SP4 EITN activity report (D4.6.1 – SGA2)

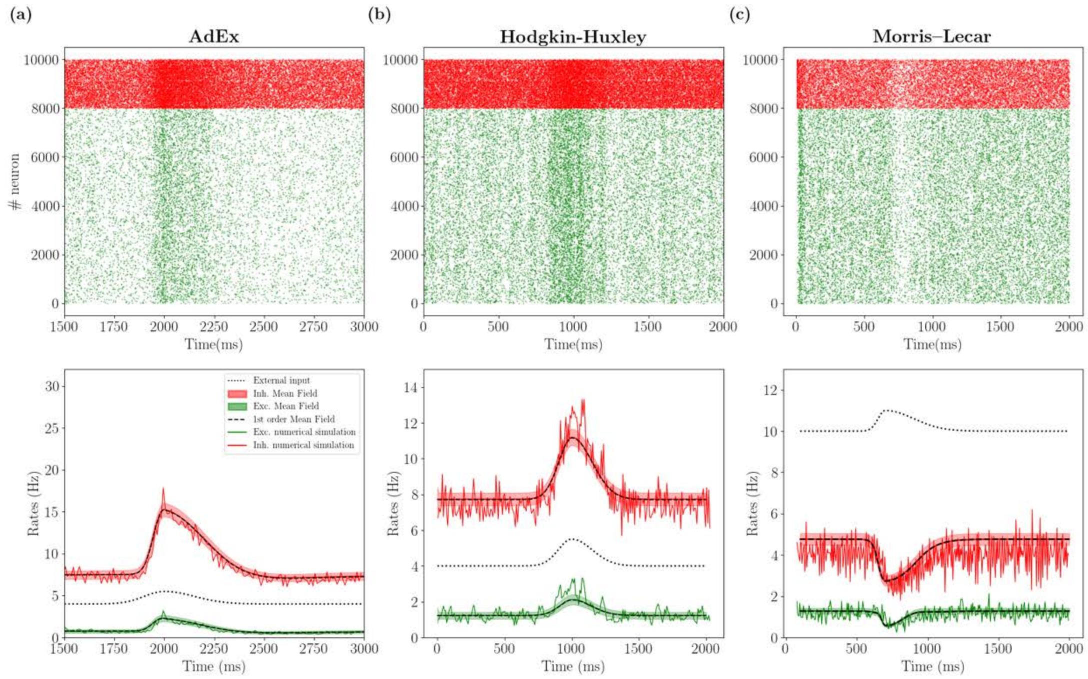

Figure 1: Mean field models of three known types of neuronal models, generated in the EITN course in computational neuroscience, and which was published with all students (Carlu *et al*., Journal of Neurophysiology, 2020)

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Author(s):	Alain DESTEXHE, Tom MESSIER, CNRS (P10)
Compiled by:	Tom MESSIER, CNRS (P10)
Contributor(s):	Alain DESTEXHE, Mallory CARLU, Damien DEPANNMAECKER, Jennifer GOLDMAN, Tomasz GORSKI, Domenico GUARINO, Julie MONGARD, Trang-Anh Nghiem, Federico TESLER, CNRS (P10)
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Description in GA:	For consistent presentation of HBP results, SGA2 M24 Deliverables describing the accomplishments of an entire SP, WP or CDP have been prepared according to a standard template, which focuses on Key Results and the outputs that contribute to them. Project management elements such as Milestones and Risks will be covered, as per normal practice, in the SGA2 Project Periodic Report.
Abstract:	This Deliverable describes the activities of the EITN during the SGA2 phase.
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1. Overview

The theoretical and computational models developed in SP4 occupy a central position in the HBP. One the one hand, they are derived from experimental data produced in the HBP. On the other hand, models are implemented in the HBP platforms, where they serve as "first users". These models also constitute the building blocks of work that will be continued in SGA3, such as bridging scales, network models, models of plasticity, models of cognitive processes and whole-brain models.

The European Institute of Theoretical Neuroscience (EITN) is an important tool in the work of SP4, because it serves as an incubator of ideas and foster the exchange of ideas between theoreticians and experimentalists, inside and outside the HBP. The institute is open to researchers from the field, from all over Europe and the rest of the World, whether they are HBP Partners or not. Besides organising inter-SP internal workshops, the Institute also organises international workshops open to everyone promote interactions between neuroscience and other disciplines.

The highlights of the work of the EITN is the successful organization of 23 international workshops on different themes, and where prestigious researchers (outside HBP) have participated, sometimes as co-organizers. The topics of the workshops ranged from the cellular level (models of single neurons, and their dendrites), up to the level of populations of neurons, and up to the level of the whole-brain and cognitive aspects. The EITN as a whole is thus participating to the multi-scale exploration of the brain. Another highlight was the success of the EITN Spring Course in Computational Neuroscience, where HBP researchers teach PhD students and postdocs theoretical and computational neuroscience concepts, and train them to use the tools of HBP. Finally, as an indication of the dynamism of the course, we were so impressed by the work of the students that we decided to write a paper with them – this paper is presently in press in *The Journal of Neurophysiology*, certainly a highlight for the EITN.

2. Introduction

The goal of WP.6 is to run and operate the EITN. The EITN was created in the ramp-up phase of HBP and was established in Paris. Since the beginning, one of the main activities of the EITN has been to organize international workshops of 2 days, where researchers outside of the project are invited together with HBP researchers. The format of the meetings is kept intentionally small (typically 30 to 40 attendees), so that there is an intense level of interaction between the participants. The workshop organized always include a theoretical and an experimental component, mixed together. This mix of disciplines and HBP and non-HBP researchers, is ideal for the EITN to play the role of incubator of ideas for the project.

Similarly, the visitor program of the EITN welcomes researchers to spend time at the EITN and interact with the researchers present. This program is much smaller than the workshop program, as it involves a handful of visitors. However, such visits are very important because it allows us to go in depth, much more than in a 2-day workshop. Note that usually, visitors are also speakers in workshops.

We have created a postdoc program, where 3 postdoc positions were assigned to the EITN. The postdocs are co-supervised by one or two HBP members (at least one from SP4), or an researcher outside of the HBP. The EITN postdocs thus serve not only to strengthen the link between HBP researchers, but also to allow the collaboration with non-HBP researchers, and thus also participate to increase the link between HBP and the community. The work of these postdocs in SGA2 is reported in detail in this deliverable.

Finally, the perspective for continuation and perhaps extension of the work of the EITN, in SGA3, will be discussed in the conclusion section.

Note that most of the models will be available in the Knowledge Graph and are in the process of being transferred.

