedded in highly interconnected neuronal networks that are thought to encode sensory input, it is also advantageous to record simultaneously from as many neurons as possible. Multiphoton imaging allows unambiguous access to cortical populations located well below the cortical surface with single cell accuracy and can be used to record neuronal spiking activity. Here I will present work from our lab based around our development of a miniaturized 2-photon microscope or ‘fiberscope’ that resolves functional action-potential derived fluorescent signals from neuronal populations in the visual cortex of freely moving animals. In addition I will present data from recent experiments where we simultaneously tracked the precise head and eye position in trained and freely behaving animals. Lastly, I will also outline efforts in our lab to record functional signals from neuronal populations in the entire cortical column, from L1 to L5b.
Sensorimotor processing in the primary motor cortex during reaching movements: Searching for a new theory

Hagai Lalazar

The primary motor cortex (M1) is a central network in the processing that generates voluntary arm movements. Yet both theory and neural implementation remain open questions. Theories of M1 function can be placed on a spectrum with regard to the complexity they predict in the properties of the neuronal responses. On one extreme, neurons have simple computational roles. They were reported to have stereotypical PSTH's—increasing their activity around movement initiation—and tuned continuously to a single movement parameter—e.g. movement direction. On the other end lie theories that predict that neurons should exhibit large heterogeneity of temporal responses, thus appearing to be tuned to a combination of sensory-motor parameters and that such tunings are not fixed but change along the trial.

To revisit this question, we trained monkeys to perform an arm-reaching task that broadly spans the space of movement parameters, as well as, dissociates the main parameters that are naturally correlated. We then recorded single and multi-unit activity from neurons in the arm area of primary motor cortex using chronically implanted 96 microelectrode arrays. We found that if we considered all well-isolated neurons without any selection bias, the classic M1 neurons are only a small fraction of the population. The neurons exhibit a rich set of temporal responses, including both increases and suppression of firing rates and, for some neurons, instructed-delay responses as strong as during movement. Moreover, most neurons were tuned to more than one sensory-motor parameter, and their tuning was dynamic throughout the trial. On the other hand, these rich dynamics are not random but show temporal structure that is aligned to the events of the task. Thus M1 neuronal responses lie somewhere in the middle of the spectrum. These results can be used to test and compare the predictions of new theories.

Advisor: Eilon Vaadia
Visually guided limb movements evoke multi-voxel patterns of fMRI activation in primary motor cortex (M1). These patterns are more correlated during similar movements than dissimilar ones, and therefore potentially contain information about the direction of movement. It is unclear, however, if direction specificity is due to the movement per-se or to the visual aspects of the task. To disambiguate the visual and motor components, participants used a joystick to move a cursor from the center to equidistant targets in the periphery. Different motor-to visual mapping rules were applied during the fMRI scan. The first run was standard, while in the second run, the cursor movement was rotated by 45 degrees with respect to the joystick movement. We find that M1 is sensitive to both the direction of hand movement and the visual aspects of the task. Importantly, mere observation of the cursor movement, without concurrent joystick control does not elicit significant activation in M1. M1 sensitivity to the visual aspects of movement is therefore determined by the visuomotor task at hand.

Advisor: Ehud Zohary
Synaptic mechanisms of sensory perception

Carl Petersen
(EPFL)

A key goal of modern neuroscience is to understand the neural circuits and the synaptic mechanisms underlying simple forms of sensory perception and associative learning. Here, I will discuss our efforts to characterize sensory processing in the mouse barrel cortex, a brain region known to process tactile information relating to the whiskers on the snout. Each whisker is individually represented in the primary somatosensory neocortex by an anatomical unit termed a ‘barrel’. The barrels are arranged in a stereotypical map, which allows recordings and manipulations to be targeted with remarkable precision. In this cortical region it may therefore be feasible to gain a quantitative understanding of neocortical function.

