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Abstract:	(see HBP Style Guide for tips on how to write an Abstract/Executive Summary)
Keywords:	EITN, Theory, workshops, postdocs

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1. Executive Summary

2. Introduction

2.1 The European Institute for Theoretical Neuroscience

From the DOW "The goal of WP4.5 was to establish a European Institute for Theoretical Neuroscience (EITN), in which theoreticians with different orientations and backgrounds can collaborate to develop new theories of brain function. One of the main objective of the EITN is to bring - through a visitor program and workshops – new theoreticians and new theoretical ideas to the HBP project. The EITN is planned to act as an incubator of ideas and new theories that will help the realization of the different objectives of the HBP. Four postdoctoral researchers will participate to the scientific animation of the institute. Each of these four postdocs will be co-supervised by one of the WP4.1 to 4.4 leaders, paid by their funding, and will be working primarily at the institute."

2.2 The Aim of this Document

This Deliverable describes the activities of the EITN between Month 18, and the end of the Ramp-Up Phase in Month 30.

3. EITN Activities

3.1 Work Conducted by the EITN's Resident Post-Docs

3.1.1 Introduction

Several resident postdocs have worked at the EITN. Initially, the 4 EITN postdocs present in the submitted proposal were removed at the negotiations because the EITN did not exist at the time, and the corresponding salaries were moved to the four WP leaders of SP4 (Destexhe, Gerstner, Deco, Maass). It was decided that these postdocs would be supervised by each WP leader, but would spend a significant fraction of time at the EITN. This appeared to be complicated because no travel and subsistence fee was available for them (as the EITN can only cover travel and subsistence fees for non-HBP members).

Nevertheless, some SP4 partners managed to allocate full-time post docs at the EITN (*see table below*) participating actively to the animation of the EITN.

Name	Institution	Date of start	End date
Mathieu Galtier	CNRS (Destexhe)	Dec 2013	Oct 2014
Bartosz Telenczuk	CNRS (Destexhe)	Oct 2014	March 2016
Gerald Hahn	UPF (Deco)	Aug 2014	Feb 2015

Ulisse Ferrari	UPMC (Marre)	April 2015	March 2016
Alberto Romagnoni	CNRS (Destexhe)	Jan 2016	March 2016

Partner EPFL (Gerstner) preferred to transfer the corresponding funds to the EITN to augment the available budget for inviting prestigious speakers at the workshops. Partner TUGRAZ (Maass) preferred not to participate to this postdoc stay, as it was too complicated to implement.

The work of the different postdocs is detailed in Deliverable D4.6.4, and is summarized as follows.

3.1.2 The post docs in detail

3.1.2.1 Mathieu Galtier (CNRS)

He worked on implementing different models of dendritic excitability, and in particular to study the integrative properties of cortical neurons under in-vivo-like conditions.

Another postdoc (Tomasz Gorski) has continued is work, and the models are now implementable in a form compatible with the new generation of neuromorphic hardware (SP9), where dendrites are now possible in the neuromorphic chips. This model is a candidate for testing the generation 2 hardware, and will be used in the neuromorphic platform. These models are detailed in the deliverable D 4.6.4 and a paper is now in preparation.

We are now continuing this work (in SGA1, Task 4.1.1) in attempting to identify different integration strategies during different brain states, such as wakefulness and the slow-wave activity during sleep.

It must be noted that Mathieu Galtier's work has been important in starting a collaboration with a PME start-up company ("RYTHM"), specialized in fabricating devices to interface the human EEG with appropriate stimulation. Together with RYTHM, we submitted and obtained a FLAG-ERA grant as partnering project of HBP, called SLOWDYN, and which consists in the study of slow-wave dynamics using models, animal experiments (mice) and human subjects, in parallel. The workshops at the EITN, and our brainstorm discussions, were essential in setting up this collaboration and we are happy that now this PME is associated with the HBP. Alain Destexhe is a member of SLOWDYN, and the EITN will host a postdoc from the project, as well as workshops to interface the project with the rest of HBP.

3.1.2.2 Bartosz Telenczuk (CNRS)

He worked on the design of models of two brain signals, the local field potential (LFP) and the extracellular spikes, both of which are routinely recorded using microelectrodes. His work has led to an in-depth characterization of the complex relationship between LFPs and spikes, and in particular to the respective contribution of excitatory and inhibitory cells. One of the outcomes of this work is to obtain a phenomenological model to generate LFPs from networks of spiking neurons (*see D464 section 2.2*). Such a model will be in principle applicable to networks of neurons developed in the Brain Simulation Platform (SP6).

A paper is now in preparation.

It must be noted that the workshops we have organized at the EITN, on the one hand on local field potentials and their biophysical origins, and on the other hand on python-based programming of networks and phenomenological models, have been very important to the rapid progress made in this project. Bartosz is considering applying to a permanent CNRS position (in Destexhe laboratory) to continue this type of research.

3.1.2.3 - Gerald Hahn (UPF)

He has worked under the co-direction of Gustavo Deco (UPF) and Alain Destexhe on the linking between structural and functional connectivity. Some of the data for this work were obtained from Stanislas Dehaene (SP3), and we are still today continuing this work, which we hope, will lead to a common SP3-SP4 publication. We have submitted a joint publication between UPF and CNRS about the modelling aspect of this work (the paper is under review).

The EITN was of course essential to this work. If we would not have had a place to host the postdoc for an extended period of time, this collaboration could not have taken place. Gerald Hahn is presently working in Deco's lab in Barcelona, and he is considering coming again for a few-month stay at the EITN.

3.1.2.4 Ulisse Ferrari (UPMC)

He was a full time at the EITN as a postdoc supervised by Olivier Marre (UPMC). The work of this postdoc is to design mathematical analysis techniques to characterize the ensemble spiking activity from the retina. Due to the fact that he was resident at the EITN, we developed a collaboration between CNRS and UPMC labs, about applying the same mathematical techniques to multi-electrode data and models. We are presently working on this collaboration. This collaboration has been possible because of the long-term stay of the postdocs at the EITN and day-to-day interactions between young researchers.

Here again, the EITN was essential to start such a collaboration, which emerged from the discussions between young researchers. We hope that more of such young researcher-driven projects will emerge in the future.

3.1.2.5 Alberto Romagnoni (CNRS)

He is supervised by Alain Destexhe (CNRS), and works on the application of recent results from our laboratory (unpublished) to design mean-field and population models. This type of model will be essential in our interaction with SP1 in the co-design project CDP1. SP1 (Pavone) will provide wide-field calcium imaging from the mouse, and we will need appropriate population models to analyse such data. In addition, such model could yield methods to extract excitatory and inhibitory population activities from voltage-sensitive dye (VSD) recordings. With such methods, we hope to attract to the HBP new partners specialized in VSD imaging, because this type of imaging is very precise and appropriate to constrain large-scale models.

This work will continue under task 4.1.3 in SGA1.