3. Key Result KR4.4 EITN Postdoctoral program

3.1 Outputs

3.1.1 Overview of Outputs

3.1.1.1 List of Outputs contributing to the KR

- Output 1: Introduction EITN program
- Output 2: Modeling Brain states
- Output 3: Mechanistic model of neuromodulation in the thalamocortical loop
- Output 4: Conductance-based Adaptive Exponential Integrate and Fire Model
- Output 5: Electrophysiological seizure in neuronal network models
- Output 6: Derive simplified neuron and neural circuit models from biophysically morphologically detailed models
- Output 7: Implementing biologically informed mean-field models in The Virtual Brain
- Output 8: LFP-BOLD correlation and the role of glial cells in neurovascular coupling'

3.1.2 Output 1: Introduction EITN program

During SGA2, the EITN postdoc program has led to numerous publications (Capone *et al*., 2020 [1]; Carlu *et al*. [2], 2020; Depannemaecker *et al*., 2020 [3]; di Volo *et al*., 2019 [4]; Goldman *et al*., 2019 [5]; Gorski *et al*., 2018 [6]; Nghiem *et al*. 2020 [8]), and several papers are presently in preparation and will be reported in SGA3. A publication also arose from one of the researchers that stayed at the EITN as a visitor (Hahn *et al*. 2019) [7].

Among the publications of the EITN postdocs, a remarkable publication must be emphasized. During the EITN *Spring School in Computational Neuroscience*, students are asked to work on modeling projects. One of these projects was particularly successful, so we proposed the students to write all together a paper on this project, with all students co-first authors. This paper was accepted in the *Journal of Neurophysiology* (Carlu *et al*., 2020) [2], and we think that it constitutes a great outcome of the EITN school.

3.1.3 Output 2: Modeling Brain states

This work is focused on investigating how consciousness emerges from neural network dynamics, through comparing conscious and unconscious brain states. In particular, it is used models inspired by statistical physics alongside data analysis of neural recordings in humans and animals at different scales from microscopic to macroscopic. At the microscopic scale, in collaboration with Olivier Marre and Ulisse Ferrari (Institut de la Vision, formerly SP4), it investigated how interactions between human cortical neurons varied between wakefulness and sleep. This work revealed a different type of neural interactions taking place in sleep, where inhibitory neurons play a key part in organising widespread synchronous events (Nghiem, … Destexhe & Ferrari, *Phys Rev E* 2018, P1344). At a neural assembly scale, it uncovered subtle dynamical differences in cortical slow wave activity between two unconscious states, anesthesia and natural sleep, distinctions found to be remarkably robust across humans, monkeys, cats, and rats. Combining data analysis from *in vivo* recordings (in collaboration with Núria Tort-Colet, data obtained in Sanchez-Vives lab, SP3), spiking neural network models, and *in vitro* pharmacological manipulation, we identified cholinergic neuromodulation as causal mechanism able to account for transitions from anesthesia-type to sleep-type slow-wave dynamics, which explained the differences in responsiveness and capacity for memory encoding between sleep and anesthesia (Nghiem, ... & Destexhe, *Cereb Cortex* 2020) [8]. Finally, I investigated macroscopic scale differences between brain states using analysis of magnetoencephalography data in human subjects during active and resting states, revealing a conservation law relating synchrony and regularity of brain signals within and across states. Modelling neural assemblies as nonlinear coupled oscillators, our work revealed that decreased coupling between oscillators from resting to active state could explain the observed conservation laws (Nghiem... Destexhe & Goldman, *arXiv* 2018). Preliminary results suggest that the effective change in coupling is consistent with variation in cholinergic neuromodulation shaping the landscape of communication between brain regions, tying together our results at different scales (Goldman, ... Nghiem, Jirsa, & Destexhe *in prep,* in collaboration with Jirsa Lab, SP4). Our views on obtaining a scale-integrated mechanistic understanding of levels of consciousness have been summarized in our perspective paper (Goldman, ... Nghiem..., and Destexhe, *Front Syst Neurosci* 2019) [5].

3.1.4 Output 3: Mechanistic model of neuromodulation in the thalamocortical loop

The electrical activity recorded either inside or outside the brain while awake or asleep changes drastically. This is mainly due to the effect of neuromodulators on neuronal and synaptic excitability across the whole brain. In order to gain a mechanistic understanding of the role of neuromodulation on the activity of large populations of cells, it has been developed a conductance based spiking network model of the thalamocortical loop that includes the effects of neuromodulation at single cell and synaptic level. By fitting the parameters of the model to reproduce the available literature on acetylcholine neuromodulation (based on in-vitro and in-vivo single cell published data from the labs of Steriade, McCormick, Connors, see Figure 2, **a** and **b** panels), the model integrated the available knowledge and yielded a map of the effects of acetylcholine on model cells and synapses (e.g. Figure 2, **c**, for the thalamic ACh map). Based on these results, a thalamocortical network has been developed, capable of reproducing several network states, characterized by different oscillatory regimes, which were dependent on the imposed level of neuromodulation (e.g. Figure 2, **d**, the values of neuromodulation predicted for NREM sleep stage 2 produced a spindle regime). These results impact the whole computational community interested in modelling different network oscillatory regimes, how they are based on underlying physiological properties, and what are their computational capabilities. To maximize the dissemination of these results, the model has been developed using PyNN, making it compatible with software (NEST) and hardware (both SpiNNaker and BrainScaleS) simulation tools. This work is still on-going and is not yet published.

