Role of Global Inhibition in Brain Criticality

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We investigate the brain criticality hypotesis and the diverse roles of global inhibition in neural circuits. Recently we showed that increasing global inhibitory feedback leads to gradual rounding of first-order transition between dynamical phases, turning it into second-order phase transition. Results are replicated across different models of neural dynamics, namely, the Wilson–Cowan model and a network of leaky integrate-and-fire neurons. Across all these systems, a critical point is always found as a function of a pair of parameters controlling local excitability and global inhibition strength, and a general explanation revealing the roles of the shape of the activation function and fluctuations versus the extinction time-scale is provided. It is speculated that the brain could use global inhibition as a versatile means of shifting between first- and second-order dynamics, addressing the conundrum regarding the coexistence in neural dynamics of phenomena stemming from both. Some reflections regarding the comparison with other physical systems and the possible physiological significance are offered, and a hypothetical setup for an optogenetics experiment on cultured neurons is put forward.

Psilocybin Accelerates EEG Microstate Transitions and Elevates Approximate Entropy

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Abstract

Although the therapeutic potential of psilocybin has been documented, its effects on brain function remain incompletely understood. The relaxed beliefs under psychedelics (REBUS) theory proposes that psychedelics work by relaxing prior beliefs and increasing neural entropy, but this has primarily been tested using fMRI rather than EEG, which offers superior temporal resolution. This study investigated how psilocybin affects the spatiotemporal dynamics of the brain on the millisecond scale, examining whether its effects are modulated by mindfulness training and different cognitive states. Using EEG microstate and approximate entropy analyzes, we compared people who completed an 8-week Mindfulness-Based Cognitive Therapy program (N = 33) with controls (N = 30) in four conditions: video watching, resting state, meditation and music listening. The results showed that the 19 mg dose of psilocybin significantly altered brain dynamics, decreasing the duration of the microstate while increasing the rates of occurrence and the complexity of the signal. Mindfulness training showed no significant effect on these changes. While brain activity patterns primarily distinguished between eyes-open and eyes-closed cognitive states, psilocybin notably diminished the typical neural differences between passive rest and attentional states (meditation and music). These findings support the prediction of the REBUS theory of increased and neural entropy and under psychedelics and suggest that psilocybin creates a more dynamic and less constrained brain state,

particularly when visual input is reduced. The combination of microstate and entropy analyses provides complementary insights into how psychedelics affect both the temporal organization and complexity of neural activity.

Synergistic high-order statistics in a neural network is related to task complexity and attractor characteristics.

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Emergence of collective functions the brain is an open question in neuroscience, as they are believed to underlie consciousness, behavioral outputs, and brain disorders. It is unknown how measurable emergent behaviors can originate and be sustained, contributing to information processing. We studied the self-emergence of high-order interactions (HOIs) in RNNs that undergo plasticity to learn to perform cognitive tasks of different complexity. HOIs are statistical structures that are present in a group of variables but not in pair-wise interactions, and are characterized by tools from Information Theory. We trained continuous-time RNNs to perform one of the following tasks: Go/NoGo, Negative patterning, Temporal Discrimination, Context-dependent Decision making. Then, the dynamics of the hidden layer was evaluated. HOIs were characterized using the O-info and S-info metrics, at different orders of interaction taking all combinations from 3 to 11 nodes. The dimension of the trajectory was assessed by the amount of variance explained by the first 5 PCA components. In our results, training causes the dynamics of hidden layer to show HOIs with high redundancy at higher orders of interaction and synergistic interactions measured at lower order. More synergy is observed after training with the context-dependent task, while more redundancy is originated by the simpler Go/NoGo. Synergistic interactions are correlated with more complex dynamics as suggested by a trajectory of higher dimension. Finally, we tested different pruning procedures to obtain sparser weight matrices, without observing an effect on the HOIs measured. Our results suggest that complex tasks promote the emergence of synergistic interactions.

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Data-inferred multiscale brain models

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Abstract:
Regional parameters of whole brain models are inferred from large-scale brain recordings to provide mechanistic insights into brain function. The interpretability and range of parameters are limited by the choice of neural mass model. As opposed to phenomenological models, mean-field models maintain a link between microscopic and mesospic parameters, but they are often subject to strong assumptions in their derivation. Here, we validate a data-driven method to upscale detailed microscopic dynamics to the whole brain and infer parameters that are not available in the mean field model. We generated (Fig. 1A) a dataset of spiking activity of a heterogenous QIF network (Izhikevich, E. M. 2007) and estimated the population dynamics using machine learning. We found that the reconstructed dynamics captured all the core features of the ground-truth exact mean-field model (MPR model, Montbrió,E. 2015) as illustrated by the phase plane reconstructions (Fig. 1B). We then compared whole brain activity using the estimated model or the ground truth model as a neural mass model in The Virtual Brain. We found the fluidity of the dynamics to be similar and the relationship between excitability and global coupling to be preserved (Fig 1.C).
Lastly, we inferred excitability, synaptic strength, and connectivity between neurons from BOLD fMRI data and revealed the inherent degeneracy between synaptic strength and neuron connectivity which is not accessible using the mean-field model (Fig 1.D).
In conclusion, estimating microscopic dynamics using machine learning techniques can successfully capture and reproduce results obtained mathematically in mean-field models.