As a mouse explores its environment, the whiskers are actively moved backwards and forwards as if searching the space for tactile input. Indeed sensory information in this pathway is usually actively acquired. It is therefore crucial to measure and manipulate cortical function in awake behaving mice. We have begun this process using whole-cell recordings, voltage-sensitive dye imaging, viral manipulations and two-photon microscopy. Through combining these techniques with behavioral training, our experiments provide new insight into sensory perception at the level of individual neurons and their synaptic connections. The main focus of this talk will be upon the synaptic mechanisms driving sparse coding in excitatory layer 2/3 barrel cortex neurons.
Controlling information flow in neuronal networks by means of detailed balance

Tim Vogels
(EPFL)

In recent theoretical work we have extended the study of signal transmission in neuronal networks by a mechanism called detailed balance. This mechanism, in which incoming excitatory signals are normally cancelled by locally evoked inhibition, leaves the targeted cell population unresponsive unless transmission is gated ‘on’ by modulating neuronal gains to upset the balance of excitatory and inhibitory membrane currents each cell receives. Detailed balance provides effective means to control, filter, and navigate broad-band signal streams in large neuronal networks, but its applicability to more than two signal streams has never been shown.

Here, we discuss basic wiring requirements to effectuate the stable function of multiple parallel gating modules. We study how the statistics of the input signal affect these conditions and show the consequences of different input-output maps on the controllability of separate signal streams. Specifically, we compare tonotopically and randomly organized connectivity schemes and investigate their processing behavior for realistic input stimuli in a large neuronal networks. To demonstrate the power of the mechanism, we filter a single multi-facetted signal from a rich and noisy background of input signals. Finally, we discuss mechanisms by which detailed balance could be autonomously established and controlled in biologically plausible scenarios.
EEG and MEG source localization by incorporation temporal constraints

Alon Keren

The inverse problem of EEG and MEG, namely, the reconstruction of complex electrical brain activity patterns from the low-resolution snapshots of electric potentials or magnetic fields outside the head, is underdetermined and cannot be solved unambiguously. However, with a reasonable model of the gross cerebral network dynamics, multiple time samples can be accumulated to uniquely constrain the solution. I will start by laying out a method for obtaining unique solutions by imposing lagged correlations between connected brain regions, and demonstrate its performance and limitations.

When such a gross model is insufficient to capture the fine details affecting the task specific responses, and/or when a detailed model is unavailable, the temporal statistics at the sensor level can be used. Previous studies have shown that some linear methods obtain unbiased localization of a single source, with improved resolution and noise immunity for adaptive methods which take advantage of the data temporal statistics. Here I will present a generalized framework for mathematical analysis and comparison of the localization bias of any of the linear methods, including the minimum norm, sLORETA and minimum variance beamforming, in cases of either a single or multiple sources. I will describe conditions under which the peaks of the imperfectly reconstructed activity are perfectly localized at the true activity sources. These theoretical findings will be demonstrated with a simulation based on real data of visual evoked potentials.

We conclude that while models of cerebral dynamics can theoretically allow perfect reconstruction of EEG and MEG sources, in practice such models may be unavailable, and methods relying on the data temporal statistics may well localize the sources under certain (but not all) conditions.

Advisors: Leon Y. Deouell & Amir B. Geva
We present a new preoperative planning method to quantify and help reduce the risk associated with needle and tool insertion trajectories in image-guided keyhole neurosurgery. The goal is to quantify the risk of a proposed straight trajectory, and/or to find the trajectory with the lowest risk to nearby brain structures based on pre-operative CT/MRI images. The method automatically computes the risk associated with a given trajectory, or finds the trajectory with the lowest risk to nearby brain structures based on preoperative image segmentation and on a risk volume map. The surgeon can revise the suggested trajectory, add a new one using interactive 3D visualization, and obtain a quantitative risk measure. The trajectory risk is evaluated based on the tool placement uncertainty, on the proximity of critical brain structures, and on a predefined table of quantitative geometric risk measures. Our preliminary results on a clinical dataset with eight targets show a significant reduction in trajectory risk and a shortening of the preoperative planning time as compared to the conventional method.

* Joint work with Leo Joskowicz and Yigal Shoshan.
Converging lines of evidence link RNA metabolism impairments to neurodegeneration, but the underlying mechanisms remain unclear. Using a transcriptome-wide approach, we found robust increase in exon inclusions in the entorhinal cortex of Alzheimer's disease patients (AD). Selective, protein-level loss of hnRNP A/B family of splicing repressors and increase of their targeting miRNA-211 accompanied these changes. Lentiviral shRNA-mediated loss of hnRNP A/B resulted in splicing impairments and drastic dendritic and synaptic loss in cortical neurons in-vitro, and caused severe memory impairments in-vivo. Aging, beta-amyloid or Tau pathology did not affect hnRNP A/B expression while destruction of cholinergic neurons in-vivo decreased brain hnRNP A/B levels and recapitulated several alternative splicing events observed in the AD cortex. Our findings thus present cholinergic-regulated hnRNP A/B proteins as key players in neurodegeneration.