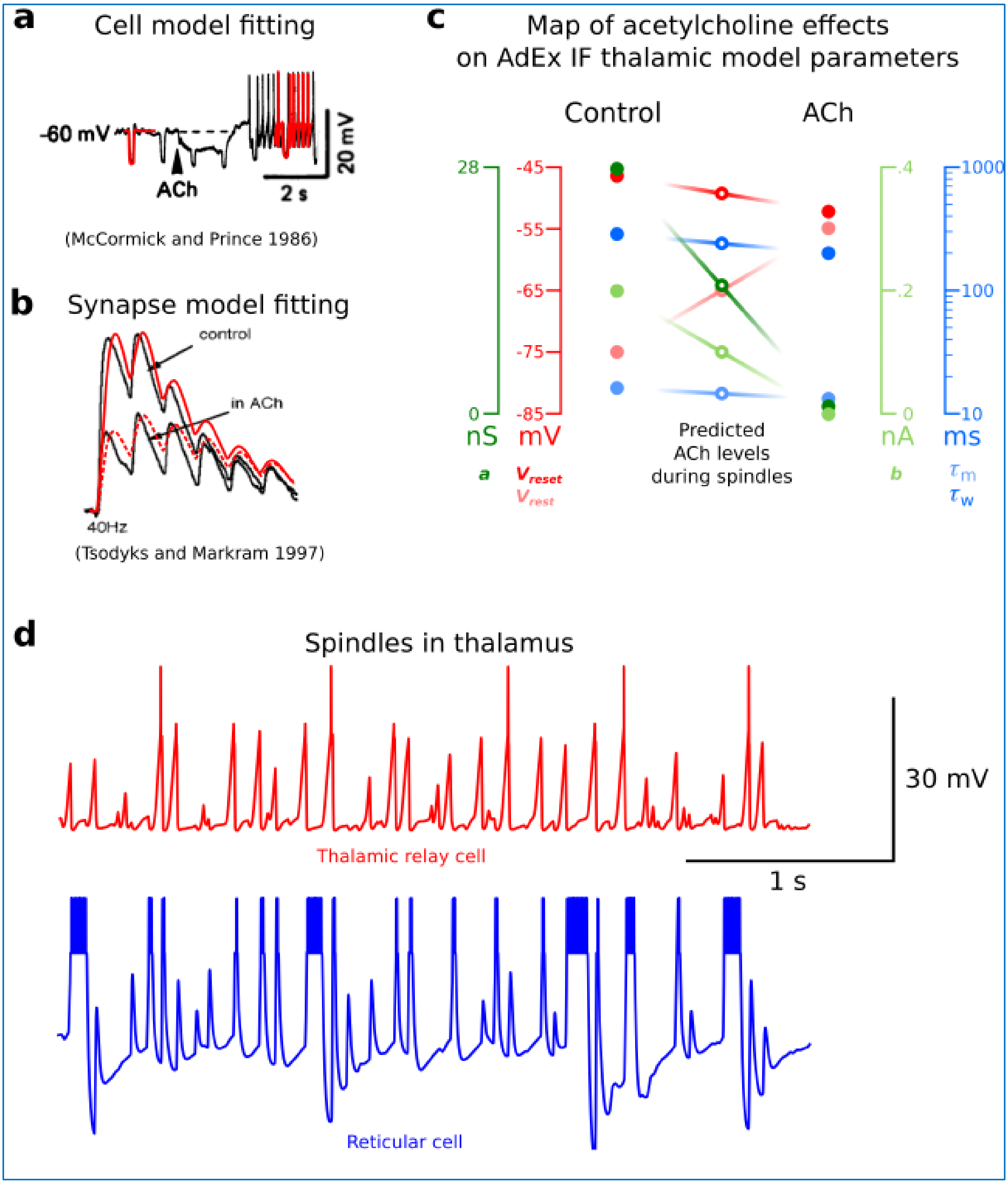

Figure 2 : Mechanistic model of neuromodulation in the thalamocortical loop

3.1.5 *Output 4: Conductance-based Adaptive Exponential Integrate and Fire Model*

The intrinsic electrophysiological properties of single neurons can be described by a broad spectrum of models, from the most realistic Hodgkin-Huxley type models with numerous detailed mechanisms to the phenomenological models. The Adaptive Exponential integrate-and-fire (AdEx) model has emerged as a convenient "middle-ground" model. With a low computational cost, but keeping biophysical interpretation of the parameters it has been extensively used for simulation of large neural networks. However, because of its current-based adaptation, it can generate unrealistic behaviors. We show the limitations of the AdEx model, and to avoid them, we introduce the Conductance-based Adaptive

Exponential integrate-and-fire model CAdEx. This work has been submitted to "Neural Computation" journal and a pre-print in available at doi: https://doi.org/10.1101/842823

3.1.6 Output 5: Epileptic seizures in neuronal network models

Based on the results of previous work on generic models (such as Epileptor), a seizure model has been developed on a network scale based on CAdEx model. In parallel, a study is being carried out on the propagation of seizures in networks to identify the mechanisms that make it possible to contain crises or not. Specific criteria such as different types of synchronization, or network topology are being studied.

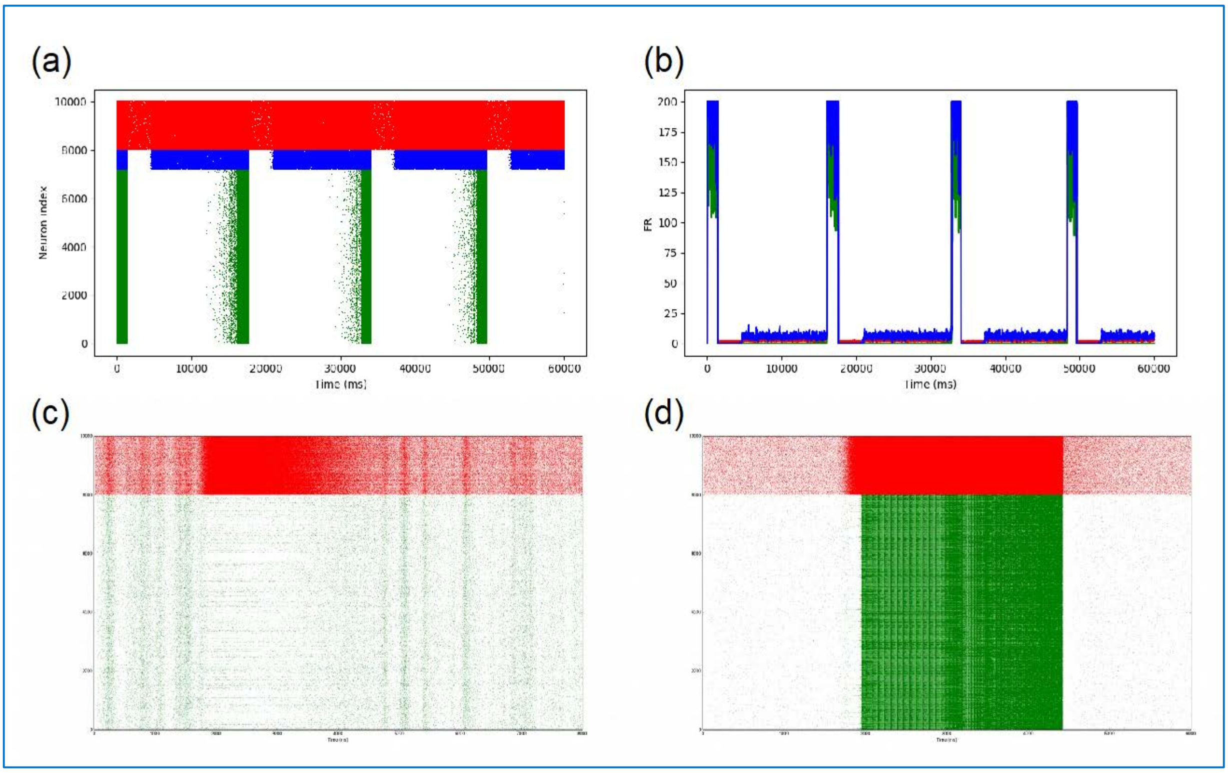

Figure 3 : Electrophysiological seizure in neuronal network models

(a) Raster plot of network constituted of three populations producing periodic seizure-like activities, (b) Corresponding population firing rate, (c) Raster plot of a network where inhibitory population is able to contains incoming seizure-like event (d) Raster plot of a network where incoming seizure-like event is strongly propagating to the excitatory population.