3.2 The EITN Visiting Scientists Programme

In the ramp-up phase, we had several visitors invited by the EITN

Name	Institution	Date of start	End date
Michael Berry	Princeton University, USA	26/05/2015	10/06/2015
Diego Contreras	University of Pennsylvania, USA	11/07/2015	17/07/2015
Serban Radu Ranta	Université de Lorraine, France	17/08/2015	21/08/2015
Yashar Ahmadian Tehrani	University of Oregon, USA	14/12/2015	08/01/2016

Fabio Vallone	CNR, Pisa Italy	04/03/2016	08/05/2016
Angelo Di Garbo	CNR, Pisa Italy	08/03/2016	11/03/2016
Marco Ferreira-Brigham	Brigham Associates BVBA, Belgium	06/03/2016	27/03/2016
Fabian Chersi	UCL (HBP SP3;SP4), UK	14/03/2016	25/03/2016
Sergiy Korogod	International Center for Molecular Physiology, National Academy of Sciences of Ukraine	11/03/2016	25/03/2016
Morgan Taylor	University of Pennsylvania, USA	14/03/2016	30/03/2016
Valentina Gliozzi	Universita di Torino, Italy	14/03/2016	31/03/2016

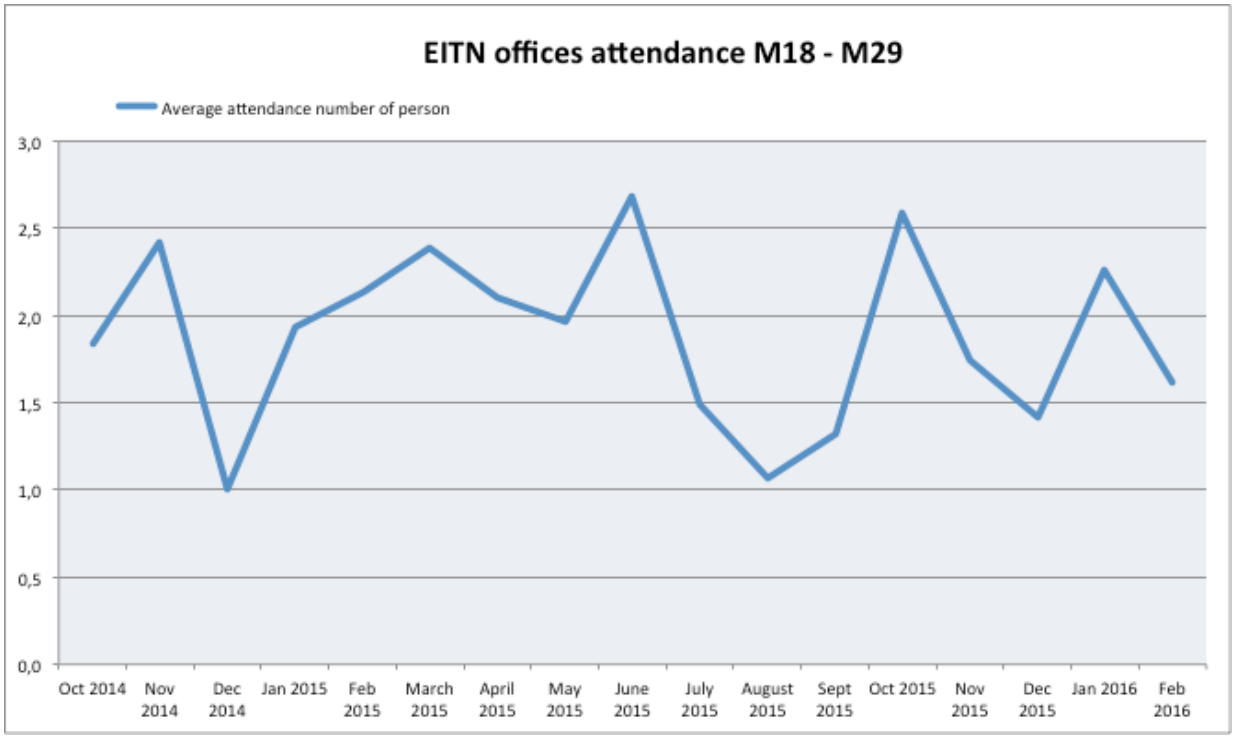
Several collaborations emerged from the hosting of these visitors.

Michael Berry is now collaborating with Olivier Marre and Ulisse Ferrari (SP4), and his stay at EITN was essential to draft this collaboration.

Diego Contreras is now collaborating with Alain Destexhe, and in this particular case, his stay at the EITN was very productive in reviving previous collaborations between the two labs. They have plans to submit together a joint application to the BRAIN initiative in the US, based on large-scale multi-electrode recordings and analysis. Diego Contreras would like to come again as a visitor, and he will be one of the invited speakers of the Vision Workshop planned in May 2016.

Marco Brigham is collaborating now with Alain Destexhe on modelling the noisy in vivo like conditions in neurons, and a paper is currently being written on this collaboration. His stay at the EITN was essential in this collaboration.

3.3 EITN attendance



The presence of post docs and long-term visitors was not reached as expected. The EITN only recent set up was one of the factors. To attract scientists for long stays they need to have either a flexible agenda or plan their stay a long time in advance. EC refused postdocs to be " homed " at the EITN and requested that they should be handled directly by SP4 partners' institution. Because the partners did not have the necessary travel budget to finance extended stays at EITN, this made it difficult to have resident post docs for the entire 24 months period. This is why we have reviewed the EITN way of working for the coming years and SGA and proposed a work plan (*WP4.6 in SGA1*) where although being co supervised by a SP4 partner and another HBP partner EITN post-docs should be assigned to the EITN from the start.

We hope that this will be made possible and everyone will be able to benefit from it.

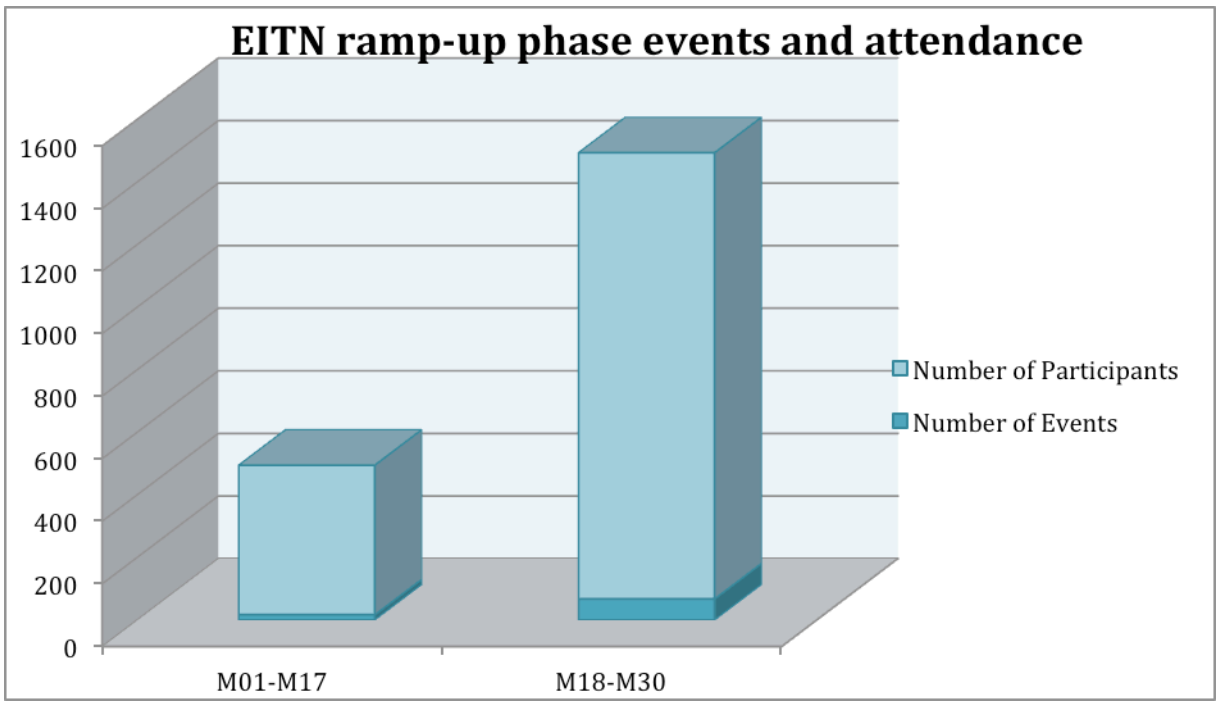
3.4 Workshops Organised by the EITN

During the ramp-up phase, EITN was opened earlier than expected, with more than 80 events held and a total of more than 1900 participants.