Advisor: Hermona Soreq
Dynamics of single neuron excitability over extended timescales

Asaf Gal

While neuronal excitability is well understood and accurately modeled over timescales of up to hundreds of milliseconds, it is currently unclear whether extrapolating from this limited duration to longer behaviorally-relevant timescales is appropriate. Here we used an extracellular recording and stimulation paradigm that extends the duration of single neuron electrophysiological experiments, exposing the dynamics of excitability in individual cortical neurons over timescales hitherto inaccessible. We show that the long-term neuronal excitability dynamics is unstable and dominated by critical fluctuations, intermittency, scale-invariant rate statistics and long-memory. These intrinsic dynamics bound the firing rate over extended timescales, contrasting observed short-term neuronal response to stimulation onset. Furthermore, the activity of a neuron over extended time scales shows transitions between quasi-stable modes, each characterized by a typical response pattern. Like in the case of rate statistics, the short-term onset response pattern that often serves to functionally define a given neuron is not indicative of its long-term ongoing response. We also show that these fluctuations on multiple time scales are best entrained by input with similar statistical properties, which minimizes the unexplained variability in the activity. These observations question the validity of describing neuronal excitability based on temporally restricted electrophysiological data, calling for in-depth exploration of activity over wider, unbounded temporal scales.

Advisors: Shimon Marom & Naftali Tishby
The “tree-dependent components" of natural scenes are edge filters

Daniel Zoran

We propose a new model for natural image statistics. Instead of minimizing dependency between components of natural images, we maximize a simple form of dependency in the form of tree-dependencies.

By learning filters and tree structures which are best suited for natural images we observe that the resulting filters are edge filters, similar to the famous ICA on natural images results.

Calculating the likelihood of an image patch using our model requires estimating the squared output of pairs of filters connected in the tree. We observe that after learning, these pairs of filters are predominantly of similar orientations but different phases, so their joint energy resembles models of complex cells.

Advisor: Yair Weiss
POSTER SESSION
Differentiating alpha and mu suppression during observation of motor acts using PARAFAC and PCA methods

Moran Aharoni

EEG oscillations between 8-12 Hz are desynchronized and their amplitude reduced in humans while observing biological movement. This EEG modulation, which has been traditionally labeled mu-suppression, is recorded primarily over the sensory-motor cortex and reflects motor activity. The specific sensitivity to motor activity and a presumed source in the sensory-motor cortex distinguish the mu rhythms from the parieto-occipital alpha waves. Nevertheless, since both rhythms share the same frequency range and, at rest, this frequency dominates the EEG across most scalp sites, disentangling mu rhythms from alpha is not trivial. This endeavor is further complicated by the evident sensitivity of alpha to the level of visual attention allocated to processing. This factor might be easily confounded with the perceptual aspects of motor manipulation. Indeed, although mu suppression is expected primarily at fronto central sites, similar (and sometime even larger) EEG modulation can be recorded from traditional alpha-dominated locations at parieto-occipital sites. In the present study we applied two analytic algorithms, Parallel Analysis of Factors (PARAFAC) and Principal Component Analysis (PCA), aimed at separating mu from alpha EEG manifestations, and compared their outcome. These algorithms were applied to data recorded while 24 observers either grasp an object repeatedly or watch a video of a hand grasping the same objects. A video of a rolling ball was used as baseline. We will present the results of the two algorithms and discuss the implementation of these methods.

Advisor: Shlomo Bentin
Experience-dependent changes in stimulus specific adaptation in auditory cortex

Livia de Hoz

Stimulus specific adaptation (SSA) is the reduction in responses to a frequency stimulus which does not (or only partially) generalize to other stimuli. We study here whether SSA is affected by experience.