These behaviors described at the network level are sought in the corresponding medium field models developed within our research group.

3.1.7 Output 6: Derive simplified neuron and neural circuit models from biophysically morphologically detailed models

In the SGA2 phase of Human Brain Project the simplified models of dendrites were created and analyzed. In particular a model of neuron with active and linear dendrite was studied.

Two active mechanism were implemented: the Hodgkin-Huxley mechanism and the Adaptive Exponential Integrate-and-Fire Mechanism.

The model was adjusted to exhibit spontaneous dendritic spikes activity similar to that observed in *in vivo* experiments. (J. Moore *et al*., 2017).

For broad ranges of electrophysiological parameters the neurons with active dendrite showed the opposite firing rate response to correlated synaptic input comparing to neurons with passive dendrite and to point neurons. This *inverse response* to correlated synaptic activity means that a firing rate of a neuron with active dendrite decreases with correlation of synaptic input (Fig.4). It was proven that collisions of dendritic spikes and dendritic refractoriness are responsible for inverse response to correlated synaptic activity.

The results of this research were published in Journal of Computational Neuroscience (Gorski *et al*, 2018) [6].

The response to correlated synaptic activity has crucial impact on the behavior of the neuronal network.

In current research a model of neural network was created in which 80% of cells are excitatory neurons with passive or active linear dendrite, and 20% of cells are inhibitory point neurons.

The active mechanism in the dendrite can be Hodgkin-Huxley mechanism or Adaptive Exponential Integrate-and-Fire mechanism.

The connectivity and activity of the network is shown in Fig.5.

Model was implemented in NEURON simulation environment, it will be accessible once that the work is published.

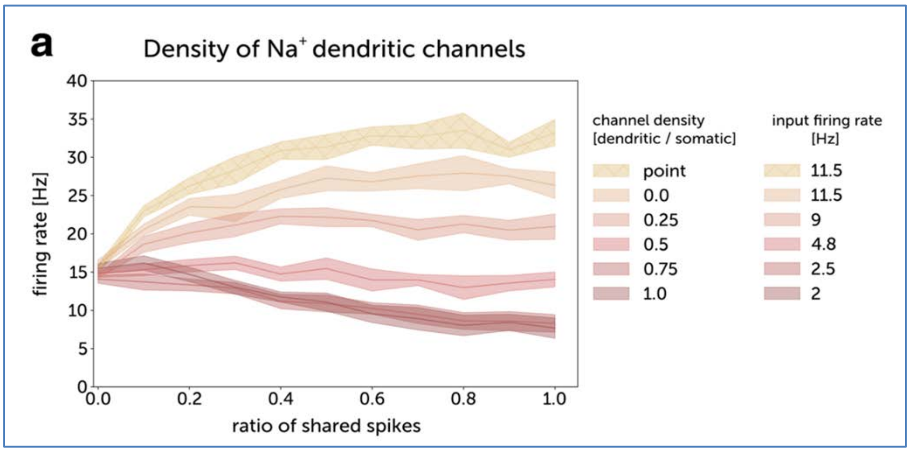

Figure 4: Firing responses for different densities of sodium channels in a dendrite

While changing dendritic densities of sodium channels, the somatic densities were left unchanged (12 mS/cm2 for Na+ conductance and 7 mS/cm2 for K+ conductance. The input firing rates were adjusted to dendritic channel densities to obtain the same somatic firing rate for uncorrealed input. Responses of neurons with dendrites are compared with the responses of point neurons with scaled synapses. The synaptic conductances were 0.5 nS for the neuron with dendrite, and 0.105 nS for the point neuron.

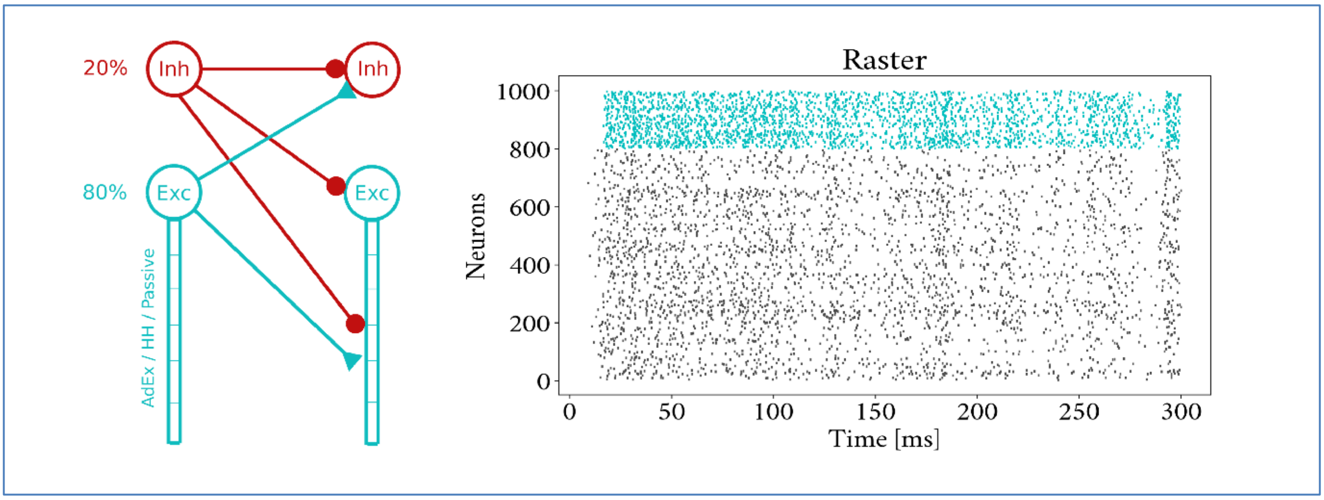

Figure 5: The network of neurons with simplified dendrite.