In the previous deliverable we were pleased to announce that the EITN started earlier than scheduled. In this deliverable we will see that events and participation has been increasing.

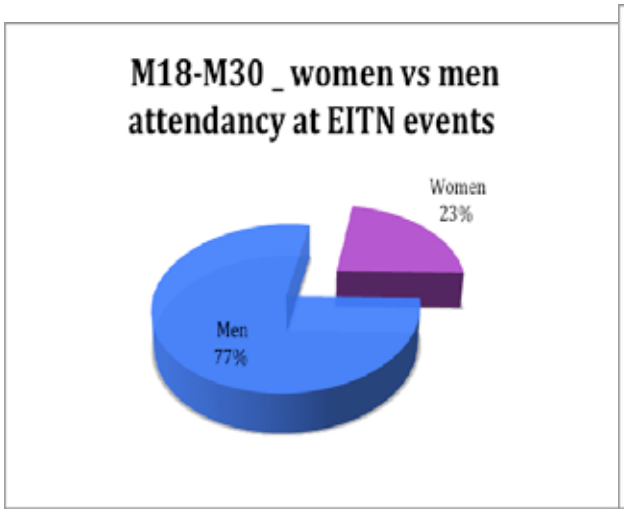
Events calendar can be found in the Annexe A.

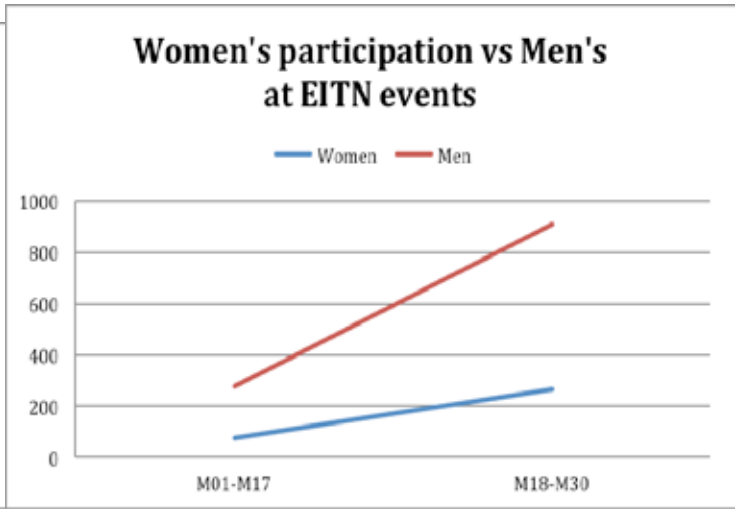
Events organized at the EITN can be of different format. We held small group discussions as well as big conference style event in the limit of the space we have.



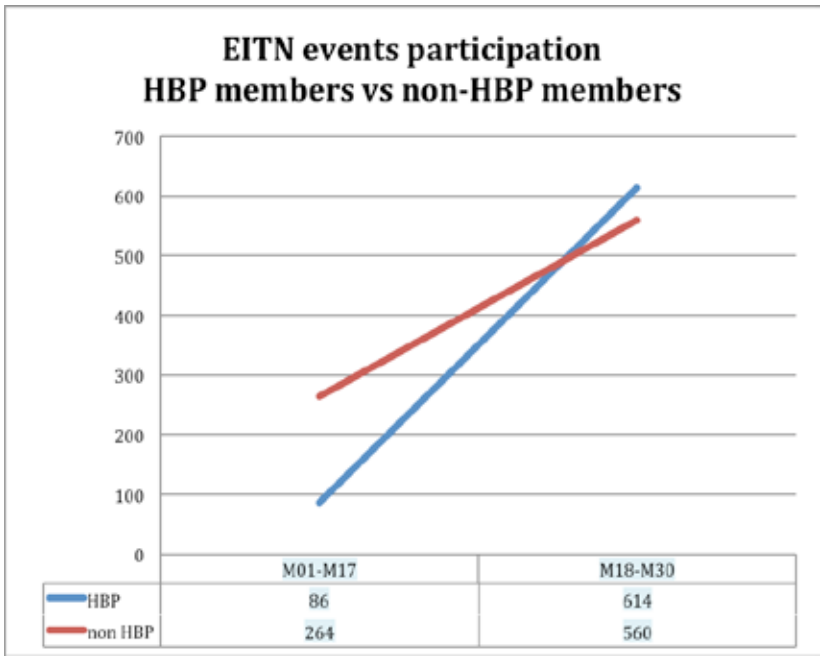
We have had several events that first planned as a one-time only have induced a serial, such as the “dendrites” workshop organized by Idan Segev (HUJI SP4) that already took place twice in the ramp-up phase, or the “Python” course held by our specialist Bartosz Telenzcuk (CNRS SP4) and that will take place in the following phase.

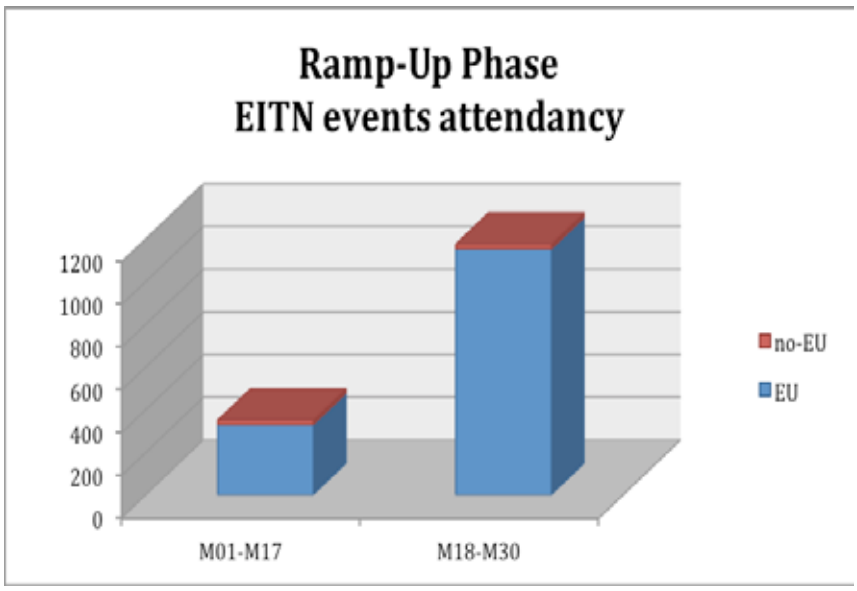
Despite our willing to see more invited women speaker we also have to take into account the fact that the neuroscience discipline and especially theory is currently more attractive to men though it is difficult to give formal numbers. One of our organizers, Marja-Lenna Linne (TUT SP4) had a great success with her workshop on neuro-glia and we hope to continue on valuing PI women.





We are able to analyse from our data that not only the number of participants has increased in that second period but that there has been a larger interest in our events from non HBP members while more HBP members have participated which means that one of our goals is being reached.





We can also see that participants mostly come from Europe, which is understandable baring our location and the short length of our events. We can foresee that more efforts have to be made if we want to reach the international community.

Examples of events outcomes can be found in Annexe B.