Mice were trained in a two-tone discrimination task using a paradigm that elicited different levels of latent inhibition. The training was performed in an Intellicage, a modified mouse cage where animals live while their behaviour is monitored automatically, by means of a reporter transponder inserted into each mouse. Water is available in a specialized corner upon nose-poke. All visits to the specialized corner were accompanied with the presentation of a train of tone pips (30 ms, every 333 ms). There were two key tone frequencies: the neutral 7 KHz (neutral visits), and the conditioned 13KHz (conditioned visits, 17% of visits). In conditioned visits, nose-pokes were followed by an air-puff and no water was available. Before conditioning begun, mice were presented in 17% of the visits to a pre-exposure frequency without any aversive outcome. Pre-exposure to frequencies between 9KHz and 14KHz, elicited latent inhibition of the subsequent conditioning to the 13KHz tone, but frequencies above and below this range did not.

We recorded from the auditory cortex of the anaesthetized mice before (baseline) or after conditioning. Two pure tones pips (30 ms) were presented to the mouse in an oddball sequence every 300ms. We found that responses in animals that showed latent inhibition were larger than responses in baseline animals to all frequencies tested, while in animals that showed no latent inhibition, only responses to the 13KHz tone were enhanced. Thus, subtle changes in behaviour can be correlated with large electrophysiological effects. SSA was increased in all conditioned animals with respect to baseline.
Statistical functional models
for single trials of LFP curves

Shdema Epstein

Local Field Potential (LFP) is the signal recorded from an extracellular electrode and then treated with a low-pass filter. LFP is assumed to represent the synchronized post-synaptic potentials induced by synaptic inputs for the neurons in the vicinity of the electrode. Similar to any neural response, LFP data can show a large variability in the trial-to-trial responses to the same stimulus. In order to extract information from the signal based on single trials, this variability needs to be modeled in a compact fashion.

For this purpose, we regard the LFP as functional data and adopt a simple semiparametric models of the form

\[ y_2(t) = f(t; a_i, b_i, c_i) = a_i f(b_i t + c_i) \]

where \( f \) is a constant ‘shape’ function for all trials and \( a_i, b_i \) and \( c_i \) are parameters representing correspondingly the scale, speed and shift parameters of each trial.

This model can also be extended to the more elaborate model:

\[ y_2(t) = g_2(t; a_i, b_i, c_i, \alpha_i, \beta_i, \gamma_i) = a_i f(b_i t + c_i) + \alpha_i g(b_i t + c_i) \]

where \( f \) and \( g \) are the constant shape functions for all trials, and \( a_i, b_i, c_i, \alpha_i, \beta_i, \gamma_i \) are the parameters of each trials.

I will present corresponding methods for estimation of the models’ parameters, which are both based on local linearization of the functions \( g_1 \) or \( g_2 \).

I will also present the results of fitting the model to real LFP data recorded in the context of an experimental setup designed to examine the Stimulus Specific Adaptation phenomena in the auditory cortex of a rat. I will demonstrate how the models provide strong tools for analysis and interpretation of the data.

Advisors: Ya’acov Ritov & Israel Nelken
Data by Nevo Taaseh
The physical mind:  
Convergence of bottom-up and top-down  
full body multisensory representations

Ran Geva

One of the characteristics of physical consciousness is awareness which enables us to perceive body and self, to project ourselves unto others, and to do simulations using for instance mental imagery of our own body. Different sensory systems permit body representations stemming from several sensory modalities: somatosensory body representations and visual body representations. Full body representation (FBR) must amalgamate congruent information from several different senses and from top down and bottom up influences in order to enable the experience of self. This central integration of both visual, tactile, bottom up with top down information is in the very basis of our ability to experience ourselves as an enduring entity that resides in the perceived human body. However very little is known about whole body integration across the senses and of bottom up vs. top down processes of the whole body.

This study focuses on the neural correlates of FBR using fMRI in humans. Specifically we focus on the integration of bottom-up and top-down somatosensory and visual information of the whole body. We used five different paradigms: tactile whole body perception, tactile whole body mental imagery, visual body perception and visual whole body imagery. To better compare our results to previous work related to the whole body multisensory perception we also used a mental projection of FBR.

Our results reveal a network of cortical areas activated throughout the different experimental conditions. This network seems to be involved in different aspects of FBR including the multi-sensory cross-modal representation of ourselves. Furthermore, there is the possibility that this network is used by us to project others upon ourselves to understand how they move and act physically, and possibly also mentally.