Left: Network connectivity. Connections between excitatory cells with simplified dendrites (blue) and point inhibitory neurons (red). Right: Raster plot of network activity. Black – excitatory cells, blue – inhibitory cells.

3.1.8 Output 7: Implementing biologically informed mean-field models in The Virtual Brain

Hallmarks of consciousness span spatio-temporal scales, from neuromodulators acting on single neuron ion channels to changes in coupling and communication between macroscopic brain regions. However, incorporating all relevant scales into biologically informed computational models to develop a more complete knowledge of differing neural computations between brain states remains challenging. Conscious and unconscious brain states differ both at baseline and in response to stimuli. During conscious states, neural activity is known to be more complex and responsiveness is increased compared to unconscious states. Strong evidence supports a role for neuromodulation-induced transisitions between brain states, with increasing levels of acetylcholine, among other neuromodulators, sustaining dynamics of high dimensional states supporting neural coding. In models of biological neuronal networks, neuromodulation can be simulated by numerically modulating neuronal conductances resulting in activity regimes that qualitatively resemble neural signals recorded during conscious and unconscious states. Conductance-based, mean-field models of neural networks developed in the HBP, in which activity displays biologically-realistic nonlinear dependence on membrane voltage (di Volo *et al*., Neural Computation 2019, P1864, [4]), are used. Specifically, second order mean-field approximations - taking into account the rate and variance of neural population activity - are scaled up to simulate full human brains, constrained and connected by subject-specific human neuroimaging data using The Virtual Brain (TVB). Quantitative comparison of full-brain simulations to previously reported data from conscious and unconscious brain states shows that microscopic-scale shifts in spike-frequency adaptation induced by neuromodulation can explain global changes in brain dynamics observed between conscious and unconscious states both at baseline and in response to perturbations. These scale-integrated results bind knowledge across spatio-temporal scales and support the hypothesis that macroscopic dynamics observed during conscious states emerge from microscopic phenomena to support neural coding.

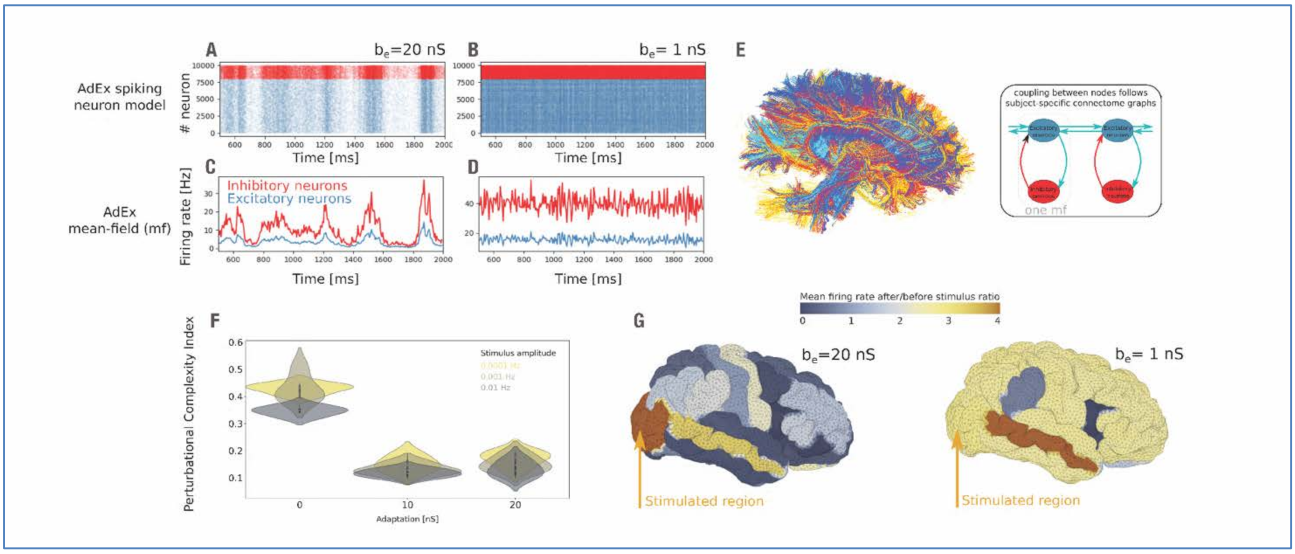

Figure 6: Spontaneous and evoked dynamics characteristic of conscious and unconscious brain states emerge from biophysical features of neuronal networks.

Simulations of AdEx networks of spiking neurons (A-B) and the population mean C-D) in unconscious-like (A,C slow wave) and conscious-like (B,D asynchronous irregular) conditions. The parameter varied to achieve brain state transitions is the spike-frequency adaptation, known to be regulated by biological variance in neuromodulation. Wiring together mean-field networks based on human tractography data (E), both spontaneous and evoked dynamics characteristic of brain states emerge (F-G). For more information see Goldman *et al*., Frontiers, 2020 and X preprint).

3.1.9 Output 8: LFP-BOLD correlation and the role of glial cells in neurovascular coupling'

The work done by Federico Tesler was focused on two main topics: (i) the role of glial cells in the neurovascular coupling and (ii) the correlation between local field potentials (LFP's) and fMRI (functional Magnetic Resonance Imaging) measurements. The final goal of the project was to develop a model of the neuro-glia-vascular system that could reproduce both LFP and fMRI signals.

fMRI is a widely used technique for measuring brain activity which relies on the coupling between blood-flow in the brain and neuronal activity. However, the origin of this coupling is not yet fully understood. It is believed that astrocytes (a type of glial cell) play a key role in the connection between the neuronal activity and the hemodynamic response (Gordon, 2008; MacVicar, 2015). In addition, it has been observed that fMRI measurements exhibit a stronger correlation with LFP signals than with single or multi-unit neuronal activity (Logothetis,2001; Mukamel, 2005). In this context, a theoretical description of the neuro-glia-vascular system may result of crucial importance for a better understanding of the information contained in fMRI measurements. The work of Dr. Tesler consisted in the development of a biologically realistic model of the neuro-glia-vascular system that was able of reproducing both fMRI and LFP signals, which is briefly described in the following. In the model developed neuronal activity triggers astrocytic calcium dynamics via glutamate uptake from synaptic release. Astrocytes in turn modulate vascular activity via Ca^{2+}-dependent release of vasomudulators (more specifically the vasodilator PGE_2). The model proposes a multi-scale approach to the system. Neuronal activity is described at the population level via a mean-field formulation (Di Volo, 2019), while astrocytes are described at a single cell level by a model of intracellular calcium dynamics (De Pittà, 2016). This is consistent with the fact that a single astrocyte cell interacts with thousands of neurons and are likely to sense population activity. The vascular response and fMRI signal are described via a phenomenological model based on the well known “balloon model” by Buxton *et al*,1998). The LFP signal generated by the neuronal population is modeled via a neuronal-dipole approximation (Einevoll, 2013). In Fig. 1 the results obtained from the model are shown. This study provides a relevant contribution to the understanding of the neurovascular coupling reflected in fMRI measurements and it may result of great importance for studies of functional connectivity in the brain based on fMRI. A multi-scale description as proposed in the model is in line with main work developed in the Human Brain Project. Similar approaches to fMRI modeling are used in main HBP platforms (i.e. Virtual Brain Project), making feasible the incorporation of the current developments to these platforms in the near future. This work is still on-going and is not yet published.