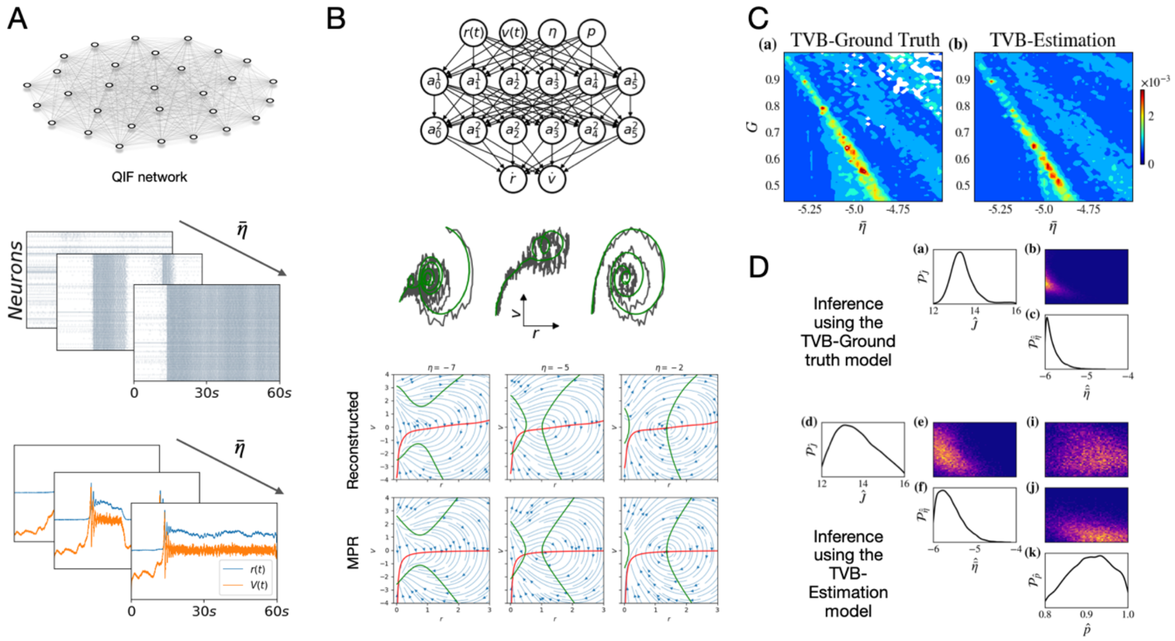

Fig 1. Graphical abstract. (A) from top to bottom: network of QIF neurons, data generated by sweeping for network parameters (here, the mode of excitability $\bar{\eta}$), extracted features (average firing rate and membrane potential). (B) Multilayer perceptron and example fitting of data trajectory in state space, reconstructed phase planes based of QIF data and MPR phase planes for different excitability. (C) Fluidity of the dynamics (variance of the functional connectivity dynamics) in a whole brain using the MPR model as neural mass (left) or the reconstructed model (right). (D) Posterior distributions from real BOLD fMRI data, using either the MPR as neural mass (top) or the reconstructed model (bottom).

Tuning to criticality in newborn brain activity induced by language prenatal experience

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Abstract

Several studies have shown that human newborns have sophisticated speech perception abilities allowing them to acquire any language. For instance, due to the rhythms and melodies that babies experience in their mother's womb during the last trimester of pregnancy, they can develop the ability to discriminate between their mother's language and other languages that are rhythmically different (but not rhythmically similar), even if these are unfamiliar to them. However, it remains unclear which neural mechanisms characterize such auditory ability. Here, using electroencephalography we investigate the newborn's brain activity analyzing the critical behavior of avalanches, their persistence, and their temporal structure during an auditory pre- and post-stimulus paradigm. Our results show a differentiation in the criticality signatures between familiar and unfamiliar languages. In the first case exponents and scaling relationships characterizing avalanche sizes and durations adjust better to the prediction of the mean-field directed percolation universality class than for the second case. Importantly, tuning to criticality induced by familiar language stimulation gets even more evident when we analyze additional dynamical properties of the cascading process. In particular, we observe that after the exposure to a familiar and rhythmically similar language the baby's neural activity presents an in- crease in the range of avalanche correlations, with the branching parameter getting closer to the critical value, and shows a peculiar temporal organization of avalanches that has been observed in the (critical) resting-state of adults. These findings may contribute to the understanding of underlying neural mechanisms governing language learning at the early stage.