Advisor: Amir Amedi
Beyond the saccadic spike potential – scalp EEG manifestation of induced gamma band responses to visual stimuli

Eden Gerber

High frequency (gamma-band) neural activity has been studied extensively as a possible correlate of cognitive processes such as object feature binding. Recently we showed that the analysis of induced gamma-band responses in scalp EEG recordings is seriously confounded by a myogenic saccade-related spike potential (SP), which manifests as a transient broadband induced response overlapping the gamma frequency band (iGBRtb). We further suggested an SP-guided artifact correction procedure based on Independent Component Analysis (ICA) to remove this confounding signal from EEG data, in order to unveil any neural signal in the gamma band present in the EEG. Here, we applied this method to analyze scalp EEG recorded from 14 subjects presented with short-duration visual stimuli. We then compared the induced gamma band responses in the corrected data and the uncorrected data, which was treated only with traditional artifact rejection methods. The results show that our method is effective in suppressing the SP artifact, allowing the investigation of neurogenic gamma-band activity thus far obscured by the higher-power myogenic iGBRtb. The results further suggest the existence of such an induced gamma-band response in the EEG, with a duration corresponding to the duration of stimulus presentation. We compare the spectro-temporal pattern of these results to previously reported intracranial recordings.

Advisor: Leon Deouell
Neural correlates of anchoring deficit: Different patterns of correlation between auditory ERP and behavior among Dyslexics and controls

Sagi Jaffe

In discrimination tasks subjects' performance quickly improves when one of the stimuli repeats itself across trials. The implicit learning of the repeated reference leads to switching from explicit working memory mechanisms to implicit ones, underlying comparisons with internal references. We previously found that dyslexic individuals do not gain as much as controls from cross trial repetition, i.e. their anchoring abilities are impaired. The anchoring deficit hypothesis of dyslexia proposes that this is a core deficit underlying dyslexics' major difficulties. Anchoring is best exhibited in a two-tone frequency discrimination task with a reference tone (Ahissar et al, 2006). A previous ERP study with control participants (Cohen & Ahissar, ISFN, 2009) found that when participants passively listen to the protocol of 2-tone discrimination with a reference tone, the delay to their automatically produced P2 component (~200ms after tone onset) is correlated with their subsequently measured behavior. Poor performers had later P2 than good performers.

We now asked whether Dyslexic subjects exhibit the same pattern of correlation between performance and delay to P2. We administered the same protocol of cognitive tests and ERP sessions to dyslexic university students. As expected, their overall performance was poorer than controls', though it greatly varied across individuals. When passively listening to the same protocol, dyslexic participants did not show the same correlation as controls. The delays to P2 among poor performers were not larger than among good performers. On the other hand, poor dyslexic performers had lower N1-P2 peak-to-peak amplitudes compared with good performers.

This different pattern of correlations between performance and ERP measures suggests that dyslexics use a compensating mechanism to overcome their anchoring deficit. Rather than shortening tones' processing time by detecting their repetition, dyslexics enhance their responses to these tones.

Advisor: Merav Ahissar
Becoming a mother- the synaptic perspective

Hagit Kopel

One of the most dramatic examples of natural behavioral plasticity is motherhood- the time when naïve females become mothers and start caring for their neonates. The transition to motherhood in most species is accompanied by a rich repertoire of maternal behaviors including e.g. licking the pups, reorganizing the nest and retrieving lost pups back to the nest. While the behavioral description of maternal plasticity has been well described, the neuronal changes underlying this phenomenon are still not known. In rodents, the olfactory bulb (OB), which is the first station of olfactory processing, is a unique site for plasticity. Specifically, the adult OB continuously incorporates new neurons into its circuitry. Even under normal conditions these neurons are known to show high levels of structural plasticity as assessed by dendritic and spine dynamics. Since the OB is necessary for producing normal maternal behaviors, we hypothesized that neuronal plasticity in the OB may correlate with transition into motherhood. In this work, we explored structural plasticity in the main OB of lactating female mice by combining genetic manipulations and imaging. Specifically, using lentivirus mediated GFP and two photon imaging, we studied the synaptic morphology and the dynamics of adult-born and pre-existing granule cells (GCs) which are the majority of neurons in the OB. Using high resolution confocal analysis, we analyzed several properties of adult-born GC synapses. Our data show differential spine distributions of adult-born GCs in lactating mothers as compared to naïve females. In addition, we describe the dynamic nature of adult-born GC spines in lactating mothers vs. naïve females using time lapse in-vivo two-photon imaging. Finally, we present preliminary results of spine morphology and dynamics of the same pre-existing GCs before and after parturition. Our data thus describe how the synapses of unique subsets of neurons in the OB may sub-serve efficient detection of olfactory stimuli by mothers.