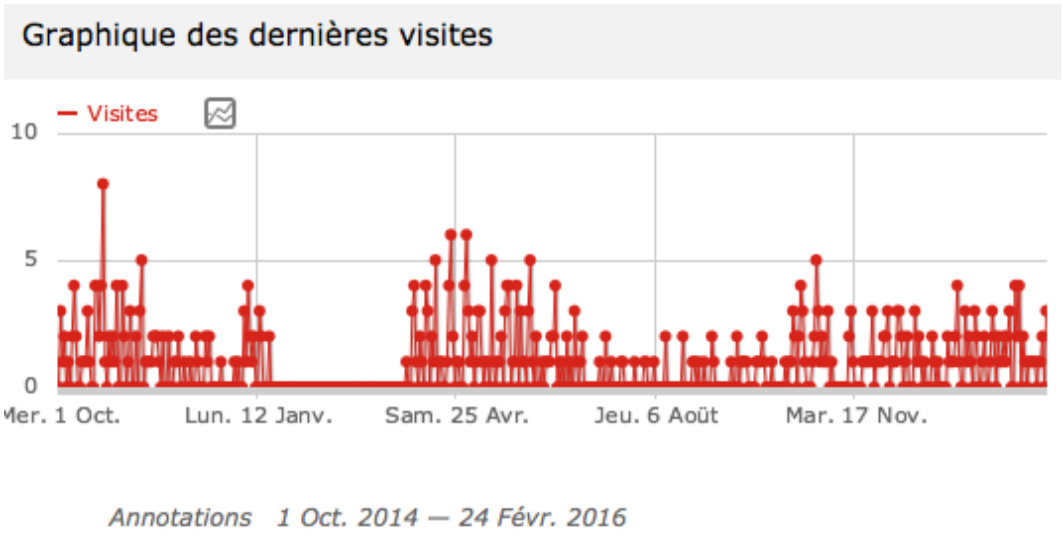
3.5 Dissemination of EITN activities

During this last period (M18-M30), we also have worked on dissemination. Time has not been on our side to allow us to fully reach our goals but actions have been identified and investigation to apply them has been started.

We have cancelled the Facebook page feeling it was not currently serving our purpose and have therefore been able to concentrate ourselves on the twitter account and the v2 of the website.

Followers and interest in tweets keep increasing though these numbers might seem small compared to other accounts. This could be explained by the fact that we do not have a full time social media manager. We do wish to be part of the social media sphere but are not acting as a marketing branch would. Our communication is being developed through several action plans and not only focusing on social medias.

The website has been visited at on an average of once a day since January 2015, and a lot from the USA and Canada. This might be a hint that international interest is there but a little bit more needs to be done to have them come visit.



The v2 of the website will allow a 3-level access (SP4, HBP members, non HBP) to find elements related to events that happened at the EITN taking into account the confidentiality issues and help continue collaboration attempts after the events. It will also put into light the SP4 partners work more efficiently.

In order to emphasis even more the EITN work during the next phase while considering the time needed to do so, we have planned to reinforce our team to help develop the dissemination of the events.

3.6 Continuing the EITN work in the Operational Phase

The EITN supports cross SP activities in relation to the SP4 themes that are, in SGA1, Bridging Scales, Generic Models of Brain Circuits, Learning and Memory, Models of Cognitive Processes, and Linking Model Activity and Function to Experimental date. The cross SP notion was establish before the creation of the CDPs and SP4 has been developing horizontal collaboration since the ramp-up phase. Part of its aim is to continue on developing these precious collaborations independently from the CDPs while avoiding redundancies to help the project and the SP achieve its goals.

The goal of the EITN has always been to serve as an incubator of ideas for the project, and interface with the community outside of HBP. We also have regular “internal” workshops between several SPs. In the ramp-up phase, we had SP3-SP4, SP4-SP6, SP4-SP9, SP4-SP10, SP2-SP4 and SP4-SP12 workshops. It is our plan to continue this activity in the SGA1. In addition, the EITN is opened to organizing HBP-wide events, such as board meetings, meetings with the admin managers, the CDP week planned to happen every year, etc.

The "dual" supervision of the 4 post-docs will be another way for SP4 to interact with other SPs through the EITN.

The long stay visitor programme gives the opportunity to non-HBP scientists to learn more about the Human Brain project and collaborate with SP4 but also with other SPs or more specific WPs if relevant. This may be one way to reach for international collaboration that Europe could be interested in.

4. Conclusion

As mentioned in this deliverable, it was difficult to have more resident postdocs, because we did not have salaries for them. The initial plan of having 4 postdocs from other HBP partners revealed to be unpractical because of the expense of living in Paris. This is why we have reviewed the EITN way of working for the coming SGA1, and proposed a work plan where although being co supervised by two HBP partners (one SP4 partner and another HBP partner), EITN post-docs should be resident in the EITN from the start. We hope that this will result in more emerging collaborations between partners.

For visitors, it must be kept in mind that we did not advertise for visitors in the ramp-up phase (else than mentioning this possibility in our web site); all the candidacies that we got were spontaneous. The setting-up of the project finished and this new phase starting, we will now be able to more formally advertise for EITN visitor opportunities.

Finally, it is important to note that the mediation, and the first (one year) review of the HBP, both recommended that the budget of the EITN should be augmented. We have implemented this request in SGA1. The EITN has now more funds available for invited speakers and visitors, which will allow us to better run our workshop and visitor programs. We also have now allocated 4 postdoc positions, which are all systematically co-supervised by two HBP partners. This will necessarily increase the opportunities of collaboration within HBP. To finish, we must also mention the fact that the EITN is directly implicated in several horizontal projects in SGA1, in particular the co-design projects CDP1 and CDP5, which explicitly use the EITN. The FLAG-ERA project SLOWDYN is also going to be in intense contact with the HBP through the EITN.

Although the EITN is not a platform, it is our goal to use the EITN as a means to attract researchers from the entire community, to interact with the HBP and its platforms, and possibly become associated partners through complementary projects.

Annex A: EITN events agenda

September 2014	Thu 11	Modeling electric and magnetic brain signals
	Thu 18	Private Event
October 2014	Wed 08	HBP-Brainscales meeting : Missing interactions in spike-based computation
	Thu 09	HBP-Brainscales Meeting : Missing interactions in spike-based computation
	Tue 14	Local Theory Meeting : Predictive information in a sensory population
November 2014	Tue 04	Local Theory Meeting: The Brian Simulator presented by Marcel Stimberg
	Thu 27	Stochastic Neural Computations _ day 1
	Fri 28	Stochastic Neural Computations _ day 2
December 2014	Tue 02	Local theory meeting
	Tue 02	Seminar of Neuromathematics of Vision
	Thu 11	Dendritic Computations
	Tue 16	Local theory meeting
	Tue 16	Brainstorm session on modeling sleep
January 2015	Tue 06	Theoretical Neuroscience Seminar: Laureline Logiaco (IDV) "Spatiotemporal spike coding of behavioral adaptation in the dorsal anterior cingulate cortex".
	Tue 06	Brainstorm session on modeling sleep
	Wed 14	Brainscales and SP4 workshop "CONFRONTING MEAN-FIELD THEORIES TO MEASUREMENTS"
	Tue 20	Theoretical Neuroscience Seminar: Ulisse Ferrari (IDV) "Inferred Model of the Prefrontal Cortex Activity Unveils Task-Related Cell Assemblies and Memory Replay".
	Tue 20	Brainstorm session on modeling sleep
February 2015	Tue 03	Theoretical Neuroscience Seminar: Pierre Yger (IDV) "Fast learning with weak synaptic plasticity".
	Tue 03	Neuromathematics seminar
	Fri 06	"Implementation Calcul Naturel" Meeting
	Tue 10	Brainstorm session on modeling sleep
	Tue 24	Theoretical Neuroscience Seminar: Denis Sheynikhovich (IDV) "A computational model of LTD/LTP".
	Tue 24	Brainstorm session on modelling sleep
March 2015	Mon 02	SP5, SP6 & SP4 workshop "Are we building the right thing? - Requirements from theory for simulation environments and neuromorphic computing"
	Tue 10	Theoretical Neuroscience Seminar: Yann Zerlaut (CNRS UNIC) "Characterizing the input-output properties of necortical neurons...".
	Tue 10	Neuromathematics seminar
	Thu 12	Power laws and multiple scales in neural systems
	Tue 17	Private EITN meeting
	Tue 24	Theoretical Neuroscience Seminar: Stephane Deny (IDV) "A flexible code: the retina dynamically reallocates its resources to code for complex motion!"
	Tue 24	Brainstorm on modelling sleep
	Tue 31	Neuromathematics seminar