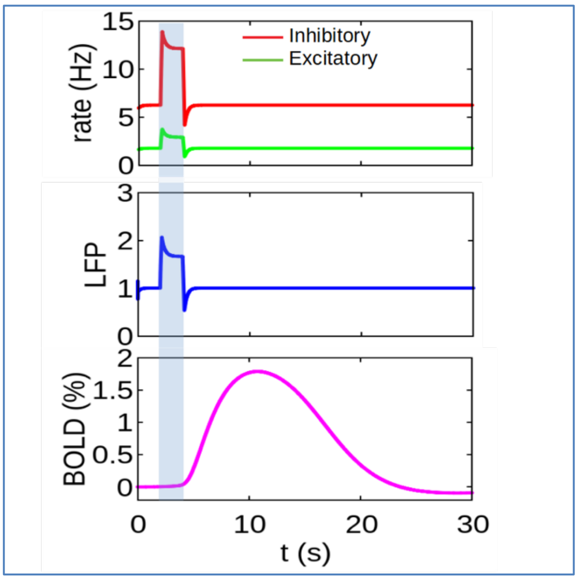

Figure 7: Results obtained from the model for a simulated external stimulus of 2 seconds.

Top panel: Firing rates of excitatory and inhibitory neuronal subpopulations. Middle panel: Local Field Potential obtained from neuronal activity. Bottom panel: BOLD signal obtained from the model. The grey area indicates the period with the stimulus on.

3.2 Validation and Impact

3.2.1 Actual and Potential Use of Output(s)

The actual and potential Use of the Outputs are already described within the Outputs.

3.2.2 Publications

[1] Capone, C., di Volo, M., Romagnoni, A., Mattia, M. and Destexhe, A. State-dependent mean-field formalism to model different activity states in conductance-based networks of spiking neurons. Physical Review E, in press, 2020. biorXiv preprint: https://www.biorxiv.org/content/10.1101/565127v1 (P1891)

[2] Carlu, M., Chehab, O., Dalla Porta, L., Depannemaecker, D., Herice, C., Jedynak, M., Koksal Ersoz, E., Muratore, P., Souihel, S., Capone, C., Zerlaut, Y., Destexhe, A., di Volo, M. A mean-field approach to the dynamics of networks of complex neurons, from nonlinear Integrate-and-Fire to Hodgkin-Huxley models. J. Neurophysiol., in press, 2020. (P2369)

Significance: All the first authors are students from the EITN Spring School, where this work originated.

[3] Depannemaecker, D., Gorski, T. and Destexhe, A. Conductance-based Adaptive Exponential integrate-and-fire model. Manuscript under review, 2019. biorXiv preprint: https://www.biorxiv.org/content/10.1101/842823v1 (P2492)

[4] di Volo, M., Romagnoni, A., Capone, C. and Destexhe, A. Biologically realistic mean-field models of conductance-based networks of spiking neurons with adaptation. Neural Computation 31: 653-680, 2019. (P1864)

[5] Goldman, J.S., Tort-Colet, N., di Volo, M., Susin, E., Boute, J., Carlu, M., Nghiem, T-A., Gorski, T. and Destexhe, A. Bridging single neuron dynamics to global brain states. Frontiers in Systems Neuroscience 13: 75, 2019. (P2222)

[6] Gorski, T., Veltz, R., Galtier, M., Fragnaud, H., Goldman, J.S., Telenczuk, B. and Destexhe, A. Dendritic sodium spikes endow neurons with inverse firing rate response to correlated synaptic activity. J. Computational Neurosci. 45: 223-234, 2018.(P972)

[7] Hahn, G., Skeide, M.A., Mantini, D., Ganzetti, M., Destexhe, A., Friederici, A.D. and Deco, G. A new computational approach to estimate whole-brain effective connectivity from functional and structural MRI, applied to language development.Scientific Reports 9: 8479, 2019. (P2368)

[8] Nghiem, T-A., Tort-Colet, N., Gorski, T., Ferrari, U., Moghimyfiroozabad, S., Goldman, J.S., Telenczuk, B., Capone, C., Bal, T., di Volo, M. and Destexhe, A. Cholinergic switch between two different types of slow waves in cerebral cortex. Cerebral Cortex, in press, 2020. arXiv preprint: https://arxiv.org/abs/1810.00816 (P1509)

4. EITN Activities

4.1 Outputs

4.1.1 EITN Workshops

During the SGA2 phase, the EITN has organized a series of events going through the beginning of the phase until the last weeks.

The aim of these event is to increase the exchange between theoreticians and experimentalists from the field of Theoretical Neuroscience focused on the quality of the exchange rather than on the quantity of attendees.

Indeed, the experience from the previous SGA1 phase has shown that a limited number of attendees allow to increase the quality of the discussion during the workshop.

The first objective of the EITN for SGA2 was to organised at least one workshop per month. This objective has been reached with a number of 26 workshop organized through the last two year with more than 600 attendees.

The topics of the workshop covered the main topics working through SP4 and all the PI involve SP4 has contributed to the organization of workshop.

<u>Topics:</u>

- Bridging scales
- Generic models of brain circuits
- Learning and memory
- Models of cognitive processes
- Linking model activity and function to experimental data

The gender balance is one of the preoccupations, from our experience we are trying to encourage the organizer of the workshop to have among their audience and speaker a fair equity between men and women.