Advisor: Adi Mizrahi
In nature, octopuses can be found in shallow waters and outside of the water for a few moments searching for prey. In these conditions the octopus employs a crawling movement. In our research, we kinematically analyze this movement in two stages: Analysis of a single arm attending the move and analysis of the coordination between the attending arms.

This research poses a biological question, but it is also a part of an ongoing project of the UI intended for designing and building bio-inspired robots with embodied intelligence. Our project is aimed to assist in building an octopus robot, which will be able to crawl independently or with human control.

Adult animals are put in shallow water and video-recorded from underneath while crawling. The video-clip is then cut into single frames. Using a designated software we developed for this purpose, the location and state (attached to the surface or not) of the arm suckers that are attending the movement are marked on all frames. The data is then analyzed to reveal the kinematic properties of the arm and of the coordination between the arms during the crawling movement.

While crawling, the octopus uses only the arms opposite to the crawling direction for pushing its body. It does not utilize pulling or paddle-like pushing. One to four arms can attend the move simultaneously and the direction and speed of crawling is the combined vector of those arms. While crawling, the orientation of the octopus does not change. The single arm pushing is performed in five stages: (1) shortening the proximal part to some percent of its basic length, (2) attaching to the surface with some proximal suckers, (3) elongating its proximal part to be longer than its basic length, (4) releasing the attached suckers and (5) shortening again to its basic length.

As seen in other movements of the octopus, it greatly reduces the number of Degrees Of Freedom while crawling, which greatly reduces the complexity of the calculations needed to perform the move.

Advisor: Benny Hochner
Does face recognition depend on the viewing pattern?

Ayelet Mckyton

Although most studies assume that healthy humans are experts in face recognition, there is much diversity in this skill between different people. For example, when walking down the street some will recognize a former school buddy after decades of not seeing one another, while others will mistakenly ignore a current work colleague.

In this study we investigated whether different scanning patterns correspond to different face recognition scores, both within and between subjects.

To establish face recognition scores we used a short questionnaire and three face recognition experiments that were performed while the subjects’ eye position was monitored:

1. Old/New experiment, in which subjects were asked to study a few faces/objects/patterns and then were asked to recognize them among new images. The objects and the patterns served as controls.
2. A Celeb experiment, in which subjects observed pictures of celebrities and were asked to recognize them.
3. Att Old/New experiment, where subjects performed the Old/New face experiment once again while their attention was directed to the eyes or to the mouth and nose of the observed faces.

Not surprisingly, results indicate that in the first two experiments subjects fixated mostly on the eyes, nose and mouth of the observed face. The location of fixations did not correlate with subjects’ scores. However, directing attention to the nose and mouth resulted in reduced performance, while directing it to the eyes did not.

In the Old/New face experiment, higher number of fixations during the study phase led to greater success in the test phase. Specifically, if a subject made more saccades on a specific face presentation in the study phase, he was more likely to recognize this face during the recognition phase. This was not true for the control (object/pattern) stimuli.

To conclude, we found that when recognizing a face, attention to the eyes is essential, while attention to the nose and mouth is not. Furthermore, more saccades (during a fixed observation time) can lead to better face recognition.

Advisor: Ehud Zohary
Finding the canonical view from internet search engines

Elad Mezuman

Even though human object recognition is robust to viewpoint, a large body of research in human perception indicates that familiar objects have a special, or “canonical” view. One definition of this canonical view is that it is the “best” photograph taken with a camera. In this work we present a simple method to find automatically in an unsupervised manner the canonical view of an object category using Internet image search engines. Our method is based on finding a clique of similar images in the set of images retrieved by an image search engine when queried for a particular object. Specifically, we use the first eigenvector of the affinity matrix between the retrieved images. Our method often finds similar views to those demonstrated in psychological experiments and also allows us to define canonical views for new object categories.

Advisor: Yair Weiss
Advances towards patterned ultrasonic neuro-stimulation

Omer Naor

Ultrasound, a non-invasive and widely used diagnostic modality, has also been shown to stimulate neuronal activity. We present our early work towards generating acoustic stimulation patterns, as required for the formation of a meaningful precept.