April 2015	Thu 02	SP4/SP9 Workshop / Theory - Neuromorphic Workshop
	Tue 07	Theoretical Neuroscience Seminar: Quentin Sabatier (IDV) "Event-Driven Fourier transform of a visual signal"
	Tue 07	Neuromathematics seminar
	Tue 14	Brainstorm on modelling sleep
	Tue 21	Theoretical Neuroscience Seminar: Charlotte Le Mouel (IDV) « WHERE » is the knowledge in the motor control ?"
	Tue 28	Brainstorm on modelling sleep
May 2015	Tue 05	Theoretical Neuroscience Seminar: Timothée Masquelier (IDV) "Envelope coding by correlated activity".
	Tue 05	Neuromathematics seminar
	Tue 19	Internal event
	Thu 21	Workshop on Neuroscience: "Theory and data for advancing future neuroscience and the Human Brain Project"
	Fri 22	Info-day Call for Expression of Interest on "Systems and Cognitive Neuroscience"
	Tue 26	Theoretical Neuroscience Seminar
	Tue 26	Brainstorm on modelling sleep
	Fri 29	"Predictive Computations in the Primary Visual Cortex", a seminar by Michael John Berry
June 2015	Tue 02	Workshop on Plasticity and Learning
	Tue 09	Theoretical Neuroscience Seminar: Romain Brette (IDV) "The sharpness of spike initiation".
	Tue 16	Neuromathematics seminar
	Tue 23	Theoretical Neuroscience Seminar: Luc Estebanez (CNRS UNIC) "Distinct sensorimotor functional cell types in mouse forelimb primary motor cortex".
	Tue 23	Brainstorm on modelling sleep
	Fri 26	Private EITN meeting
July 2015	Wed 15	Seminar of Prof. Diego Contreras at the EITN
September 2015	Tue 01	Private EITN meeting
	Thu 10	Probabilistic Inference and the Brain -Meeting SP3/SP4-
	Tue 22	Private EITN meeting
October 2015	Thu 01	Private EITN meeting
	Tue 06	Private EITN meeting
	Thu 22	Private EITN meeting
	Thu 29	SP4 workshop "Biophysical Origins of Local Field Potentials"
November 2015	Tue 03	Neuromathématics seminar
	Tue 03	Brainstorm on modelling sleep
	Wed 04	Private EITN meeting
	Tue 10	Theoretical Neuroscience Seminar: Claire Meissner-Bernard (College de France) "Encoding of olfactory memory traces in the piriform cortex".
	Tue 17	Brainstorm on modelling sleep
	Thu 19	Python course
	Tue 24	Theoretical Neuroscience Seminar: Catherine Villard (IPGG) "Neurosciences on a chip: how to specify axons, connect neurons, and beyond".
December 2015	Tue 01	Neuromathematics seminar
	Mon 07	Private EITN meeting
	Tue 08	Brainstorm on modelling sleep
	Thu 10	SP4 workshop "Neuron-Glia Interactions"
	Tue 15	Theoretical Neuroscience seminar: David Colliaux (ISIR) "Biochemical reactions involved in micro-algae phototaxis".

January 2016	Tue 12	Private EITN meeting
	Tue 12	Brainstorm on modelling sleep
	Thu 14	Theoretical Neuroscience Seminar: Alberto Romagnoni (CNRS UNIC) « Pinwheel-Dipole structures in V1: Exhaustivity, parsimony and balanced detection ».
	Tue 19	SP4 -SP3 workshop "Modelling the visual system" part 1
February 2016	Tue 02	Theoretical Neuroscience Seminar: Liudmyla Kushnir (Columbia University NYC) "Neural classifiers with limited connectivity and local recurrent readouts".
	Tue 02	Neuromathematics Seminar
	Wed 03	SP4 internal meeting
	Thu 04	HBP internal meeting
	Fri 05	Private EITN meeting
	Tue 09	Private EITN meeting
	Wed 10	Workshop on "Population models and mean-field approaches to in vivo brain activity states"
	Mon 15	Private EITN meeting
	Tue 16	Theoretical Neuroscience Seminar: Georges Debregeas (UPMC) "A visually-entrained central pattern generator driving spontaneous eyes saccades".
March 2016	Tue 01	Neuromathematics Seminar
	Thu 10	SP12 Seminar: Dual-use, future computing and Neurorobotics
	Tue 15	SP4 workshop "Dendritic Sophistication: From Structure to Function"
	Wed 23	Private EITN meeting
	Thu 31	HBP internal meeting
April 2016	Wed 20	Private EITN meeting
May 2016	Thu 12	SP4-SP9 workshop on Multiple scales, Plasticity and Learning in Neuromorphic Systems
	Wed 18	Private EITN meeting
	Thu 19	SP3-SP4 workshop "Modelling of the early visual system" _ part 2

Annex B: Examples of Event Reports

4.1 Expert seminar

EITN, May 21st and 22nd 2015

Organized by The Danish Board of Technology Foundation (SP12) and EITN (SP4)

Theory and data for advancing future neuroscience and the Human Brain Project (HBP)

On May 21st and 22nd, 2015, the European Institute for Theoretical Neuroscience (EITN) together with the Danish Board of Technology Foundation (DBT) of the Human Brain Project's ''Science and Society" sub-project 12, hosted the expert seminar "Theory and data for advancing future neuroscience and the Human Brain Project (HBP)". The seminar welcomed HBP researchers and neuroscientists outside of the HBP.

In the course of the seminar a constructive conversation developed on the goals, approaches and future contribution of the HBP to neuroscience. Among the issues, the participants expressed a need for the HBP to communicate its diversity: for example by explaining and showcasing the sub-projects in greater detail. Participants were particularly critical and curious towards the HBPs approach to modeling and simulation (parts of) the brain. Particularly there was concern about how plasticity and neuromodulation would be taken into account in the models and important questions on the multi-level integration of the molecular with the cognitive level. Other questions addressed the mice/rat as a model organism.

Participants also commented extensively on the goal of the HBP. Many felt that such a huge project should work towards a contribution to better drug development or take one or more diseases as a starting point. Without doing so, or without pursuing multiple objectives the project might be setting itself up for failure.

Finally, all advocated the need for the HBP to develop in collaboration with the neuroscience community. The project will need to identify and engage with (end) users and figure out how to bridge the gap between them and the project. Participants recognized the huge effort involved with network building across ICT and neuroscience communities. Successful network building could be seen as a success in itself.

The seminar will be followed by a brief report, which will be written with input from the speakers, commentators, session chairs and participants.

4.2 Power Laws and Scale Invariance in Neural Systems

EITN, March 12-13 2015

Organized by Gaute Einevoll (UMB) and Alain Destexhe (CNRS).