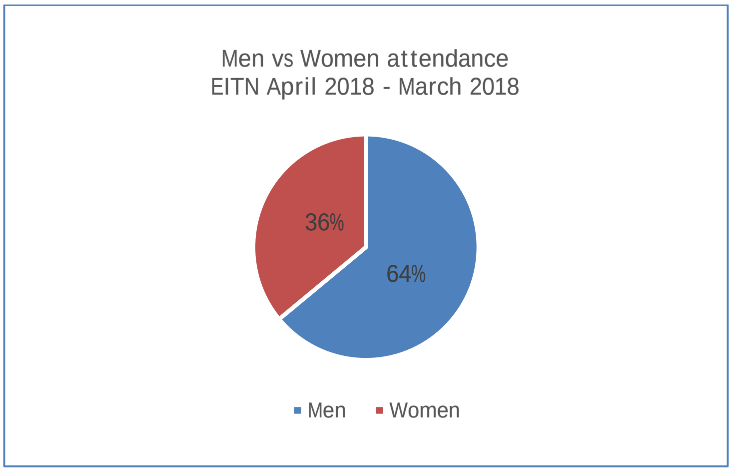

Figure 8: Gender balance for attendance to the EITN Workshops

The workshops are participating in the spreading of HBP works, for that we increase our focus on an external target audience and we crossover the symbolic point of more than 50% of non-HBP member.

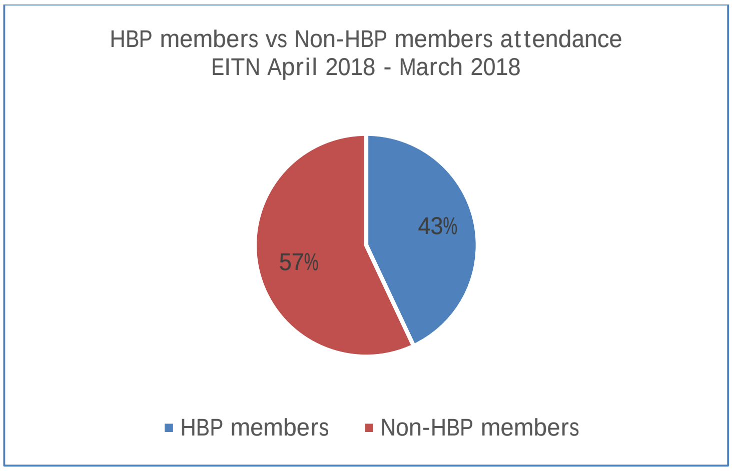

Figure 9: HBP member proportion for EITN Workshops

As a European institute, the participation of international researcher to our workshop allow to increase the work of HBP through the borders.

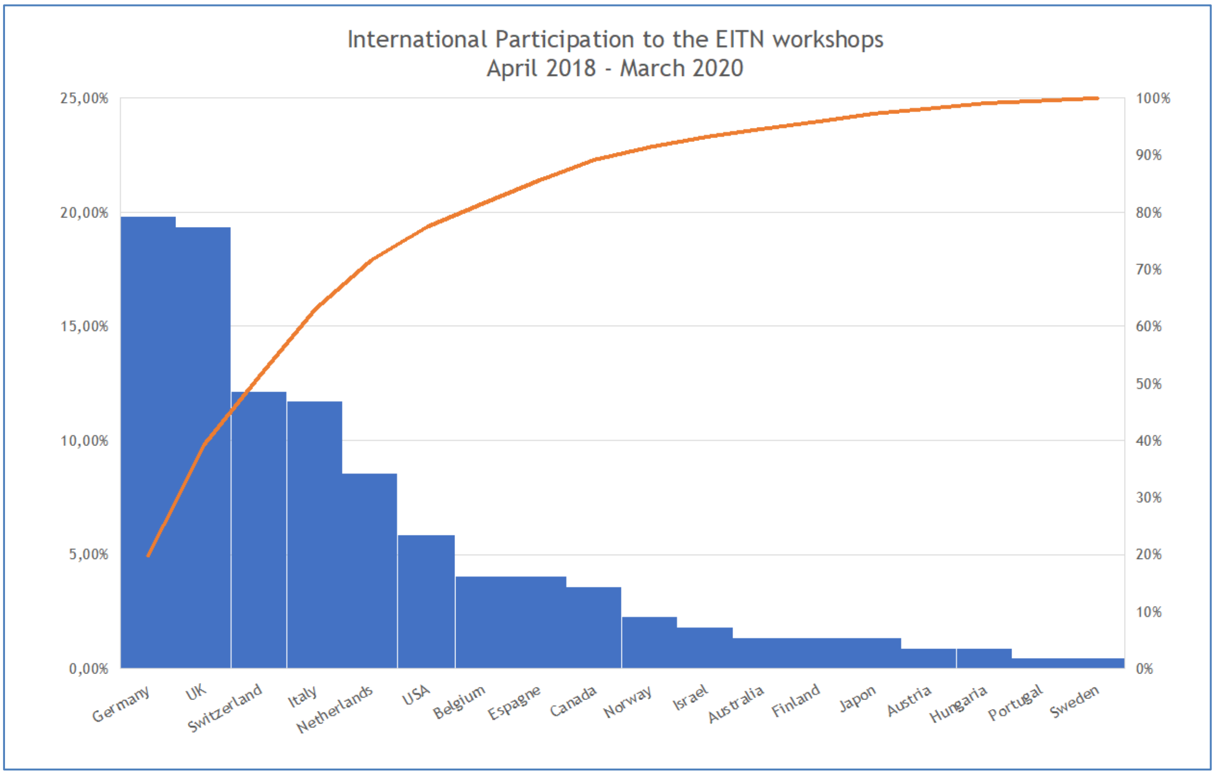

Figure 10: Proportion of international attendees to EITN Workshops

4.1.2 The EITN Spring Schools

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Figure 11 : Example of EITN Spring School advertising (edition 2020)

Based on the experience of a first Spring School during the SGA1 phase, it appears that more space and time was needed in order to increase the quality of the course. For that, the EITN organized one Spring School per year.

A new organization has been set, with bigger venue and extra time. Now, the Spring School are running on 10 days instead of 5 days. And the number of students is limit to 20 students.

The course is typically aimed for PhD students, young postdocs or master students interested to learn more about techniques of computational neuroscience, and the use of various simulation environments for model building. The students will form thematic groups to work on predefined subjects, with the help of tutors.

The school is organizing around tutorials and project. The tutorials are given by HBP researcher mostly. At the end the students have to provide result for each project done during the school.