State-dependent modulation of sensory populations by cortical feedback

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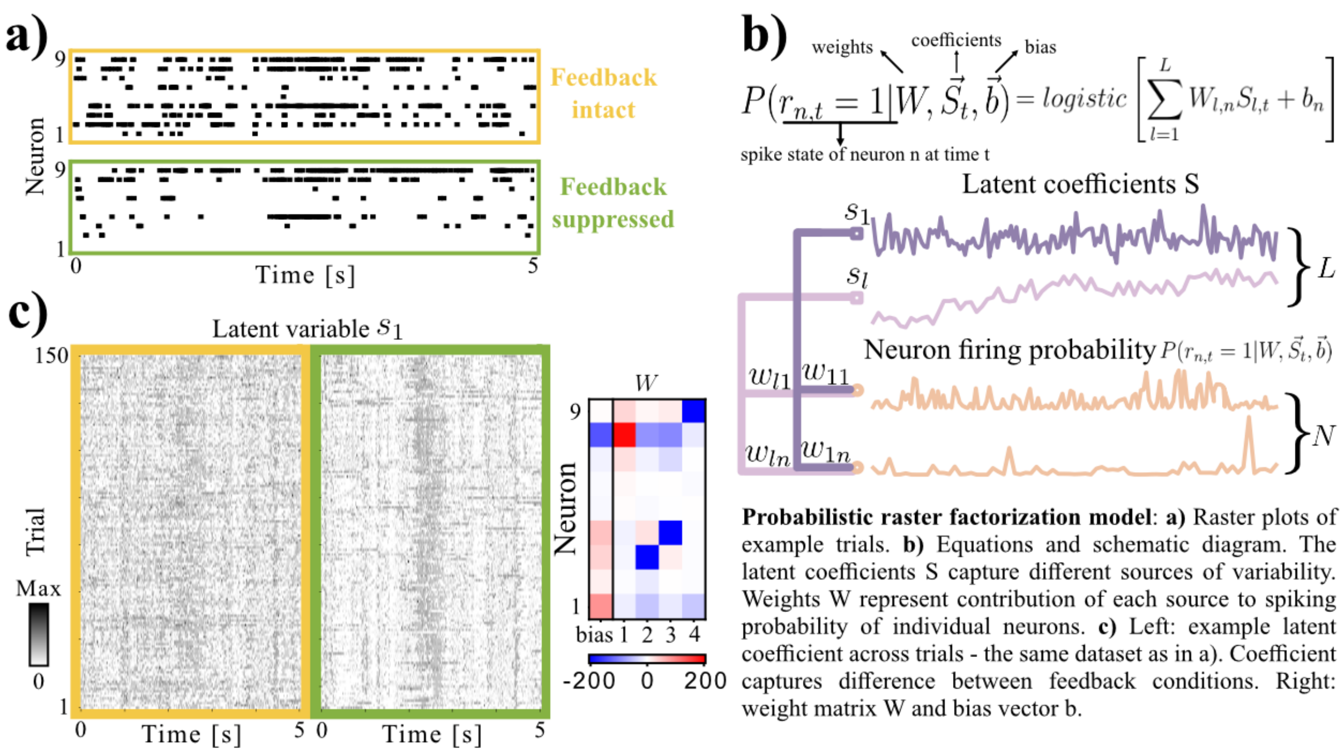
The role of feedback in sensory systems remains a major puzzle in neuroscience. Classical computational theories such as hierarchical predictive coding or hierarchical inference postulate abstract normative goals for the role of feedback connections. However, predictions derived from these theories are typically specified at the level of individual neurons. Whether feedback shapes collective properties of neural populations and how such changes may impact encoding of sensory signals remains unknown.

Here we tackle these questions directly by studying the population coding of natural stimuli in the dorsolateral lateral geniculate nucleus (dLGN) of behaving mice. Extracellular electrophysiological recordings were performed in the mouse dLGN, while corticothalamic feedback from primary visual cortex was optogenetically suppressed.

To understand how cortical feedback impacts population codes in dGLN, we derived a statistical model of population activity: probabilistic raster factorization. The model identifies correlated activity patterns at the resolution of individual spikes and assigns different sources of correlated fluctuations to individual latent variables. In this way it conveniently parameterizes sources of variability in population responses - stimulus changes, fluctuations of behavioral state and the presence of feedback.

Analysis of learned latent variables revealed that within-trial and between-trial variability of population activity is higher with feedback intact. At the same time, the dynamics of feedback modulation depend on the behavioral state of the animal. These results challenge the classical computational theories of feedback in sensory coding and suggest that it's role may be much more nuanced and adaptive than expected.



Probabilistic raster factorization model: **a)** Raster plots of example trials. **b)** Equations and schematic diagram. The latent coefficients S capture different sources of variability. Weights W represent contribution of each source to spiking probability of individual neurons. **c)** Left: example latent coefficient across trials - the same dataset as in a). Coefficient captures difference between feedback conditions. Right: weight matrix W and bias vector b.