This meeting was organized in the framework of Task 4.1.2 of HBP, on the modeling of brain signals at multiple scales. After an introduction by the two co-organizers, Alain Destexhe and Gaute Einevoll, the first keynote speaker, John Beggs (Indiana U.), made a very complete introduction of the field of self-organized critical systems, distinguishing between « critical », « subcritical » and « supercritical » systems. He outlined studies that support the fact that the brain operates in a critical state, based on the power-law relations of measured variables. He also pointed out that many studies showed evidence clearly against the existence of critical states, in particular in the awake brain. He also reviewed sources of errors, such as the subsampling of the system (inherent in brain recordings), or the possible spurious power-law relations that could appear in non-critical systems (such as

thesholded stochastic processes). He showed new results from a recording system consisting of 512 extracellular electrodes in 2D. In a recent paper published in Physical Review Letters, he and his colleagues could demonstrate the presence of power-law scaling from unit (spikes) data, as well as a universal scaling function, all indicative of critical systems. He finished by elaborating on the concept of « quasi-critical » systems, where spontaneous activity is taken into account. Such systems may more realistically describe complex systems such as neuronal networks.

The next speaker, Gerald Hahn (UPF), showed that avalanche dynamics creates correlated activity between brain areas and that the main prediction of such large-scale critical systems is, besides power-law relations, the presence of long-range correlations in the system. He also showed that the investigation of power-law relations from electrophysiological (multi-electrode) data, is only seen in some of the experiments, and not in others. In one case, a power-law was reported one day, and the same animal lost its scale invariance the next day! He also showed evidence for systems where there is no evidence for criticality from unit activity, but the LFP displays power-law relations. As in Curto et al. 2009 (ref?), this suggests that there is a continuum of different brain states, from which the system can switch. Finally, he showed an original analysis consisting of a PCA-based decomposition of the dynamics, which showed that, indeed, the system switches between periods of desynchronized and synchronized activities. In this analysis, the synchronized state scales as power-law (-3/2 exponent) while the desynchronized state scales similar to a Poisson stochastic process.

Olivier Marre (Vision Inst.) made the point that there is no natural order parameter in the experimental estimation of criticality. To determine a general criterion, he used the concept of « heat capacity », which is basically the variance of the log Probability of observing patterns of spikes. Using this concept, he showed that in critical systems, the heat capacity diverges at a critical point. This leads to a method that estimates the "proximity" to a critical state, and that fully takes into account the temporal dynamics of the system.

The next speaker, Viola Priesemann (Max Planck Gottingen), showed evidence that the brain is « slightly subcritical ». This slight subcriticality was found by analyzing monkey data, where there is no evidence for power-law scaling from spikes, in agreement with previous data, and where subsampling was not sufficient to explain the data. It is necessary to take into account the external input that the system receives. Use of a new measure (the spike ratio), which measures spike clustering, reveals that the system follows a dynamics slighly below the critical point (hence the term « slighly subcritical ». The argument is that this state is close to having optimal information transfer capabilities, but avoids going to the supercritical regime (runaway excitation). In human LFP data, the avalanche analysis indicates criticality but the spike ratio does not show it. She next discussed an estimator of branching parameter called MLR. Such a measure also shows that the brain is slightly subcritical.

In the next talk, Jonathan Touboul (College de France), showed evidence for power law scaling in the absence of criticality. He first described previous work that puts into question the thresholding procedure to detect criticality from LFP data. The analysis showed that a thresholded stochastic process can display spurious power-law scaling, although there is no criticality in this system. This issue of « spurious scaling » was further investigated using network of balanced excitatory and inhibitory activity. Such models display asynchronous-irregular (AI) states, where the spiking is continuous and irregular, and synchronous irregular (SI) states, where the system exhibits periods of synchronized activity and silences. The SI state is characterized by a power-law scaling of avalanche size, but a random surrogate (clearly non-critical) also displays the same. He also showed that calculating LFP from networks in AI states also leads to power-law scaling, although there is no criticality in the system. Interestingly, these systems displayed the universal scaling function in all cases.

Hermann Cuntz next presented scaling laws associated with dendrites in neurons. Artificially generated dendrites can be simulated based on a cost function that involved cable length and attenuation profile. If these two are appropriately balanced, the simulations can generate known cellular morphologies, such as pyramidal neurons, stellate cells, Purkinje neurons, etc. He showed that the total length of dendrites scales as a power-law as a function of the number of synapses, with a 2/3 exponent. In 2D, this exponent is 1/2. The latter was verified experimentally in larvae neurons.

The next speaker, Claude Bedard (CNRS), discussed the « one-over-f » frequency scaling of brain signals, and how such scaling can be explained by Maxwell's theory of electromagnetism. The main finding is that the inhomogeneous nature of the extracellular space around neurons is fundamental to this observation. However, to deal with inhomogeneous media, the standard Maxwell equations must be generalized, because the usual « free charge current » is not necessarily conserved anymore, and one must use the generalized current (free charge current + displacement current), which is the only quantity that is conserved in all cases. Using the generalized current, it is then possible to derive methods such as cable equations or current-source density analysis, in a way compatible with media having complex electrical properties. Finally, he showed brain impedance measurements realized at the UNIC, where the complex electrical properties could be measured using a dual-electrode recording system.

Gaute Einevoll demonstrated how power laws in the high-frequency tail of power-spectral densities can arise from the basic biophysical properties of neurons as described by the standard cable equation. Taking advantage of the analytical tractability of the so called ball-and-stick neuron model, he showed how homogeneously distributed input currents across the neuronal membrane gives rise to power-laws in the asymptotic high-frequency limits for the soma membrane potential, soma membrane current and the single-neuron current-dipole moment giving rise to EEG signals. Comparison with available data suggested that the apparent power laws observed in the high-frequency end of the PSD specta may stem from uncorrelated current sources, which are homogeneously distributed across the neural membranes and themselves exhibit pink (1/f) noise distributions. This again suggested that observed high-frequency (>50-100 Hz) power laws may originate intrinsic ion-channel noise even if the PSD at lower frequencies is dominated by synaptic noise.

In the final talk of the first day, Alain Destexhe gave an overview of data showing that there is no avalanche dynamics from the spikes recorded in awake animals, using recordings with Utah-arrays (100 electrodes), in cat, monkey and human, during wake and sleep states. He next showed that the LFP in these systems displays 1/f scaling at low frequencies, and $1/f^3$ scaling at high frequencies, but no sign of such invariance was found in the units. This suggests the existence of a « 1/f filter » in the extracellular medium. Indeed, it was shown theoretically that ionic diffusion can provide such 1/f scaling, in a way consistent with recent impedance measurements. Thus, including the effect of ionic diffusion, allows to reconcile why 1/f scaling is found in the LFP of awake animals, while there is no evidence for power-law scaling in unit activity. It was emphasized that this is the only theory that so far explains the available data in awake animals.

The second day began with a keynote talk by Bi-yu He (NIMH) on scale-free dynamics in the brain. She reviewed data from Electro-corticogram (EcoG) in humans, showing scaling approximately in 1/f at very low frequencies, and 1/f^3 (approx; perhaps closer to 2.5 ?) at high frequencies (from 1 to 50 Hz). This high-frequency band correlates best with the firing rate of single units. She also analyzed the scaling found in fMRI signals. The power-law scaling during the resting state reduces its exponent with increasing task difficulty. Other measures, such as "Hurst exponent" and Detrended Fluctuation Analysis (DFA), not only can help quantifying the system, but they can also lead to the detection of pathologies. Finally, she showed a firing-rate based network model which reproduces the spectrum of EcoG signals. Changing the correlated input changes the slope at low frequencies in this model.

Nima Dehghani talked about ways to quantify the variability in space and time of brain signals. Results from an avalanche analysis of human, monkey and cat recordings with large multi-electrode arrays were shown. Units do not display evidence for power-law scaling, in any of the wake/sleep states. The best model that fits the spiking data is a double exponential process. The human and monkey recordings also show a tight "balance" between excitatory and inhibitory activities, across time. This balance is seen at different timescales, therefore there is a time-scale invariant balance of excitation and inhibition in the human, monkey and cat during the waking state.