We adapted optical computer generated holography (CGH) algorithms from the field of optical field sculpting to pattern the ultrasonic (US) fields and assessed their performance via simulations and MR-thermometry. The new CGH-inspired algorithm resulted in more efficient and uniform generation of sparse patterns when compared to a predominant algorithm in the field of ultrasonic hyperthermia. A second version of the same algorithm succeeded in overcoming the difficulties in generating contiguous patterns as well. The achievable resolution of multiple spot-patterns is very similar to that of a single focal spot, on the order of 0.5 mm.

These results also constitute a first step towards the design of ultrasonic neuro-prostheses.

Advisor: Shy Shoham
Online Learning in the Manifold of Low-rank Matrices

Uri Shalit

When learning models that are represented in matrix forms, enforcing a low-rank constraint can dramatically improve the memory and run time complexity, while providing a natural regularization of the model. However, naive approaches for minimizing functions over the set of low-rank matrices are either prohibitively time consuming (repeated singular value decomposition of the matrix) or numerically unstable (optimizing a factored representation of the low rank matrix).

We build on recent advances in optimization over manifolds, and describe an iterative online learning procedure, consisting of a gradient step, followed by a second-order retraction back to the manifold. While the ideal retraction is hard to compute, and so is the projection operator that approximates it, we describe another second-order retraction that can be computed efficiently, with run time and memory complexity of $O((n + m)k)$ for a rank-$k$ matrix of dimension $m \times n$, given rank-one gradients. We use this algorithm, LORETA, to learn a matrixform similarity measure over pairs of documents represented as high dimensional vectors. LORETA improves the mean average precision over a passive-aggressive approach in a factorized model, and also improves over a full model trained over pre-selected features using the same memory requirements. LORETA also showed consistent improvement over standard methods in a large (1600 classes) multi-label image classification task.

Advisors: Daphna Weinshall & Gal Chechik
The localization of auditory stimuli is based on an estimation of an objects position relative to head orientation, as well as information regarding the head's position and orientation in space. We can therefore distinguish between a basic egocentric (or head centered) coordinate system and a more complex allocentric system, which determines an objects position in space. While early auditory localization mechanisms utilize binaural information and form a head-centered representation, it is the body- or world-centered (allocentric) view that eventually guides our actions. However, little is known about the neural coding of these distinct representations. In an ERP experiment, we attempted to dissociate the two coordinate systems and reveal in which manner spatial representation is organized in the human auditory cortex. We used MMN (Mismatch Negativity), a well studied EEG effect evoked by acoustic changes from an established regularity. Subjects (N=11) were instructed to reorient their heads after hearing a series of repetitive auditory stimuli (“standards”). This was followed by a similar auditory stimulus (“deviant”) located in one of two distinct locations: either deviating from the standards in an egocentric manner (i.e located in a different position relative to head orientation); or in an allocentric manner (i.e located in a different absolute position). Our findings reveal that both egocentric and allocentric systems take part in early processing: we observed significant MMNs for both allocentric and egocentric deviant stimuli, with similar scalp distributions. These findings may imply that there are multiple representations of stimuli location in the auditory cortex. Whether they are served by different (yet proximate) populations of neurons, or by the same neurons, remains for future research.

Advisor: Leon Deouell
Do purkinje cells remember?

Merav Stern, Yarden Tohar, Segi Jaffe
Ido Maor & Avi Libster

It is now well established that Purkinje cells exhibit bi-stability of membrane potential and spike rates. Transitions between the membrane potential states can be triggered by an input. We investigate the responses of cells to current injections of both polarities, delivered at different times after a state transition. Essentially, we question whether Purkinje cells have memory of state duration. Activity of Purkinje cells was recorded in a whole-cell configuration, using cerebellar sagittal slices. State transitions were readily observed. Positive and negative current pulses were delivered at different times, and the transitions induced by these pulses were monitored. We define the memory trace parameter (MT) calculated as the difference between the probability of inducing a transition by injection of current and the probability of spontaneous transition, as a function of time spent in the present state. We found that MT changes as function of time. It seems that neither the polarity nor the intensity of the current affect the behavior of MT. We conclude that Purkinje cells do remember how long they spent in their present state. This supports the hypothesis idea that the Purkinje cell is a state reporter rather than an event detector.