A Multi-Compartment Computational Approach to Cerebellar Circuit Dysfunction in Autism

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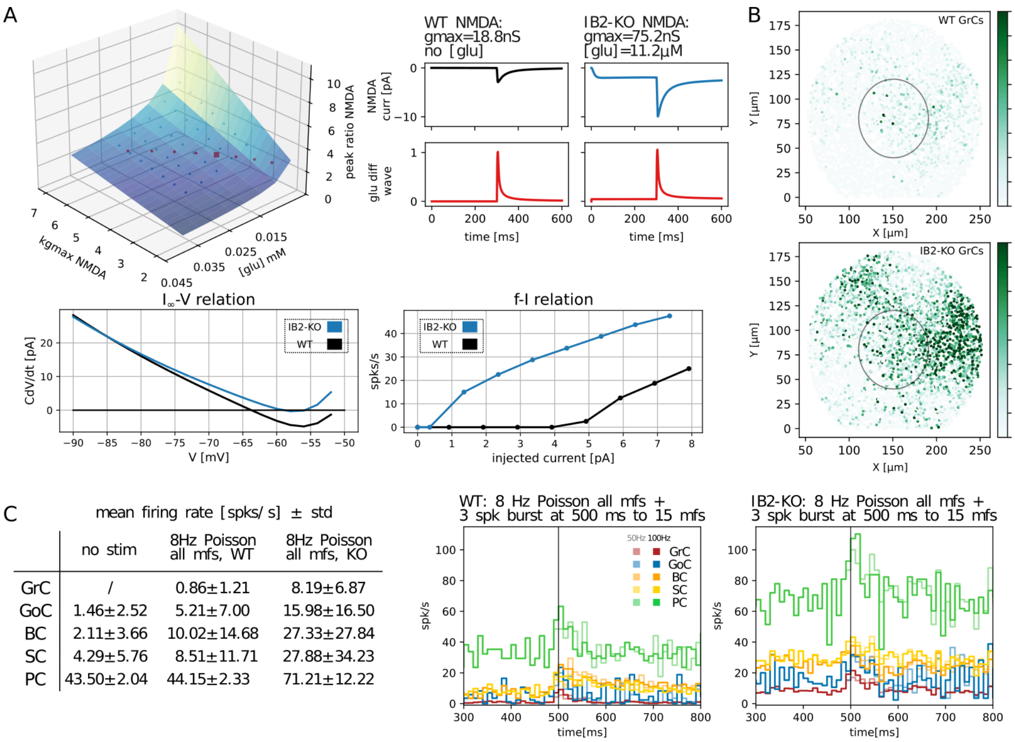
Abstract

Modeling brain dynamics requires addressing processes that span different temporal and spatial scales [1]. Our aim is to study how single-cell alterations affect circuit dynamics in a mouse model of autism (IB2 knock-out, KO), within the context of the cerebellar cortical microcircuit. We re-parameterized a wild-type (WT) granule cell (GrC) multi-compartment model [2] to match the empirical properties of IB2-KO GrCs [3]. At the network level, we employed a bottom-up approach, by placing all the cell types that characterize the cerebellar cortex, preserving their physiological morphology, density and connection affinity. On the simulation side, the entire process was managed by the Brain Scaffold Builder framework [4,5] interfaced with the NEURON simulator [6].

In the WT GrC model we increased Na and K maximum conductances (gmax) to match the higher in/outward currents in IB2 GrCs. Tonic glutamate levels [glu] in mossy-fiber-GrC synapses and NMDA gmax were adjusted to replicate experimental I-f and NMDA currents, predicting [glu] at 11.2 μM and a 4x NMDA gmax increase. The IB2 GrC model was integrated into the canonical cerebellar circuit, assuming no other cell changes (empirical IB2 Purkinje cell (PC) spks/s = 51.8, std 11.7, no sign. vs. WT). Network comparisons revealed greater stimulus spread through the Gr-layer, Fig.1B. Fig.1C shows peri-stimulus histograms for both circuits under different input, predicting an overall firing increase (rates from 9.5x in GrCs to 1.6x in PCs). To further validate whole-circuit activity, we are currently comparing our predictions with in vitro MEA recordings from both mouse models, in spontaneous regime and under mossy-fiber impulse stimulations.



mean firing rate [spks/s] ± std

	no stim	8Hz Poisson all mfs, WT	8Hz Poisson all mfs, KO
GrC	/	0.86±1.21	8.19±6.87
GoC	1.46±2.52	5.21±7.00	15.98±16.50
BC	2.11±3.66	10.02±14.68	27.33±27.84
SC	4.29±5.76	8.51±11.71	27.88±34.23
PC	43.50±2.04	44.15±2.33	71.21±12.22

Figure 1. A: Effect of NMDA gmax (kgmax NMDA) and ambient glutamate ([glu]) on NMDA currents in IB2-KO GrCs. B: How a 20 Hz stim propagates through the granular layer, applied to mossy fibers (*mf*s) within the circular target, r=40 µm. C: Firing rates of each cell type under three conditions: no stimulus, an 8 Hz Poisson basal input to all *mf*s, and basal input plus high-frequency stim targeted to 15 *mf*s.