In the next contribution, Virginie VanWassenhove (NeuroSpin) discussed how do abstract representations drive bottom-up analyses of sensory inputs. The integration of visual and auditory information can be studied in humans, in parallel with magnetoencephalography (MEG) recordings. Human MEG recordings reveal "hierarchies" in the combination of sensory inputs (VanVassenhove, unpublished) or in sensory learning (Ahissar et al.) In the frequency domain, MEG recordings can also show 1/f scaling, at low frequencies. It was speculated that this 1/f structure is due to the hierarchy of oscillatory activities at multiple frequencies. The question of what is the right "processing unit" is still open at this cognitive level of investigation.

From the same laboratory, Philippe Ciuciu showed a more detailed analysis of MEG signals. The techniques used are DFA method and estimation of the Hurst exponent. The results obtained were consistent with Dehghani et al. (JCNS 2010). There is good evidence for multifractality in brain MEG signals. Interestingly, it is found that the degree of self-similarity decreases during the task. Changes of H also correlate with behavior.

The final speaker, Adrian Ponce (UPF Barcelona) discussed the emergence of resting-state temporal synchronization. The method shown consists of first estimate the connectivity using DTI imaging, then integrate this connectivity into a model that generates activity, which is then compared to fMRI. The model is a canonical model with excitatory and inhibitory pools, with GABA and AMPA/NMDA synaptic interactions. A mean-field approximation is made to obtain a Wilson-Cowan type equation (Deco, Ponce-Alvarez et al. 2013). The authors also use a Kuramoto type model to capture the phase statistics; this model shows the emergence of meta-stable states (but without power-law behavior).

Finally, a general discussion took place, where many questions were discussed. What does it take to identify a power law in experimental data? It was agreed that power-laws in nature are necessarily bounded by experimental constraints such as the finite size of the system and the finite resolution at small scales. It was also a clear consensus that power-law relations may indicate criticality, but not necessarily the case, and thus it is not a sufficient criterion to identify criticality. The existence of a universal scaling function is also not sufficient since it can emerge from non-critical systems. More stringent criteria are given by new measures, such as the heat capacity introduced by Marre and his colleagues.

Power-laws were also discussed in terms of spectra (time) or in terms of size distributions (space), which represent two fundamentally different aspects of the system. It was underlined that here again, similar spectra can be generated by fundamentally different systems, such as an exponential, or brownian motion, both of which generate Lorentzian PSD.

Finally, it seemed to be a general consensus that the workshop had been useful and informative – and kept in the type of light-hearted atmosphere that makes it easier to sort out what is agreed upon, what is not agreed upon and how to proceed to make progress in the field.

4.3 "Dendritic Computations"

EITN, December 11-12, 2014,

Organized by Alain Destexhe (CNRS) and Idan Segev (HUJI)

The goal of this first workshop on dendrites was to encourage a discussion between experimentalists and theoreticians on the type of computations that dendrites might perform, and on the associated dendritic non-linearities, and how such computations could be implemented in computational models. An important problem, especially for the Human Brain Project (HBP), is how to develop simplified models that still capture the most salient features of dendritic computations.

In the first day of the meeting, chaired by Alain Destexhe, the first speaker was David DiGregorio (Institut Pasteur) who presented a talk on "Dendritic computations by thin dendrites of cerebellar interneurons", and showed that although many central neurons summate inputs supra-linearly, the summation was sub-linear in cerebellar stellate cells. The experiments could show that nevertheless, the summation of calcium signal was supra-linear. A second talk, given by Thierry Bal (CNRS, UNIC), on "Imaging dendrites using intracellular voltage-sensitive dyes", showed that the intracellular use of voltage-sensitive dyes (VSD) can reveal the dynamic role of dendrites, such as calcium spikes and sodium spikes. In the thalamus, these spikes can directly trigger synaptic release, and thus dendrites can be seen as “dendraxons”.

A next series of theory talks, started by Walter Senn (U. Bern) on "Synaptic plasticity on dendrites: the advantage of dendrites for learning", showed an online learning paradigm where the NMDA spikes could implement a form of error backpropagation, and used in dendrites for subsequent plastic changes which take into account these errors. The neuron is seen as an intrinsic predictor, where dendrites predict somatic spiking. The next talk by Mathieu Galtier (EITN & DREEM) "A theoretical approach for active dendrites in vivo", reviewed a model that investigates the role of propagating dendritic spikes in processing correlated synaptic activity. The main finding was that the presence of these spikes provides the dendrites with an opposite dependence on correlations (compared to a model without dendrites), which is one of the rare case of a qualitative effect provided by dendrites. The next contribution by Eilif Muller (EPFL) "Large-scale biophysical models of neocortical tissue: Role of dendrites", overviewed the detailed models of a dense cortical network developed as part of the “Simulation” sub-project of the HBP. A prominent result was that the authors were able to incorporate most of the available anatomical and physiological constraints into a model of cortical networks, which makes it probably the most biologically-realistic model of any circuit so far available. The speaker emphasized the role of dendrites in cortical connectivity. In the following talk, Szabolcs Kali (Hungarian Academy of Sciences) "Systematic simplification of compartmental neuronal models based on electrotonic structure" discussed methods to obtain simplified neuronal models. The main point was that like detailed models in the previous talk, the simplified models could be obtained by including possible constraints from experimental data, such as clustering synaptic efficacies from different dendritic subtrees into a single “computational unit”.

Finally, the first day was concluded by an invited speaker presentation by Mike Hausser (UCL) on "Dendritic computation and plasticity". This talk showed that for the stellate cells in Layer 2 of the enthorinal cortex (forming the “grid cell” structure), it is possible to obtain recordings in behaving animals, together with 2-photon imaging of the cell. Contrary to the sublinear summation of cerebellar stellate cells, the enthorinal stellate cells summate supralinearly. The advantage is this nonlinearity was shown to enhance the grid cell structure and thus improve the spatial navigation of the animal. This provides a possible correlation between dendritic properties and the behavior of the animal.

The second day, chaired by Idan Segev, began with a second invited speaker presentation by Matthew Larkum (Univ. Berlin) on "Dendritic computation and NMDA receptors". The main focus of this talk was on NMDA spikes, how they were characterized and proven to be of functional importance using both in vivo and in vitro preparation. NMDA spikes are implicated in dendritic integration, in particular for distal dendritic events. Many of the

effects of NMDA antagonists could be due to the loss of dendritic NMDA spikes, and the associated perturbations in dendritic integration.

The next presentation, by Simon Friedmann (U. Heidelberg) "Multi-compartment neuron models in neuromorphic hardware", overviewed the VLSI neuron hardware technology and the type of models that could be implemented on such hardware, including millions of VLSI "neurons" which together form large, energy efficient, neuronal networks. In particular, a new generation of neuromorphic chip, including dendrites, will be designed and realized in the HBP, and the help from theoreticians and modelers is needed to determine the features that will be implemented in this new VLSI prototype. Next, Jugoslava Acimovic (Tampere U) presented a talk on "The effect of neuron morphology on graph theoretic measures of network connectivity", where she emphasized that the local structure of the dendritic and axonal trees is key in determining the connectivity structure (the emergence of structural "motifs" in the corresponding neural networks). Thus, (before plasticity) the micro-level (the structure of single neurons) already has an important effect on the macro-level (the structure of the neuronal circuit).