Advisor: Yarom Yosef
Output spikes of the Inferior Olive (IO) are of great importance to cerebellar function because they directly trigger complex spikes in the Purkinje cells. There is ample evidence that the exact timing of IO output relates to underlying sub-threshold oscillations. Thus, the IO can be seen as an internal clock and "timing" can be related to the frequency and the exact phase of the sub-threshold oscillations. Since the IO network is dynamically divided into several functional units that act as clocks for different actions, there is some cross-talk between those groups. In this work we investigated how these units keep can keep track of time under the presence of perturbations or cross-talk from other units. We compare our theoretical and experimental findings and discuss the differences between both.

Advisor: Idan Segev
Considering the fact that the organization of the somatotopic information in humans in M1 should enable the encoding of a large repertoire of movements, which involves the synchronized activation of several different muscles, very often from distant parts of the body, but also the suppression of the movement of irrelevant muscles, the exact spread of information needs to be investigated. Using this periodic non-invasive fMRI design we revealed the most detailed Penfield's homunculus map found so far in humans. This was achieved by implementing for the first time phase-locking analysis in the motor system. This approach proved to be highly valuable in studying topographic maps in vision (retinotopic mapping) and in other domains (Engel et. al., 1994; Engel et. al., 1997; Hertz & Amedi, 2010). When characterizing the information in the different parts of M1, we found that not only activation is organized in a specific, somatotopic manner, but also deactivation, which creates a weaker and less organized, but still very clear and significant somatotopic organization, which is inverse to the pattern of activation in M1.

Advisors: Tamar Flash & Amir Amedi
Carbachol dependent persistent activity
in the rat somatosensory cortex

Sam Zibman

Cholinergic systems have been associated with a wide range of cognitive and behavioral activities. Cholinergic input mediates the brain's ability to select specific stimuli and preserve them for extended processing (Sarter and Bruno, 1997). Bistable neurons, which display a persistent state of firing along with a state of quiescence, are found throughout the cortex and are often dependent on cholinergic inputs (Schwindt, 1988; Fraser and MacVicar, 1996; Haj-Dahmane and Andrade, 1996, 1997, 1998; Klink and Alonso 1997). Using calcium imaging and whole cell recordings accompanied by pharmacological agents, we explored persistent activity in the rat somatosensory cortex. This activity is dependent on carbachol (CCh), an acetylcholine receptor agonist. Bath application of 20 μM CCh depolarizes pyramidal neurons by 7.72 ± 3.63 mV, increases the input resistance by 34.5 ± 26.1 MΩ, and in 60% of cells recorded (48/80), primes them for seconds long afterdepolarizing potentials that outlast stimulation with depolarizing current pulses. This activity is independent of the surrounding network as it can be induced even under complete blockade of synaptic activity. Furthermore, we characterize the stimulus-response relationship that leads to persistent activity. The persistent activity is likely induced with a stimulus that exceeds 5 action potentials at a frequency of 5 Hz. Calcium imaging shows that in the presence of CCh, there is an increased accumulation of spike induced calcium. While this increase is not sufficient to cause persistent activity, the use of BAPTA, removal of external calcium, and the addition of flufenamic acid, a specific blocker of I_{CAN} conductance, all prevent the appearance of persistent activity, thus showing calcium to be necessary. These results show somatosensory, layer V pyramidal neurons are capable of a transient, non-synaptic ‘memory’ of excitation, which may play a crucial role in the computational processing of the cortex.

Advisors: Haim Sompolinsky & Yosi Yarom
Semantic knowledge of word meaning was suggested to be represented in a category-specific manner. This hypothesis was supported by recent evidence of a somatotopic representation of action-related words in the motor and premotor cortex. Here, we report for the first time fMRI experiments aiming to explore the involvement of somatosensory and motor areas in passive perception of body parts names. Furthermore, we tested whether body parts names are represented semantically in the sensorimotor cortex. We show that in addition to auditory cortex activation, passive listening to the naming of body parts from a list elicited significant activations in the left ventral somatosensory and motor cortices. The evoked responses were restricted to the ventral areas in the sensory and motor homunculi. Regardless of the body part name that was heard the activations were specific to the lip and tongue representations in Penfield’s homunculi. The lack of somatotopic organization indicates that the sensorimotor cortex activation during perception of naming of body parts reflects a more general multisensory processing which is specific for speech articulators without semantic representation.

Advisor: Amir Amedi