Acknowledgements

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Contextual modulation of neural activity in the Superior Colliculus and its behavioural impact

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The superior colliculus (SC) is a midbrain structure in the mammalian brain that receives direct input from the retina and other early sensory circuits. SC output signals can induce survival-critical behavioral responses to specific visual stimuli like those typically associated with potential threats. The SC is understood to work as a saliency detector and as an integrator for multiple streams of sensory information, yet most experimental studies focus solely on individual cell tuning properties. Ongoing work has shown that contextual information (such as the amount of environmental light) can modulate the behavioural output, however the neural processing underlying these changes is still not well understood. Here we analyze the neural activity in head-fixed Neuropixels recordings from various transgenic mice. The animals were exposed to a set of fear-inducing visual stimuli under varying ambient light conditions and had freedom to move, escape, or freeze in response. We developed statistical models with the goal of disentangling stimulus coding, its modulation by the environmental context or genetic background, and its effects on behavior across the neural population in the SC and pre-motor areas. Preliminary results indicate the existence of neural subpopulations in SC with opposite modulation by environmental light levels. This suggests that contextual information can act on very early elements of the visuo-motor circuits to flexibly adjust behavior.

Energy-Efficient Neural Coding Under Food Restriction: Structure, Noise, and Resilience

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Energy efficiency is a key constraint shaping the architecture and function of neural codes across the brain. While a recent study has revealed how individual neurons and behaviour adapt to energy limitations [1], it remains unclear how such constraints shape network-level coding. Here, we investigate how food restriction impacts population coding in the visual cortex of male mice. Analyzing neuronal responses to oriented bar stimuli in V1, we find that food-restricted animals exhibit elevated noise correlations [2], yet maintain decoding performance through a reorganization of the neural code that reduces alignment between signal and noise directions.

Building on this, we found that food-restricted mice paradoxically exhibit a higher effective dimensionality, with increased average eigenvalue magnitude and fewer noise-dominated modes. This suggests a shift toward a more structured and complex population code, even under metabolic stress. To evaluate coding efficiency, we computed Fisher and Mutual Information quantities, which confirm robust information encoding under energy constraints. To explore the origin of these adaptations, we developed a computational model demonstrating that increased synaptic failures under energy constraints give rise to structured noise correlations [3]. Rather than degrading the code, these failures promote a reorganization that harnesses noise beneficially —preserving function while reducing energy demands.

These findings suggest that neural circuits adapt to energy constraints by restructuring their correlation patterns in a way that sustains efficient coding. This highlights a broader principle: metabolic pressure can drive functional reorganization at the network level, offering a new perspective on how energy efficiency shapes neural computation.

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An interspike statistics-preserving simplified model for noisy FitzHugh-Nagumo neurons on a network

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While many relevant questions regarding the dynamical emergence of self-sustained activity and synchronization in the brain can be tackled with Dynamical Systems on Graphs, the discrete formulation of Information Theory makes these models unwieldy for the study of the information processing capabilities of realistic neuronal networks. We intend to bridge this gap by building a discrete neuron model that retains the firing statistics of a nonlinear FitzHugh-Nagumo (FHN) Neuron in the presence of white noise.
The first step in this construction entails the approximation of the neuron firing rate as a Kramers transition rate problem modulated by the time elapsed since the last event. Despite some limitations linked to parametric noise-like effects due to the non-separability of timescales, an analytical form for the Inter-Spike Interval (ISI) of the noisy FHN neuron is obtained, which, upon regression, can be discretized to define the transition rules of a binary stochastic system whose states 0 and 1 are interpreted as quiescent and firing states. By further endowing the system with a memory variable that keeps track of the time of last firing for the neuron, the binary unit is able to reproduce the ISI histogram of a FitzHugh-Nagumo neuron. (Figure 1).
We finally discuss how to move from the single neuron to a network perspective considering a loop of neurons. We obtain a partial match of dynamical behaviours with the the emerging travelling wave states obtained with noisy nonlinear models, which is interpreted in light of findings on the latter type of systems.

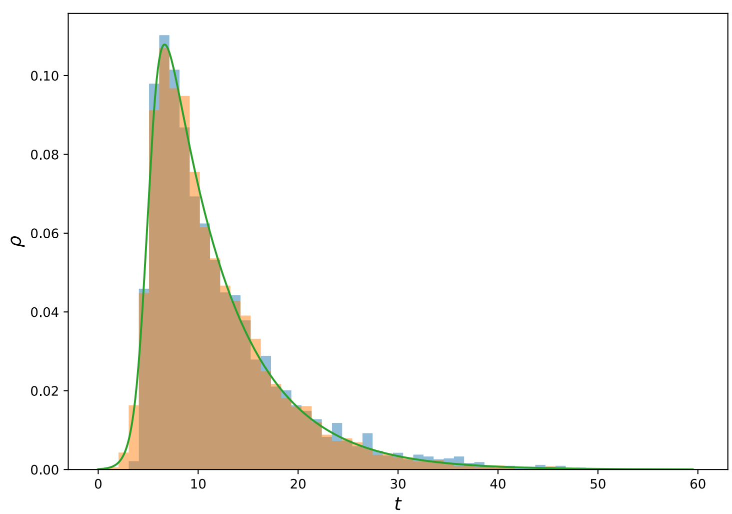

Figure 1: Comparison of the ISI distribution of a noisy FitzHugh-Nagumo neuron (blue shade region), simplified model (orange shade). The solid green line shows the analytical distribution function with parameter values obtained from regression.