The afternoon started by a talk by Romain Caze (Imperial College) on "Synaptic clustering or scattering? A model of synaptic plasticity in dendrites". It was shown that following competitive rule, synchronous excitatory synapses may be functionally assembled into dendritic subregion, as found experimentally in several systems. This arrangement (synaptic clustering) could serve as an error detection. Next, Idan Segev (Hebrew Univ.) presented a talk on "Modelling human cortical cells" where L2/3 pyramidal cells from human temporal cortex, taken out during operation were characterized physiologically and 3D reconstructed. A first draft cable and compartmental model was presented following the reconciliation between model and experiments. The last talk was given by Alain Destexhe (CNRS UNIC & EITN) on "The generalized cable", where it was first shown experimentally that impedance measurements in natural condition reveal that the extracellular medium is not a resistor but is more complex. In such a case, the classic cable equation (as developed by W. Rall) must be generalized. It was shown that such a generalization can have important consequences on properties such as voltage attenuation in dendrites and, thus, on dendritic integration in vivo.

Finally, towards the end of the meeting a lively and extended general discussion took place, emphasizing several key points. The first was what dendrites are crucial for implementing several computations as demonstrated in a few talks. Several properties were suggested, such as implementing recurrent processing in layered structures require dendrites (Caze), implementation of synaptic delays and shaping PSP's time course (Segev) and localized NMDA spikes (Larkum). It was also demonstrated that analog computation in dendrites are key for learning (Senn), by providing an analog handshaking between dendritic input and spike output in the axon. It was also argued that dendrites are required if the neuron should be sensitive to uncorrelated synaptic events (Galtier).

Several posters were presented in this meeting, one by Francesca Barbieri (CNRS UNIC) on "Modeling the magnetic field generated by complex dendritic morphologies". Another by Pozzorini Christian (EPFL) on "Spike-timing prediction in cortical neurons responding to somatic and dendritic current injections". Finally, a poster by Yann Zerlaut (CNRS UNIC) on the "Impact of dendritic structure and properties on the dynamics of recurrent networks: a mean-field approach".

The general feeling of that meeting was of enthusiasm and a sense of comradeship among the participants. The attendees were very happy with the discussions as it was a god summary of were we should be heading, where are the open questions. This field is obviously very active and clearly needs experiments and theory working hand in hand, and so the role of such workshops appears essential for such a collaborative effort. We anticipate that another similar meeting would be initiated in a year time or so, in order to focus perhaps more on the network level aspects of dendritic function. There will be

another meeting between the VLSI hardware team (SP9) and theoretical neuroscience (SP4) in early April 2015, which will be more specifically on implementing dendritic models on hardware.

4.4 Workshop on Stochastic Neural Computation

EITN, November 28 2014

Organized by Wolfgang Maass (TUGRAZ)

Thanks to Michael Pfeiffer for collecting notes (with contributions from Michael Hopkins), and thanks to all participants for their contribution to the discussion!

4.4.1 Notes from the Discussion of Open Problems at the Workshop on Stochastic Neural Computation on November 28, at the EITN in Paris

We discussed two classes of open problems:

4.4.1.1 1. What is the existing experimental evidence that sampling over network states is used by brain computations, and which future experiments could provide additional information on that?

--A prerequisite for experimental tests is a clear formulation of the hypotheses that one wants to prove or disprove.

--There exist in fact several versions of the hypothesis that brain computations involve neural sampling: The more common version postulates that the brain carries out probabilistic inference (e.g., computation of posterior marginal probabilities) through neural sampling. A weaker hypothesis proposes only that the brain searches through (more or less) stochastically generated network states in order to arrive at a solution of a computational task (e.g., a constraint satisfaction problem, see e.g. the paradigm considered in the second part of (Habenschuss, Jonke et al., 2013)).

--It is also not clear, what the right notion of network state is in this context. Substantial evidence, see e.g. (Luczak et al., 2009, 2012), suggests that cortical networks produce primarily variations of a surprisingly small repertoire of spatio-temporal firing patterns (of various durations from 50 ms to seconds), rather than „static“ firing patterns.

--A weaker version of the sampling hypothesis proposes, that these stereotypical spatio-temporal firing patterns represent learnt knowledge (e.g., procedural knowledge, such as, how to carry out a specific movement or behaviour) that biases the actual network response (like a prior, but perhaps not within a rigorous probabiistic inference framework), see e.g. (Harvey et al., 2012)

--A very weak version of the sampling hypothesis suggests only that at least some brain computations make use of the observed stochasticity of network responses.

-- It is nontrivial to judge whether trial-to-trial variability found in neural recordings results from hidden variables, or from stochastic neural computation via sampling.

--Such analysis also requires that experimentalists record and analyze 2nd order moments of neural responses, rather than just the mean response.

-- A key test is whether such variability can be related to uncertainty of the organism (perceptual uncertainty, behavioural uncertainty, uncertainty about the solution of a problem). For this it is beneficial if the uncertainty of the organism in a trial can be controlled (modified) by the experimentalist, as e.g. in forthcoming work of Mate Lengyel

--Results on brain responses to ambiguous stimuli suggest some form of sampling over different percepts, see e.g. the classical literature on binocular rivalry (Leopold et al.,

1999). But these experimental data only support a slow sampling on the time-scale of seconds.

--Also the data by (Karlsson et al., 2012) --on brain responses when the animal realizes that the currently followed rule for getting rewards no longer works-- only support stochastic sampling on a larger time-scale.

--The data of (Jezek et al., 2011) can be interpreted as sampling on a faster time-scale (the theta rhythm of the hippocampus) if information about the current environment is ambiguous

--For the less stringent interpretation of the neural sampling hypothesis (sampling as solving a constraint satisfaction problem by searching for a low-energy network state ---which amounts to solving a MAP (maximal a-posteriori problem in the language of probabiistic inference) there are also two experimental studies from mouse hippocampus which can be seen as some support of this hypothesis: (Pfeifer et al., 2013), and (Gupta et al., 2010). Both of these studies address motor planning tasks, which can be seen as special cases of problem solving.

--The latter tasks are special cases of computational tasks where even in a digital computer solutions are harder to find without some sort of stochasticity, such as movement planning, imagination, and more general versions of problem solving, Note that memory recall may require similar computational mechanisms as imagination (some experimental data suggest that it engages in fact similar brain areas, see e.g. (Buckner et al., 2008)).

4.4.1.2 2. Important open problems on neural sampling that concern both biological organisms and neuromorphic implementations

--So far most paradigms for neural sampling consist of network constructions (however one could view (Nessler et al, 2013), (Habenschuss, Puhr, et al., 2013)..) and (Kappel et al., 2014) as exceptions to this rule). How can neural networks for sampling be learned?

--What is the role of different types of inhibitory neurons for neural sampling?

--Which methods for faster sampling in non-reversible Markov chains (beyond the standard non-reversible neural sampling of (Buesing et al., 2011)) could be implemented in biological or neuromorphic neural networks?

--It was pointed out that Gibbs sampling is in general one of the slowest sampling strategy (compared with other sampling methods known in machine learning, such as Metropolis-Hastings, where the values of several random variables can be changed simultaneously at a sampling step).

--What methods can employed that enable neural networks to find low-energy states through stochastic search which avoid that the network revisits previously searched parts of the state space?

--Can experimental data on the occurrence of stereotypical sequences of network states be viewed as evidence for a more directed search for desirable solutions to a problem?

--Which methods can be employed that allow the network to cash previously found partial or approximate solutions?

--Could network oscillations play a special role for neural sampling (as somewhat suggested by the data of (Jezek et al., 2011))? One could view each cycle of an oscillation in this context as stereotypical temperature regulation scheme (in the sense of temperature regulation in simulated annealing), where an initial high temperature supports wider exploration, and a subsequent cooling supports homing in on a (more or less local) minimum energy state.

--Such underlying oscillations could avoid problems caused by spike transmission delays in the range of ms (by slowing down the sampling to the rhythm of the oscillation).

--Can nested oscillations of different frequencies support search of other optimization processes on several temporal and spatial scales?

--Which methods support network sampling from distributions with continuous random variables?

--Which methods even support efficient network sampling from high-dimensional distributions with continuous random variables?

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