In 2019, the projects made by the students have given a publication in the Journal of Neurophysiology (Carlu *et al*, 2019, P2369)

4.1.3 The EITN Visiting Scientists Program

Table 1: Planning of the long term EITN visitor

Name	Institution	Starting Date	Ending Date
Stephen Grossberg	Boston University, United States	25/06/2019	25/06/2019
Diego Contreras	Pennsylvania University, United States	06/10/2018 14/10/2019	12/10/2018 25/10/2019
Tara Babaie Janvier	The University of Sydney, Australia	05/01/2019	31/06/2019
Miwa Fukino	Panasonic, Japan	01/10/2019	31/03/2020

Besides the large number of invited speakers at the workshops, some of which visited the EITN for a short time, we had 4 longer term visitors. Prof Steven Grossberg from Boston University is a well-known figure of neuronal modeling, we had very useful exchanges with him about the mean-field models developed in HBP. The same theme was also at the focus of interaction with Dr. Tara Babaie, a long-term visitor from the University of Sydney (Australia). Prof. Diego Contreras from the University of Pennsylvania is a well-known in vivo electrophysiologist working on the visual system. His stay at the EITN was very fruitful and really helped to constrain network simulations developed in HBP. Finally, Dr. Miwa Fukino from Panasonic (Japan), was visitor at the EITN during 6 months, and she helped us with analysis programs applied to EEG recordings. Note that both Babaie and Fukino were paid by their institution and only needed office space to interact with the researchers of the EITN.

4.1.4 EITN Dissemination

During this last period, a work has been done to continue the dissemination activity.

A continuation of the communication with Twitter in order to spread and enlarge the audience of the publications of our partners and the organization and feedback of the EITN workshops.

Table 2: EITN Twitter Statistic

Subscriber	Printing	Visit	Mention
839	277675	2632	43

The website is still a useful place for everyone is searching information about the activities of the institute. Its frequentation is stable with an average of 15 visits per day which show that the interest of the public still remain constant.

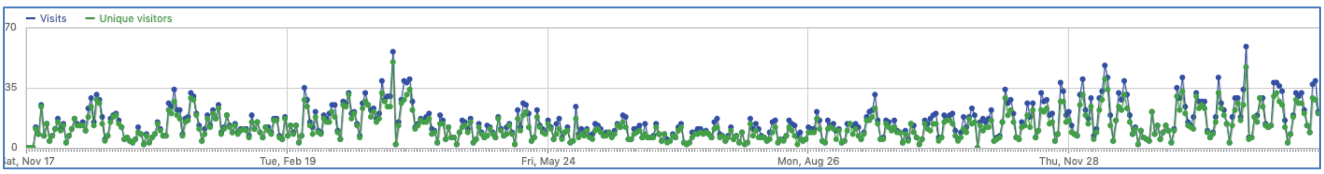

Figure 12: Daily visitors on the EITN website

For the next phase, we plan to integrate the EITN inside the HBP website (EBRAINS).

5. Conclusion and Outlook

In conclusion, the EITN has realized its program in SGA2, in particular all tasks of SP4 have organized at least one international workshop, where many researchers, including prestigious names, have accepted to participate as speakers. The EITN is now beginning to have a reputation in the field of theoretical and computational neuroscience. We plan to continue this workshop program in SGA3.

A second outcome of SGA2 is the completion of the postdoc program. We reported here that all postdocs have published their work, while some more publications are still in preparation. Some postdocs have 2 publications (Depannemaecker, Romagnoni), 3 publications (Goldman) or 4 publications (Capone, Gorski). This very good publication rate demonstrates that the EITN postdoc program is effective to increase the global impact of the HBP.

In 2020, the CNRS has committed to give 180 m2 of permanent office space to the EITN in the new Paris-Saclay Neuroscience Institute (NeuroPSI), just next door to the NeuroSpin brain imaging institute. The two institutes constitute an important hub for the HBP, with partners in subprojects SP1, SP2, SP4, SP5, SP6 and SP9, as well as the EITN. The EITN will thus be located in an interesting neuroscience environment, with experimental labs from molecular, cellular, circuits, sensory systems up to brain imaging, as well as theoretical neuroscience and neuroinformatics groups. We therefore anticipate that it will constitute a particularly attractive scientific environment for postdocs and visiting scientists.

In SGA3, the EITN will continue as part of EBRAINS and will be hosting the French national hub of EBRAINS. The postdoc program, although productive, will be discontinued (following the Reviewers request), but the two other programs, the workshop program and visitor program, will continue. The EITN scope will be more general in SGA3, and will also participate to motivate theoreticians to use EBRAINS. We will form a faculty of theoreticians and computational neuroscientists in HBP, which will constitute the task force to organize the future workshops. The EITN will also participate to the general outreach of HBP, playing a role in ESFRI and the national hub of EBRAINS.

Appendix: List of the EITN Workshop during SGA2

Table 3: EITN Workshop planning during SGA2

Name of the Workshop	Start Date	Duration
Meeting on slow wave dynamics	26/04/2018	1 day
Brainstorm on Mean-field	14/06/2018	1 day
Modeling alpha rythm	15/06/2018	1 day
Modeling of brain signals in hippocampus and neocortex	26/06/2018	1 day
Neuroplasticity: From Bench to Machine Learning	13/06/2018	2 days
Neurododo: Workshop on modeling sleep	26/09/2018	1 day
Some Dynamic properties of thalamocortical	10/09/2018	2 days
Fall Science & Art School	22/10/2018	2 days
Multi-level integration on the modelling and data sides using epilepsy	19/11/2018	2 days
Are we building the right user-level documentation ? For spiking neuronal network simulation engines	21/11/2018	2 days
Alpha Scales	06/12/2018	1 day
The many flavours of 'Effective Connectivity': From neuronal cultures to fMRI	10/12/2018	2 days
Predictive coding	16/01/2019	2 days
Modelling the Hippocampus	28/01/2019	2 days
SP4 Meeting	20/02/2019	1 day
Neuro Slam	13/03/2019	2 days
Mean field approaches	03/04/2019	2 days
EITN Spring School 2019	10/04/2019	10 days
Workshop on Visuo-motor integration	06/06/2019	2 days
Roles and Mechanisms of Cortico-cortical Feedback	06/11/2019	2 days
Perception and attention mechanisms in the primate brain	26/11/2019	1 day
Network science for cortical circuits: specificity versus regularity	04/12/2019	2 days
Workshop on modeling brain signals	09/01/2020	2 days
Workshop on Synaptic plasticity	14/01/2020	2 days
Neural Excitability: Theory and Experiments	31/01/2020	1 day
EITN Spring School 2020	03/03/2020	10 days
Neural coding in high dimensional, nonlinear systems	24/03/2020	2 days