Generative random latent features models and statistics of natural images

Philipp Fleig *[1] and Ilya Nemenman [2,3,4]

Complex, high-dimensional data are often analyzed by grouping their constituent units into components, sometimes referred to as latent features, which afford physical or biological interpretation. However, *a priori* many different types of latent features and data decompositions can be defined, and one typically uses a trial and error approach to determine a decomposition that is natural to the system and its data. Principled understanding of which decomposition is appropriate for a given dataset is needed. In this work, we take a step in this direction and argue that sample-sample correlations carry important information to this effect. We construct a generative random latent feature matrix model of high-dimensional data based on linear mixing of latent features. As a key ingredient, we allow for statistical dependence between the mixing coefficients. We argue that, with only two parameters (latent dimensionality and the structure of the statistical dependence), the resulting model captures characteristic properties found in many types of natural data. Specifically, the model can produce (overlapping) clusters, sparse mixing, and constrained (non-negative) mixing. We describe typical correlations and eigenvalue distributions of each pattern. Finally, we fit the model on correlation patterns in a benchmark natural images dataset and find a good match between the data and the sparse mixing regime of our model. This is in line with the well-known sparse coding structure in natural images, arguing that our approach identifies a correct latent decomposition of these data. We believe that our work will deliver similar insights for other diverse datasets.

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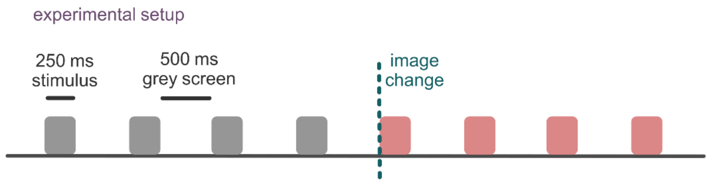
Title:

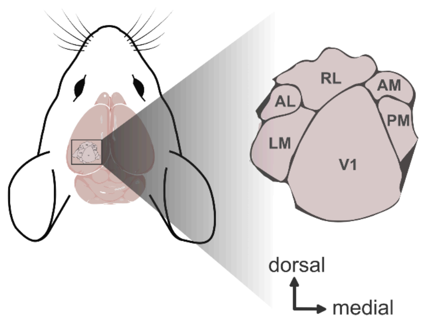
Identifying plasticity mechanisms underlying context-dependent neural responses in cortical circuits

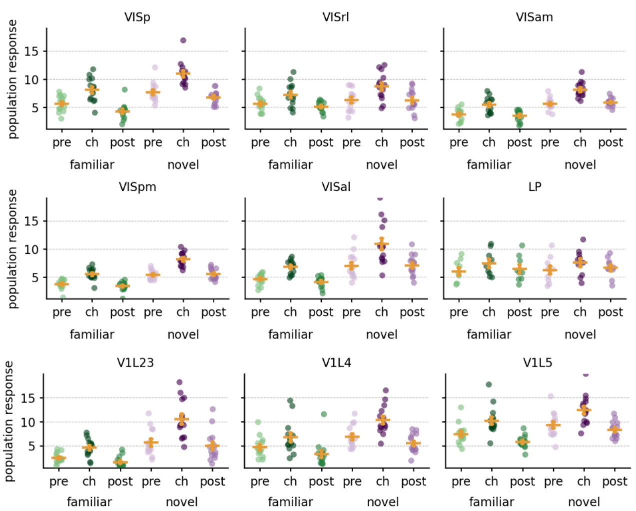
Summary:

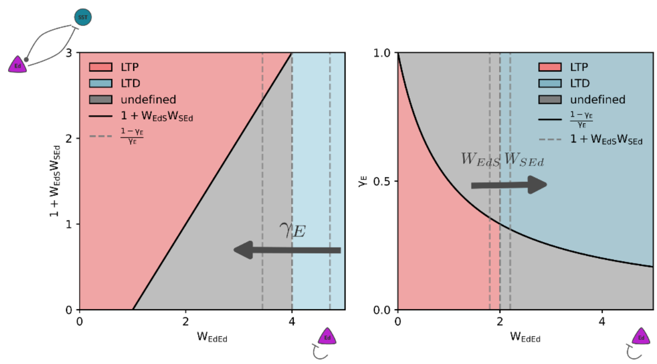
Biological circuits rapidly adapt to sensory stimuli through experience and ongoing learning in a non-trivial manner. Extensive experimental evidence indicates that neural circuits operate in distinct processing modes based on contextual information characterised by differential responses to the same stimuli. In early sensory cortices, different neuronal subtypes are thought to have specialized functional roles in controlling sensory information flow through the cortical hierarchy. Specifically, in mouse primary visual cortex (V1), populations of pyramidal and vasoactive-intestinal-peptide-expressing (VIP) cells show pronounced responses to novel and unexpected visual stimuli, while they rapidly adapt to elicit moderate responses to familiar or expected ones. However, the exact plasticity and circuit mechanisms that establish these distinct responses are not fully characterised.

Here, we analysed electrophysiological recordings from visual cortex and adjacent visual areas of mice performing a sequential visual discrimination task that establishes contextual stimulus expectations. Our analyses identified distinct inter-area communication patterns based on stimulus condition, suggesting selective, context-driven information routing to V1. To characterise the circuit design constraints and synaptic plasticity mechanisms that explain our empirical findings, we developed a data-constrained recurrent neural network model with three inhibitory interneuron subtypes. Using linear response theory on a mean-field approximation of the model, we derived the necessary circuit conditions on population interactions to replicate the experimentally observed responses. Our work provides a mechanistic explanation of how cortical circuits adjust their activity in response to contextual cues and stimulus expectations.









Modeling connectome structure using avalanche-based models with Hebbian learning on hierarchical modular networks

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Brain studies mainly focus on the anatomical wiring of the brain and its topological qualities to ascertain the exact relationship between anatomical structure and function. In this study, we examine the weighted degree distributions of representative large connectomes. We find that the behavior of the node strength (weighted degree) distribution varies according to the scale under consideration. The distributions exhibit power-law behavior on a global scale, with an approximately universal exponent near 3. However, this tendency deviates at the local level as the node strength distributions follow the log-normal distribution suggestive of underlying random multiplicative processes which support non-locality of learning in a brain near the critical state. Furthermore, to gain insight on the dynamics that led to this observed scale-free behavior of the global weight distributions of connectomes, we impose an avalanche-based model with Hebbian learning over Hierarchical modular network (HMN) architecture to simulate the dynamic process of reinforcement [weakening] of preferred [unused] pathways. HMNs recover key features of neuronal activity, making them good representative baseline structures for modeling cortical activity. Via targeted link creation and/or reinforcement for dynamically activated sites in a sandpile-like avalanche, and a random weakening and/or pruning during stasis times, we recover edge weight distributions that closely resemble the empirical connectome edge weight distributions.

Enhancement of memory storage capacity in recurrent neural networks through synaptic tagging and capture

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Lifelong learning systems must continuously integrate new information while preserving existing knowledge, which entails an issue known as the stability–plasticity dilemma. A central challenge in this process is catastrophic forgetting, where newly acquired information interferes with previously learned representations, leading to significant performance degradation. Biological systems seem to offer potential solutions to this, possibly through synaptic consolidation processes that stabilize learning over time.
Inspired by such mechanisms, we build on previous work modeling long-term synaptic plasticity and the synaptic-tagging-and-capture (STC) hypothesis. STC offers a biologically grounded process for memory stabilization, where transient synaptic changes are selectively consolidated depending on the dynamics of different molecules.

Here, we extend a biologically plausible spiking neural network model to investigate how synaptic consolidation influences memory capacity during the sequential encoding of multiple patterns of certain sizes. We show that a two-phase plasticity mechanism, with early and late phases governed by STC, enhances memory retention and reduces interference in overlapping representations. Unlike abstract models, our framework incorporates physiological dynamics to directly link functional memory performance with biological plausibility.

Additionally, we introduce a reduced version of the model that preserves key features of STC and calcium-modulated plasticity while offering greater computational efficiency. This simplification also enables analytical exploration and, thus, a generalized theoretical description of the memory-stability trade-off. Our results demonstrate how synaptic consolidation mechanisms can enhance memory persistence and reduce forgetting, which is important for both neuroscience and the design of artificial learning systems capable of continual adaptation.

Testing the impact of noise correlations on stimulus decoding in a two-neuron system

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ABSTRACT

Sensory neurons encode information about the external world through their collective spiking activity. This activity is both noisy and correlated across neurons. How correlations affect the encoded information in neural populations remains a matter of ongoing debate. Theoretical studies typically distinguish between *signal correlations*, which reflect similarities in stimulus tuning across neurons, and *noise correlations*, which arise from shared sources of noise. Understanding how the interplay between these two types of correlation influences stimulus representation remains a central challenge in computational neuroscience. Studies based on local stimulus discrimination (*Fisher Information*) have suggested that noise correlations reduce encoded information when they share the same sign as signal correlations, and are beneficial when they have opposite signs. More recent theoretical work, based on a global metric of information (*Mutual Information*), partially supports these findings but also reveals an additional regime in which strong noise correlations can be advantageous. Here, we address the problem from a decoding perspective —specifically, by reconstructing the stimulus from the noisy neural activity. We evaluate the performance of Bayesian decoding using the responses of two neurons with or without correlations. The results not only confirm the presence of the additional regime predicted with Mutual Information, but they also highlight the centrality of noise correlations in the trade-off between local and global stimulus discrimination. Moreover, we show that under certain conditions, correlated noise can enhance decoding performance even when it increases local uncertainty between stimuli (*information-limiting correlations*) —a regime considered always detrimental in the literature.

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Patterns replay and Criticality in a modular spiking neural network : comparison with MEG data

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ABSTRACT

Healthy brains exhibit a rich dynamic repertoire with flexible and diverse spatiotemporal pattern replays across both microscopic and macroscopic scales. We hypothesize that the system must operate near a critical regime for the functional repertoire to be fully explored, and flexible dynamics to emerge. To test this hypothesis, we employ a modular Spiking Neuronal Network model, where each group of Leaky Integrate-and-Fire neurons represents a cortical region. A learning rule based on Spike-Timing-Dependent Plasticity (STDP) is used to encode patterns of activations that propagate between modules. The patterns exploit empirical information on the number of white-matter fibers between regions. The model displays two distinct dynamical regimes: an uncorrelated low-rate state and a strongly correlated state, marked by a high Order Parameter value (indicating the similarity of spontaneous activity with one of stored patterns). These regimes are separated by either a first-order or second-order phase transition, depending on the strength of global inhibition and structured connections. When the hysteresis loop shrinks, a continuous phase transition occurs, and it opens up an extended region with high order parameter fluctuations (close a Widom line with maxima of fluctuations). The model's predictions are compared with empirical data from magnetoencephalographic (MEG) recordings in healthy adults. The Levenshtein distance is used to quantify the similarity between the sequences of region activations in neural avalanches from both the empirical data and the model simulations. Notably a similar repertoire of sequence is observed in synthetic data and MEG only when the model operates within the critical extended regime.

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Quantifying (hidden) hearing loss through optimal neural codes

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Even though auditory nerve deafferentiation is likely to be a primary cause of noise-induced hidden hearing loss (NIHHL), the specific link between observed physiological changes and perceptual effects of subtle acoustic trauma remains an open problem in hearing research. This work addresses this gap by using a computational framework based on normative brain theories (Mlynarski et al. 2021), viewing spike-train recordings from the auditory midbrain of small mammals in terms of optimal neural coding. Specifically, we derive optimization priors for acoustic contexts defined by probability distributions of intensity (quiet, moderate and loud), for then calculating a posterior based on rate-intensity functions parameter distributions (threshold and gain) measured experimentally, associating neural recordings with the statistics of these optimal solution spaces. By contrasting the dynamics within neural coding utility, neural gain regulation, and entropy of solution spaces, the model provides a unified lens to examine neural adaptation processes in NIHHL and conductive hearing loss, crucially, being consistent that neural gain is up-regulated following loss of afferent inputs, and that such gain regulation has different and measurable consequences for the efficiency and variability of neural codes, depending on the acoustic context. The consistency of these results across groups and recent literature supports the idea that optimal coding models offer a principled starting point for understanding and measuring hearing dysfunction, departing from the clinical audiogram for which thse pathologies remain hidden, quantifying them through shifts in representational capacity and information processing optimality.

Modelling Response of Brain Activity to Perturbations

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ABSTRACT

Understanding the brain's response to transcranial magnetic stimulation (TMS) is crucial for advancing both basic and clinical neuroscience. This study applies neural mass modelling to analyze TMS-evoked potentials (TEPs) through electroencephalography (EEG). Building on Momi et al. (2023) [1], who used source-localized TMS-EEG analyses to disentangle local from network dynamics, we aim to replicate and extend these findings by modelling the response from the resting state.

We adopt the whole-brain Hopf model proposed by Ponce-Alvarez and Deco (2024) [2],

$$\frac{dz_j}{dt} = (a_j + i\omega_j)z_j - |z_j|^2 z_j + g\sum_{j\neq k} C_{jk}\left[z_k(t+m_{jk}) - z_j(t)\right] + \eta_j \tag{1}$$

adapting it to EEG data [3]. Our results show that this model can reproduce resting state activity in the Fourier domain, while the TMS-evoked dynamics are accurately captured in the EEG trajectory space. This highlights the model's potential in bridging spontaneous and perturbation-driven brain activity.

Current efforts focus on integrating site-specific effective connectivity into the model, estimated for different TMS stimulation targets. This approach aims to capture how local connectivity profiles shape both spontaneous and evoked activity. By combining resting state dynamics with region-dependent effective connectivity, we aim to predict perturbation responses more accurately across stimulation sites. This direction holds promise for informing stimulation strategies and improving individualized neuromodulation protocols.

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